COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 11-1		FOR NSF USE ONLY
NSF 12-590	11/09/12	NSF PROPOSAL NUMBER
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)		1311389
DEB - Evolutionary Ecology		

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
11/09/2012	1	08010000 DEB	7377	005421136	08/02/2013 12:09pm S

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)	SHOW PREVIOUS AWARD NO. IF THIS IS ☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)
362177139		

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
University of Chicago	Chicago, IL 606375418 US
AWARDEE ORGANIZATION CODE (IF KNOWN)	
0017749000	
NAME OF PRIMARY PLACE OF PERF	ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
University of Chicago	University of Chicago 1025 E. 57th Street Chicago ,IL ,606375418 ,US.

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions) ☐ SMALL BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ MINORITY BUSINESS ☐ WOMAN-OWNED BUSINESS ☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **DISSERTATION RESEARCH: Inferring ecology in fossil terrestrial ecosystems**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 14,960	24 months	06/01/13	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR (GPG I.G.2)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date ______
PHS Animal Welfare Assurance Number ______
☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number ______
Exemption Subsection ______ or IRB App. Date ______
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)
☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)

PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
Department of Geology	1025 E. 57th St. Culver Hall 402 Chicago, IL 60637 United States
PI/PD FAX NUMBER	
312-665-7641	

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME Kenneth D Angielczyk	PhD	2003	312-665-7639	kangielczyk@fieldmuseum.org
CO-PI/PD Jonathan S Mitchell	MS	2012	773-702-8602	mitchelljs@uchicago.edu
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the Authorized Organizational Representative or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, lobbying activities (see below), responsible conduct of research, nondiscrimination, and flood hazard insurance (when applicable) as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG) (NSF 11-1). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

Conflict of Interest Certification

In addition, if the applicant institution employs more than fifty persons, by electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

The following certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure of Lobbying Activities," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:
(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:
(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF Grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

Certification Regarding Responsible Conduct of Research (RCR)
(This certification is not applicable to proposals for conferences, symposia, and workshops.)

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.B., the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research.
The undersigned shall require that the language of this certification be included in any award documents for all subawards at all tiers.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE		SIGNATURE	DATE
NAME Denise Dooley		Electronic Signature	Nov 9 2012 2:36PM
TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS ddooley@uchicago.edu		FAX NUMBER

* EAGER - EArly-concept Grants for Exploratory Research
** RAPID - Grants for Rapid Response Research

Directorate for Biological Sciences
Division of Environmental Biology
Evolutionary Ecology

Proposal Classification Form
PI: Angielczyk, Kenneth / Proposal Number: 1311389

CATEGORY I: INVESTIGATOR STATUS (Select ONE)

- [x] Beginning Investigator - No previous Federal support as PI or Co-PI, excluding fellowships, dissertations, planning grants, etc.
- [ ] Prior Federal support only
- [ ] Current Federal support only
- [ ] Current & prior Federal support

CATEGORY II: FIELDS OF SCIENCE OTHER THAN BIOLOGY INVOLVED IN THIS RESEARCH (Select 1 to 3)

- [ ] Astronomy
- [ ] Chemistry
- [ ] Computer Science
- [x] Earth Science
- [ ] Engineering
- [ ] Mathematics
- [ ] Physics
- [ ] Psychology
- [ ] Social Sciences
- [ ] None of the Above

CATEGORY III: SUBSTANTIVE AREA (Select 1 to 4)

- [ ] BIOGEOGRAPHY
- [ ] Island Biogeography
- [ ] Historical/ Evolutionary Biogeography
- [ ] Phylogeography
- [ ] Methods/Theory
- [ ] CHROMOSOME STUDIES
- [ ] Chromosome Evolution
- [ ] Chromosome Number
- [ ] Mutation
- [ ] Mitosis and Meiosis
- [ ] COMMUNITY ECOLOGY
- [ ] Community Analysis
- [ ] Community Structure
- [ ] Community Stability
- [ ] Succession
- [ ] Experimental Microcosms/ Mesocosms
- [ ] Disturbance
- [ ] Patch Dynamics
- [x] Food Webs/ Trophic Structure
- [ ] Keystone Species
- [ ] COMPUTATIONAL BIOLOGY
- [ ] CONSERVATION & RESTORATION BIOLOGY
- [ ] DATABASES
- [ ] ECOSYSTEMS LEVEL
- [ ] Physical Structure
- [ ] Decomposition
- [ ] Biogeochemistry
- [ ] Limnology/Hydrology
- [ ] Climate/Microclimate
- [x] Whole-System Analysis
- [ ] Productivity/Biomass
- [ ] System Energetics
- [ ] Landscape Dynamics
- [ ] Chemical & Biochemical Control
- [ ] Global Change
- [ ] Climate Change
- [ ] Regional Studies
- [ ] Global Studies
- [ ] Forestry
- [ ] Resource Management (Wildlife, Fisheries, Range, Other)
- [ ] Agricultural Ecology
- [ ] EXTREMOPHILES
- [ ] GENOMICS (Genome sequence, organization, function)
  - [ ] Viral
  - [ ] Microbial
  - [ ] Fungal
  - [ ] Plant
  - [ ] Animal
- [ ] MARINE MAMMALS
- [ ] MOLECULAR APPROACHES
- [ ] Molecular Evolution
- [ ] Methodology/Theory
- [ ] Isozymes/ Electrophoresis
- [ ] Nucleic Acid Analysis (general)
  - [ ] Restriction Enzymes
  - [ ] Nucleotide Sequencing
  - [ ] Nuclear DNA
  - [ ] Mitochondrial DNA
  - [ ] Chloroplast DNA
  - [ ] RNA Analysis
  - [ ] DNA Hybridization
  - [ ] Recombinant DNA
- [ ] Amino Acid Sequencing
- [ ] Gene/Genome Mapping
- [ ] Natural Products
- [ ] Serology/Immunology
- [ ] PALEONTOLOGY
- [ ] Floristic
- [ ] Faunistic
- [x] Paleoecology
- [ ] Biostratigraphy
- [ ] Palynology
- [ ] Micropaleontology
- [ ] Paleoclimatology
- [ ] Archeozoic
- [ ] Paleozoic
- [ ] Mesozoic

- ☐ Cenozoic
- ☐ POPULATION DYNAMICS & LIFE HISTORY
- ☐ Demography/ Life History
- ☐ Population Cycles
- ☐ Distribution/Patchiness/ Marginal Populations
- ☐ Population Regulation
- ☐ Intraspecific Competition
- ☐ Reproductive Strategies
- ☐ Gender Allocation
- ☐ Metapopulations
- ☐ Extinction
- ☐ POPULATION GENETICS & BREEDING SYSTEMS
- ☐ Variation
- ☐ Microevolution
- ☐ Speciation
- ☐ Hybridization
- ☐ Inbreeding/Outbreeding
- ☐ Gene Flow Measurement
- ☐ Inheritance/Heritability
- ☐ Quantitative Genetics/ QTL Analysis
- ☐ Ecological Genetics
- ☐ Gender Ratios
- ☐ Apomixis/ Parthenogenesis
- ☐ Vegetative Reproduction
- ☐ SPECIES INTERACTIONS
- ☐ Predation
- ☐ Herbivory
- ☐ Omnivory
- ☐ Interspecific Competition
- ☐ Niche Relationships/ Resource Partititioning
- ☐ Pollination/ Seed Dispersal
- ☐ Parasitism
- ☐ Mutualism/ Commensalism
- ☐ Plant/Fungal/ Microbial Interactions
- ☐ Mimicry
- ☐ Animal Pathology
- ☐ Plant Pathology
- ☐ Coevolution
- ☐ Biological Control
- ☐ STATISTICS & MODELING
- ☐ Methods/ Instrumentation/ Software
- ☐ Modeling (general)
- ☐ Statistics (general)
  - ☑ Multivariate Methods
  - ☐ Spatial Statistics & Spatial Modeling
  - ☐ Sampling Design & Analysis
  - ☐ Experimental Design & Analysis
- ☐ SYSTEMATICS
- ☐ Taxonomy/Classification
- ☐ Nomenclature
- ☐ Monograph/Revision
- ☐ Phylogenetics
- ☐ Phenetics/Cladistics/ Numerical Taxonomy
- ☐ Macroevolution
- ☐ NONE OF THE ABOVE

CATEGORY IV: INFRASTRUCTURE (Select 1 to 3)

COLLECTIONS/STOCK CULTURES

- ☑ Natural History Collections
- ☑ DATABASES

FACILITIES

- ☐ Controlled Environment Facilities
- ☐ Field Stations
  - ☐ Field Facility Structure
  - ☐ Field Facility Equipment
- ☐ LTER Site
- ☐ INDUSTRY PARTICIPATION
- ☐ Technique Development

TRACKING SYSTEMS

- ☐ Geographic Information Systems
- ☐ Remote Sensing
- ☐ NONE OF THE ABOVE

CATEGORY V: HABITAT (Select 1 to 2)

TERRESTRIAL HABITATS

- ☑ GENERAL TERRESTRIAL
- ☐ TUNDRA
- ☐ BOREAL FOREST
- ☐ TEMPERATE
  - ☐ Deciduous Forest
  - ☐ Coniferous Forest
  - ☐ Rain Forest
  - ☐ Mixed Forest
  - ☐ Prairie/Grasslands
  - ☐ Desert
- ☐ SUBTROPICAL
  - ☐ Rain Forest
  - ☐ Seasonal Forest
  - ☐ Savanna
  - ☐ Thornwoods
  - ☐ Deciduous Forest
  - ☐ Coniferous Forest
  - ☐ Desert
- ☐ TROPICAL
  - ☐ Rain Forest
  - ☐ Seasonal Forest
  - ☐ Savanna
  - ☐ Thornwoods
  - ☐ Deciduous Forest
  - ☐ Coniferous Forest
  - ☐ Desert
- ☐ CHAPPARAL/ SCLEROPHYLL/ SHRUBLANDS
- ☐ ALPINE
- ☐ MONTANE
- ☐ CLOUD FOREST
- ☐ RIPARIAN ZONES
- ☐ ISLANDS (except Barrier Islands)
- ☐ BEACHES/ DUNES/ SHORES/ BARRIER ISLANDS
- ☐ CAVES/ ROCK OUTCROPS/ CLIFFS
- ☐ CROPLANDS/ FALLOW FIELDS/ PASTURES
- ☐ URBAN/SUBURBAN
- ☐ SUBTERRANEAN/ SOIL/ SEDIMENTS
- ☐ EXTREME TERRESTRIAL ENVIRONMENT
- ☐ AERIAL

AQUATIC HABITATS		
☐ GENERAL AQUATIC	☐ Open Ocean/Continental Shelf	☐ EXTREME AQUATIC ENVIRONMENT
☐ FRESHWATER	☐ Bathyal	☐ CAVES/ ROCK OUTCROPS/ CLIFFS
☐ Wetlands/Bogs/Swamps	☐ Abyssal	☐ MANGROVES
☐ Lakes/Ponds	☐ Estuarine	☐ SUBSURFACE WATERS/ SPRINGS
☐ Rivers/Streams	☐ Intertidal/Tidal/Coastal	☐ EPHEMERAL POOLS & STREAMS
☐ Reservoirs	☐ Coral Reef	☐ MICROPOOLS (Pitcher Plants, Tree Holes, Other)
☐ MARINE	☐ HYPERSALINE	
MAN-MADE ENVIRONMENTS		
☐ LABORATORY	☑ THEORETICAL SYSTEMS	☐ OTHER ARTIFICIAL SYSTEMS
NOT APPLICABLE		
☐ NOT APPLICABLE		

CATEGORY VI: GEOGRAPHIC AREA OF THE RESEARCH (Select 1 to 2)

☐ WORLDWIDE	☐ Eastern South America (Guyana, Fr. Guiana, Suriname, Brazil)	☐ North Africa
☑ NORTH AMERICA	☐ Northern South America (Colombia, Venezuela)	☐ African South of the Sahara
☐ United States	☐ Southern South America (Chile, Argentina, Uruguay, Paraguay)	☐ East Africa
☐ Northeast US (CT, MA, ME, NH, NJ, NY, PA, RI, VT)	☐ Western South America (Ecuador, Peru, Bolivia)	☐ Madagascar
☐ Northcentral US (IA, IL, IN, MI, MN, ND, NE, OH, SD, WI)	☑ EUROPE	☐ South Africa
☐ Northwest US (ID, MT, OR, WA, WY)	☐ Eastern Europe	☐ West Africa
☐ Southeast US (DC, DE, FL, GA, MD, NC, SC, WV, VA)	☐ Russia	☐ AUSTRALASIA
☐ Southcentral US (AL, AR, KS, KY, LA, MO, MS, OK, TN, TX)	☐ Scandinavia	☐ Australia
☐ Southwest US (AZ, CA, CO, NM, NV, UT)	☐ Western Europe	☐ New Zealand
☐ Alaska	☐ ASIA	☐ Pacific Islands
☐ Hawaii	☐ Central Asia	☐ ANTARCTICA
☐ Puerto Rico	☐ Far East	☐ ARCTIC
☐ Canada	☐ Middle East	☐ ATLANTIC OCEAN
☐ Mexico	☐ Siberia	☐ PACIFIC OCEAN
☐ CENTRAL AMERICA (Mainland)	☐ South Asia	☐ INDIAN OCEAN
☐ Caribbean Islands	☐ Southeast Asia	☐ OTHER REGIONS (Not defined)
☐ Bermuda/Bahamas	☐ AFRICA	☐ NOT APPLICABLE
☐ SOUTH AMERICA		

CATEGORY VII: CLASSIFICATION OF ORGANISMS (Select 1 to 4)

☐ VIRUSES	☐ Radiolaria	☐ Dinoflagellata
☐ Bacterial	☐ FUNGI	☐ Euglenoids
☐ Plant	☐ Ascomycota	☐ Phaeophyta
☐ Animal	☐ Basidiomycota	☐ Rhodophyta
☐ PROKARYOTES	☐ Chytridiomycota	☐ PLANTS
☐ Archaebacteria	☐ Mitosporic Fungi	☐ NON-VASCULAR PLANTS
☐ Cyanobacteria	☐ Oomycota	☐ BRYOPHYTA
☐ Eubacteria	☐ Zygomycota	☐ Anthocerotae (Hornworts)
☐ PROTISTA (PROTOZOA)	☐ LICHENS	☐ Hepaticae (Liverworts)
☐ Amoebae	☐ SLIME MOLDS	☐ Musci (Mosses)
☐ Apicomplexa	☐ ALGAE	☐ VASCULAR PLANTS
☐ Ciliophora	☐ Bacillariophyta (Diatoms)	☐ FERNS & FERN ALLIES
☐ Flagellates	☐ Charophyta	☐ GYMNOSPERMS
☐ Foraminifera	☐ Chlorophyta	☐ Coniferales (Conifers)
☐ Microspora	☐ Chrysophyta	☐ Cycadales (Cycads)

- ☐ Ginkgoales (Ginkgo)
- ☐ Gnetales (Gnetophytes)
- ☐ ANGIOSPERMS
- ☐ Monocots
- ☐ Arecaceae (Palmae)
- ☐ Cyperaceae
- ☐ Liliaceae
- ☐ Orchidaceae
- ☐ Poaceae (Graminae)
- ☐ Dicots
- ☐ Apiaceae (Umbelliferae)
- ☐ Asteraceae (Compositae)
- ☐ Brassicaceae (Cruciferae)
- ☐ Fabaceae (Leguminosae)
- ☐ Lamiaceae (Labiatae)
- ☐ Rosaceae
- ☐ Solanaceae

☐ ANIMALS

- ☐ INVERTEBRATES
- ☐ MESOZOA/PLACOZOA
- ☐ PORIFERA (Sponges)
- ☐ CNIDARIA
- ☐ Hydrozoa (Hydra, etc.)
- ☐ Scyphozoa (Jellyfish)
- ☐ Anthozoa (Corals, Sea Anemones)
- ☐ CTENOPHORA (Comb Jellies)
- ☐ PLATYHELMINTHES (Flatworms)
- ☐ Turbellaria (Planarians)
- ☐ Trematoda (Flukes)
- ☐ Cestoda (Tapeworms)
- ☐ Monogenea (Flukes)
- ☐ GNATHOSTOMULIDA
- ☐ NEMERTINEA (Rynchocoela) (Ribbon Worms)
- ☐ ENTOPROCTA (Bryozoa) (Plant-like Animals)
- ☐ ASCHELMINTHES
- ☐ Gastrotricha
- ☐ Kinorhyncha
- ☐ Loricifera
- ☐ Nematoda (Roundworms)
- ☐ Nematomorpha (Horsehair Worms)
- ☐ Rotifera (Rotatoria)
- ☐ ACANTHOCEPHALA (Spiny-headed Worms)
- ☐ PRIAPULOIDEA
- ☐ BRYOZOA (Ectoprocta) (Plant-like Animals)
- ☐ PHORONIDEA (Lophophorates)
- ☐ BRACHIOPODA (Lamp Shells)
- ☐ MOLLUSCA
- ☐ Monoplacophora
- ☐ Aplacophora (Solenogasters)
- ☐ Polyplacophora (Chitons)
- ☐ Scaphopoda (Tooth Shells)
- ☐ Gastropoda (Snails, Slugs, Limpets)
- ☐ Pelecypoda (Bivalvia) (Clams, Mussels, Oysters, Scallops)
- ☐ Cephalopoda (Squid, Octopus, Nautilus)
- ☐ ANNELIDA (Segmented Worms)
- ☐ Polychaeta (Parapodial Worms)
- ☐ Oligochaeta (Earthworms)
- ☐ Hirudinida (Leeches)
- ☐ POGONOPHORA (Beard Worms)
- ☐ SIPUNCULOIDEA (Peanut Worms)
- ☐ ECHIUROIDEA (Spoon Worms)
- ☐ ARTHROPODA
- ☐ Chelicериformes
- ☐ Merostomata (Horseshoe Crabs)
- ☐ Pycnogonida (Sea Spiders)
- ☐ Scorpionida (Scorpions)
- ☐ Araneae (True Spiders)
- ☐ Pseudoscorpionida (Pseudoscorpions)
- ☐ Acarina (Free-living Mites)
- ☐ Parasitiformes (Parasitic Ticks & Mites)
- ☐ Crustacea
- ☐ Branchiopoda (Fairy Shrimp, Water Flea)
- ☐ Ostracoda (Sea Lice)
- ☐ Copepoda
- ☐ Cirripedia (Barnacles)
- ☐ Amphipoda (Skeleton Shrimp, Whale Lice, Freshwater Shrimp)
- ☐ Isopoda (Wood Lice, Pillbugs)
- ☐ Decapoda (Lobster, Crayfish, Crabs, Shrimp)
- ☐ Hexapoda (Insecta) (Insects)
- ☐ Apterygota (Springtails, Silverfish, etc.)
- ☐ Odonata (Dragonflies, Damselflies)
- ☐ Ephemeroptera (Mayflies)
- ☐ Orthoptera (Grasshoppers, Crickets)
- ☐ Dictyoptera (Cockroaches, Mantids, Phasmids)
- ☐ Isoptera (Termites)
- ☐ Plecoptera (Stoneflies)
- ☐ Phthiraptera (Mallophaga & Anoplura) (Lice)
- ☐ Hemiptera (including Heteroptera) (True Bugs)
- ☐ Homoptera (Cicadas, Scale Insects, Leafhoppers)
- ☐ Thysanoptera (Thrips)
- ☐ Neuroptera (Lacewings, Dobsonflies, Snakeflies)
- ☐ Trichoptera (Caddisflies)
- ☐ Lepidoptera (Moths, Butterflies)
- ☐ Diptera (Flies, Mosquitoes)
- ☐ Siphonaptera (Fleas)
- ☐ Coleoptera (Beetles)
- ☐ Hymenoptera (Ants, Bees, Wasps, Sawflies)
- ☐ Chilopoda (Centipedes)
- ☐ Diplopoda (Millipedes)
- ☐ Pauropoda
- ☐ Symphyta (Symphyla)
- ☐ PENTASTOMIDA (Linguatulida) (Tongue Worms)
- ☐ TARDIGRADA (Tardigrades, Water Bears)
- ☐ ONYCHOPHORA (Peripatus)
- ☐ CHAETOGNATHA (Arrow Worms)
- ☐ ECHINODERMATA
- ☐ Crinoidea (Sea Lilies, Feather Stars)
- ☐ Asteroidea (Starfish, Sea Stars)
- ☐ Ophiuroidea (Brittle Stars, Serpent Stars)
- ☐ Echinoidea (Sea Urchins, Sand Dollars)
- ☐ Holothuroidea (Sea Cucumbers)
- ☐ HEMICHORDATA (Acorn Worms, Pterobranchs)
- ☐ UROCHORDATA (Tunicata) (Tunicates, Sea Squirts, Salps, Ascideans)
- ☐ CEPHALOCHORDATA (Amphioxus/Lancelet)
- ☑ VERTEBRATES
- ☐ AGNATHA (Hagfish, Lamprey)
- ☐ FISHES
- ☐ Chondrichthyes (Cartilaginous Fishes) (Sharks, Rays, Ratfish)
- ☐ Osteichthyes (Bony Fishes)
- ☐ AMPHIBIA
- ☐ Anura (Frogs, Toads)
- ☐ Urodela (Salamanders, Newts)
- ☐ Gymnophiona (Apoda) (Caecilians)
- ☐ REPTILIA
- ☐ Chelonia (Turtles, Tortoises)
- ☐ Serpentes (Snakes)
- ☐ Sauria (Lizards)
- ☐ Crocodylia (Crocodilians)
- ☑ AVES (Birds)
- ☐ Passeriformes (Passerines)
- ☐ MAMMALIA
- ☐ Monotremata (Platypus, Echidna)
- ☐ Marsupalia (Marsupials)
- ☐ Eutheria (Placentals)
- ☐ Insectivora (Hedgehogs, Moles, Shrews, Tenrec, etc.)
- ☐ Chiroptera (Bats)
- ☐ Primates
- ☐ Humans
- ☐ Rodentia
- ☐ Lagomorphs (Rabbits, Hares, Pikas)
- ☐ Carnivora (Bears, Canids, Felids, Mustelids, Viverrids, Hyena, Procyonids)
- ☐ Perissodactyla (Odd-toed Ungulates) (Horses, Rhinos, Tapirs, etc.)

☐ Artiodactyla (Even-toed Ungulates) (Cattle, Sheep, Deer, Pigs, etc.) ☐ Marine Mammals (Seals, Walrus, Whales, Otters, Dolphins, Porpoises)	☐ TRANSGENIC ORGANISMS ☑ FOSSIL OR EXTINCT ORGANISMS	☐ NO ORGANISMS

CATEGORY VIII: MODEL ORGANISM (Select ONE)

☑ NO MODEL ORGANISM MODEL ORGANISM (Choose from the list)	☐ Escherichia coli ☐ Mouse-Ear Cress (Arabidopsis thaliana)	☐ Fruitfly (Drosophila melanogaster)

Project Summary

My project is an examination of how ecology has evolved in birds, and how it may have contributed to their rise. I am using large datasets to robustly predict ecology in fossil birds, and comparisons of modern and fossil bird assemblages to understand how incomplete preservation biases our record. I am also putting bird ecology in the broader context of terrestrial ecosystem change through time. Currently, I am drawing data from the large skeletal collections of the Field Museu, early Cretaceous fossil birds from China, and the Eocene birds of the Green River Formation. Funding this proposal would allow me to extend my analyses to the extremely diverse fossil bird faunas of Europe, as well as collect data on extant birds of the Old World.

Intellecual Merit: I will be quantitatively assessing ancient bird assemblages that, in many cases, hardly resemble modern ones. For instance, in the Eocene of North America, frogmouths and hoatzins lived in North America, whereas neither does today, nor do these taxa coexist anywhere on Earth. Likewise, Eocene Europe had hummingbirds and other non-native clades. Quantifying and understanding these radically non-analog communities can help put ecological theory into the broader context of not just explaining the ecosystems we see today, but also those alien systems of the ancient past. Examining these long lost food webs will help reveal the nature tempo and mode of environmental change, and help put the current biotic crisis into a deep-time perspective.

My work on broader ecosystem patterns will also improve the methods for predicting extinction used by ecologists and conservation biologists. We can test ecological models by fitting them to fossil data, predicting which taxa should go extinct, and then examining the next time interval up to see how well the method worked. Likewise, I will be testing models of trait evolution by comparing the ecological diversity predicted from time-calibrated trees of birds with the ecological diversity actually observed in the fossil record at discrete time bins.

Broader Impacts: My work generates a large amount of data that I am making available to other researchers. For instance, I currently have measurements on over 1100 specimens of modern bird, and 109 fossil specimens. I am collaborating with the Bird Collection manager at the Field Museum to make these measurements publically searchable and available via the museum's existing specimen interface.

I also currently use my work to help my involvement in several active public outreach programs. I am collaborating with the Education Department at the Field Museum on outreach to the general public via the "Dozin' with the Dinos" program, as well as helping proof-read various teaching supplements distributed by the museum to Chicago Public School teachers. I am also working with the E^2SP program by providing training in science to Chicago Public School teachers for their professional development. I have previously presented my research to general audiences in New Mexico and South Carolina, as my research takes me there, and I will continue to offer to give public talks on future museum visits. Likewise, both in conjunction with the Chicago Program City Year, and on my own, I have given many talks to elementary, middle and high school classes both during and after school (over a dozen classes since coming to Chicago). Finally, my collaborations with researchers here and in China has led to me helping train various museum interns and students in statistical methods.

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*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

DISSERTATION RESEARCH: Inferring Ecology in Fossil Terrestrial Ecosystems

PI: Kenneth D. Angielczyk, Co-PI: Jonathan S. Mitchell

Introduction

Molecular data and the fossil record often disagree about the broad-scale picture of the history of life (Harmon et al., 2003; Ingram et al., 2012; Ksepka and Boyd, 2012). To date, the debate has centered on the relative importance of the imperfections in the fossil record (Hedges and Kumar, 2004) versus molecular models (including a lack of extinction data; Finarelli and Flynn 2006; Foote 2010). Ecological theory often forms the basis of qualitative explanations of processes in both molecular and paleontological models, yet is regularly ignored when it comes to data collection (Ingram et al., 2012). For my dissertation, I will combine morphological and ecological data on modern and fossil birds with a molecular phylogeny of birds to interpret fossil bird ecology. I will then explore the tempo and mode of ecological radiation in fossil birds by focusing on patterns of ecological diversification. Finally, I will examine how the avian radiation fits into the broader scale of ecological change across terrestrial systems in deep time.

Most work on the avian radiation has focused on the timing of diversification events (e.g., Brown and Van Tuinen, 2011; Jetz et al., 2012), but these diversification events reflect explicit hypotheses of the rate of ecological evolution. Currently, we simply do not know much about when bird lineages diversified into their modern ecological niches, regardless of when the actual splits in the phylogeny occurred (Penny and Phillips, 2004). My research focuses on comparing distinct, well-sampled bird assemblages from before and shortly after the end-Cretaceous extinction and comparing these systems with ecosystems we see today. By focusing on fossil sites with exceptional preservation (lagerstätten), I am putting the functional diversity of birds from these exceptional deposits in a broader context (these sites also preserve insects, fish, mammals, etc). This has allowed me to 'rarefy' these deposits to make explicit comparisons with other sites of similar age but inferior preservation.

The fossil record of birds is better than often assumed, and rapidly improving (Ksepka and Boyd, 2012). Fossil birds provide data critical to understanding the ecological radiation of birds, as fossil deposits show unique co-occurrences not found in the modern world, such as European hummingbirds (Mayr, 2004) and North American hoatzins (Mayr et al., 2011). These (and other) ecological configurations would be impossible to predict working solely from extant data, and will have a major impact on any reconstruction of ecological diversification rates. Previous studies in other groups have shown that ancestral states can differ radically from those predicted solely by molecular phylogenies (Webster and Purvis, 2002; Finarelli and Flynn, 2006; Slater et al., 2012). Interpreting the ecology of fossil birds is possible because birds have been extremely well-studied ecologically in the modern realm (e.g., MacArthur, 1958; Sanchez et al., 2000) and fossil birds sometimes preserve critical data, such as gut contents, which can be used to test morphometric predictions of ecology (e.g., Zhou et al., 2004).

My dissertation explores the topic of avian diversification and ecological evolution in three parts:

I *Avian ecomorphology:* I hypothesize that continuous limb measures and categorical beak characters will predict habitat and diet in modern birds after taking phylogeny into account. I will test this hypothesis by using morphology to predict the ecology of extinct taxa with known gut contents and comparing my predictions to the extrinsic fossil observations. My preliminary morphological data set of six limb measurements and four categorical beak variables for 1112 specimens and an ecological dataset of 496 species, and used the Hackett et al. (2008) and Jetz et al. (2012) trees to conduct phylogenetic canonical correlations (Revell, 2012) to build my predictive framework. I have also projected 109 specimens of fossil birds into modern bird ecomorphospace to understand ancient bird ecology, and tested my predictions against extrinsic evidence. I seek funding to include data on the Eocene Messel Pit birds for comparison with the modern, Cretaceous and Green River fossils, as well as European modern birds for broader ecological scope.

II *Modeling fossil preservation:* Fossil preservation is non-random with respect to ecology, and this bias shifts our view of functional diversity in fossil deposits. I hypothesize that preservation will leave a distinct signature on bird functional diversity, which can and must be accounted for in studies of fossil birds. My preliminary morphological dataset is based on the Field Museum collections and contains almost every genus of bird in North America, range data for these genera, recent fossil occurrences from across North America, as well as over 109 fossil specimens from the Early Cretaceous of China (funding for travel provided by the NSF East Asia and Pacific Summer Institute grant). To model biases resulting from fossilization, I am comparing the functional diversity of modern and relatively recent ($\leq 15,000$ years old) avian assemblages. The fossil birds from China lack the very ecologies that are most likely to be preserved (large aquatic forms and abundant aerial forms), suggesting legitimate biological differences between the two. I am currently writing these results up, and extending my sample to include Eocene ($\approx$ 50Ma) birds from North America, which I predict will show fewer biological and more preservational differences with the modern assemblages, and so provide a poignant comparison. This proposal would allow me to extend my analyses beyond North America and include data on fossil and modern birds of Europe, improving my ability to fit preservation models and extend my comparative power.

III *Modeling changes in ecosystem structure:* These ancient fossil deposits are temporally closer to the origin of birds than modern assemblages, so I predict that evolutionary rates as well as ecological factors will influence the amont of functional diversity observed. Using basal avian data to calibrate 85,000 simulations, I have shown that the Early Cretaceous birds are more disparate than expected, suggesting that the stem rates of evolution were higher than the basal crown rates. Likewise, I am testing an ecological model to explore changes in Mesozoic ecosystems, with some of my results described in a recent PNAS paper (Mitchell et al., 2012). DDIG funding would allow me to gather data on Cretaceous deposits of Europe (Las Hoyas, London Clay) to further expand my analyses and further test both the predictive power of my model and the role of birds in Mesozoic ecosystems.

Preliminary Results & Proposed Work

I Extend morphological analyses to fossil birds of Europe

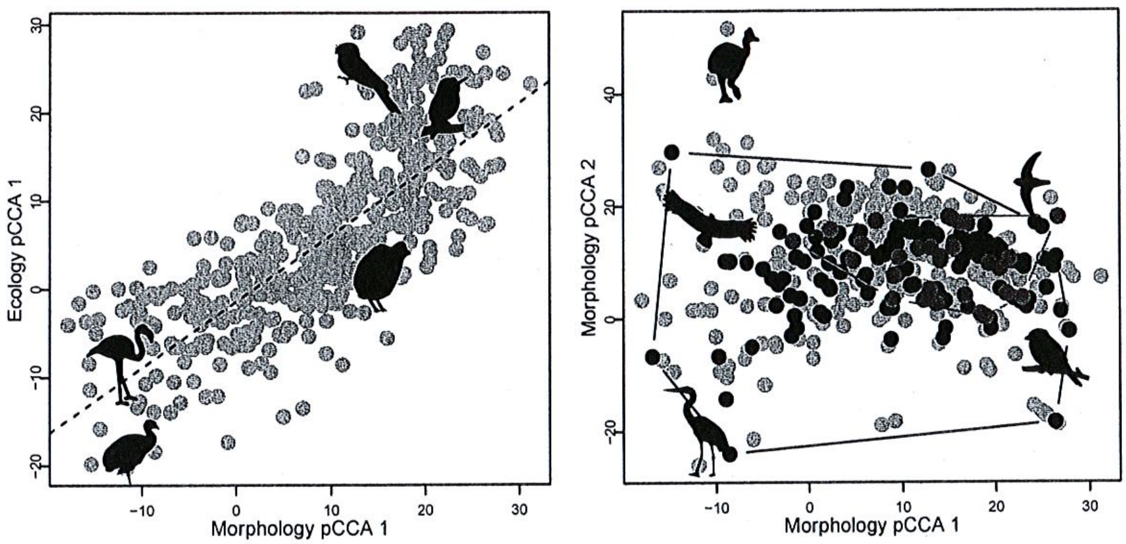

Figure 1: Left: Phylogenetic Canonical Correlations Analysis (pCCA) between ecology (y-axis) and morphology (x-axis) for 451 extant genera of birds (Spearman's $\rho = 0.81$; phylogeny from Hackett et al. 2008). Right: Ecomorphospace based on first and second pCCA axes of morphology, with all birds (•), extant Yellowstone birds (•) and Jehol ($\approx$ 125Ma) birds (•) shown. Axes are unit-less multivariate composites, and silhouettes represent ecologically diverse extant taxa.

The use of morphology as a proxy for ecology has a long history, especially with regards to birds (Ficken et al., 1968; Morse, 1967; Ricklefs and Travis, 1980; Miles et al., 1987). Although birds lack the ecological hallmarks of many other vertebrate taxa (e.g., teeth), aspects of the bird body plan, such as beak shape, have been widely recognized as useful proxies for diet (Ricklefs and Travis, 1980). Despite using almost identical morphological proxies and methodologies, bird ecologists (Ricklefs and Travis, 1980) and paleontologists (Bell and Chiappe, 2011) have largely gone about their work in parallel, rarely citing one another or collaborating. This lack of cross-communication has impeded the development of insight regarding how morphological evolution on the short-term and long-term may be related.

To help develop these insights, I will use phylogenetic comparative methods to create a morphological framework to predict ecology in modern birds, and apply this framework to fossil birds. These data will improve our ability to look at bird functional diversity in deep time deposits. I have generated an ecological database of 14 binary, 2 categorical and one continuous variables for 496 species of modern bird, using standard metrics (diet & habitat [binary], foraging mode [categorical], and body mass [continuous]; Dunning 2008; Kissling et al. 2012; Luck et al. 2012). I have also compiled a morphological dataset using 6 limb measures from 1112 specimens of extant bird, representing 455 genera in 138 families. I also quantified beak shape in 65 extant species using 3D morphometrics, and then found four categorical variables to best explain differences in beak shape among extant birds (fossil bird skulls are often crushed, so categorical data is necessary). I am collaborating with the collection managers at the Field Museum to make all of my morphological data available to other researchers via the museum's bird database. Finally, I used principal coordinates analysis (PCo) in combination with phylogenetic canonical correlations analysis (pCCA; Revell, 2012) to find the combination of morphological variables in modern birds that best predict their ecology. With funding from NSF, I was able to measure 109 specimens representing over 30 species of fossil bird (some yet to be described) from the Jehol biota of China ($\approx$ 125 million years old). I used the morphology of these fossil birds to project them into the modern bird ecomorphospace and made quantitative predictions about their ecology.

One useful attribute of the Jehol birds is that many of them contain gut contents, which can serve as an independent test of my statistical analyses (Zanno and Makovicky, 2010). The two fossil birds known with exclusively fish remains in their guts (Dalsätt et al., 2006; Zhonghe et al., 2009) both clustered near piscivorous or carnivorous modern birds, while the two known exclusively with evidence of granivory (seeds and gastroliths/gizzard stones; Zhou and Zhang, 2002, 2006) both cluster closest to granivorous modern taxa. The one Jehol bird, *Yanornis*, known with evidence for both herbivory and piscivory (Zhou et al., 2004) falls closest to generalist taxa. Finally, the fossil bird *Gansus* is known to have webbed feet and an enlarged cnemial crest (an adaptation for diving; You et al. 2006) and is best represented in my framework with the diving grebe.

These results support the use of my framework for extrapolating the ecology of extinct birds. I am currently incorporating birds from the species-rich Green River Formation (Eocene, $\approx$ 55Ma from Wyoming) using money awarded by various other grants (Paleontological Society, University of Chicago Hinds Fund). Quantifying the ecology of individual fossil species opens the door to broader paleoecological reconstructions. I have compared the Jehol birds (•) to the birds of Yellowstone National Park (•), a modern climate analog (Amiot et al., 2011) and found that the Jehol birds are exceptionally ecologically impoverished (Fig 1, right).

In this proposal I seek to expand my fossil sample to include data from the staggeringly diverse Messel Pits of Germany ($\approx$ 50Ma Franzen, 1985; Morlo et al., 2004), as well as examine Eocene and Oligocene birds housed in French and German museums (see budget; Mayr, 2008; Sanz and Buscalioni, 1994; Mayr, 2008). The principal institution housing these specimens is Forschungsinstitut Senckenberg, in Darmstadt, whose curator I have contacted. I will use funding from this proposal to incorporate birds from the Messel Pit ($\approx$ 55Ma) of Germany, the Cretaceous London Clay of England, and various European Oligocene deposits as well (see Budget justification), vastly expanding my taxonomic, geographic and temporal sample of fossil birds. My modern bird sample is biased by the skeletons available at the Field Museum, and so is comprised mostly of North American birds. Funding to go to European museums would thus also allow me to incorporate a broader range of extant biotas in my comparisons.

II Bird functional diversity in deep time: Preservation bias

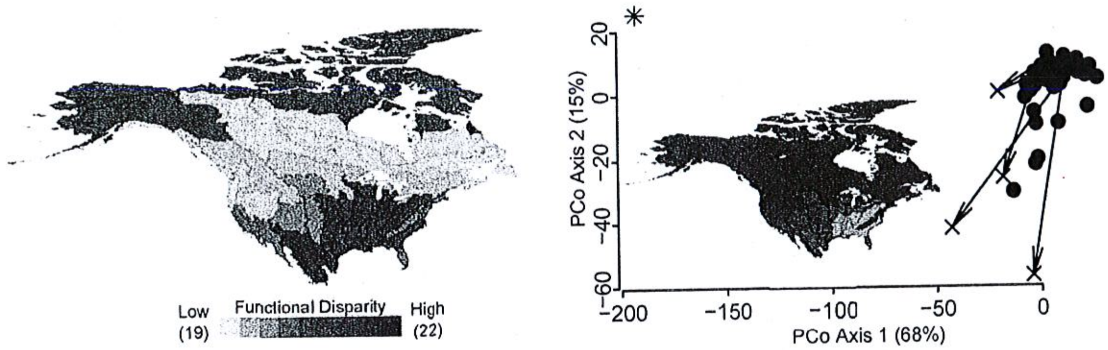

Figure 2: Bird Conservation Regions (BCRs) color coded by functional diversity (left) and by similarity to the Jehol (right inset). (Right) Principal coordinate analysis of bird faunas showing how the 4 Pleistocene sites (×) differ from the 46 BCRs (•) and the Jehol (∗). Arrows (↓) connect modern bird faunas to their geographically similar Pleistocene counterparts, and thus show the direction of change imposed by preservation bias.

Even if birds did fill their modern ecospace almost immediately after diversifying, the functional diversity of fossil deposits could appear restricted because certain ecologically distinct species were not preserved. Evolutionary biologists have known for a long time that the fossil record is imperfect. However, in recent years our empirical understanding of exactly *how* the fossil record is biased has greatly improved (Behrensmeyer and Hill, 1980; Spencer et al., 2003; Behrensmeyer et al., 2003; Butler et al., 2009). Essentially, whether an organism is preserved or not can be viewed as a probabilistic statement, with the organism's traits influencing that probability. Widespread, abundant, larger-bodied creatures with hard skeletons that live in aquatic habitat have exceptional preservation potential, while rare, small-bodied, lightly skeletonized terrestrial creatures are less likely to be preserved (Behrensmeyer and Hill, 1980).

Viewing preservation as a quantifiable probability, that is based on traits (such as body size and abundance) opens the door to making rigorous comparisons between fossil deposits and modern ecosystems. As a first step, gathering data on the morphology and ecology of a large number of taxa from across a wide geographic range is necessary. I currently have representatives of every genus of bird natively occurring in North America in my ecomorphological dataset, and so can map the functional diversity of the various Bird Conservation Regions (BCRs) of North America (Fig 2, left). I then compared the functional diversity of these BCRs with the Jehol birds to see which ecosystems are the "best match" (Fig 2, right inset). Intriguingly, even before accounting for preservation, the closest matching ecosystems are at approximately the same latitude and mean annual temperature as the Jehol birds occupied in life (Amiot et al., 2011).

As a preliminary step towards modeling preservation, I have collated data on four diverse ($\geq$ 20 species) bird sites from the Late Pleistocene ($\approx 11,000$ year old) of North America, and reconstructed their functional diversity using my datasets. The differences between ecomorphospace occupation of birds in these very young localities and the ecomorphospace occupation of modern birds in the same places serves as a preliminary attempt at controlling for preservation biases. I put the 46 BCRs, as well as the 4 Pleistocene and the Jehol bird faunas in a principal coordinates analysis based on summaries of their functional diversity, and found that the first axis was primarily defined by the difference between the Cretaceous and Cenozoic, and the second (statistically independent) axis was primarily defined by the difference between the Pleistocene and the modern (Fig 2, right). This strongly suggests that the reduced functional diversity of the $\approx$ 125Ma old Jehol birds is not due solely to preservational biases, as we would expect (the Jehol birds co-occurred with pterosaurs and large dinosaurs).

One caveat is that the Pleistocene and Modern, although very similar, differ substantially due to both natural climate change and human impacts. I am currently addressing this by focusig on presence/absence data, instead of abundances, and by seeking to further integrate paleontological (e.g., pbdb.org) and ecological (e.g., ebird.org) databases. Logistic modeling of preservation as a function of habitat and body size is one approach I am pursuing, and I am fitting the model both to the differences between the modern and recent fossil data, as well as to repeated occurrences in the fossil formations. That a given bird occurs in a fossil deposit more often than another is strong evidence that it has a higher preservational potential. For the Jehol birds, species known from multiple specimens do not differ significantly in ecomorphospace than those known from one in the Jehol (MANOVA, p-value $\approx$ 0.48), and preservation modeling supports the notion that the differences are likely biological. As I expand my attempts to mechanistically model preservation, I will use the multiple occurrences of taxa within a deposit as a check on any models I develop from a comparison between the human-altered modern faunas and those of the ancient past.

One key prediction of my preliminary results is that, because the differences between the Jehol and modern are more biologically-based than preservationally-based, when I include fossil birds from older Cenozoic deposits (Oligocene of France, Eocene of Germany & the U.S.), those bird faunas will plot in the empty diagonal space between the Cretaceous birds and the Pleistocene birds. If the younger deposits do not, that could suggest that my method of inferring preservation bias is flawed, and so I will turn more heavily to theoretical models (Terry, 2008; Benson and Mannion, 2011), or it could suggest that, even in the Cenozoic, early, pre-human ecosystems were fundamentally different from those seen today. Funding requested in this proposal would allow me to collect data on birds from a wider range of both fossil (Messel Pits, Oligocene birds of France, London Clay and Las Hoyas birds) and extant ecosystems (European and North African birds), and so improve my power to quantify and interpret fossil bird faunas. Further, it would allow me to extend my analyses more broadly to take into account other taxa present in terrestrial systems and put bird functional diversity in a broader ecological context.

III Bird functional diversity in deep time: Biological context

Now that I have established that preservational biases are unlikely to be solely responsible for the lack of functional diversity in early Cretaceous birds, I am testing potential biologic factors. Specifically, two non-exclusive factors that could explain the lack of ecological disparity are that there had not yet been enough time for birds to sufficiently radiate and that there were different systems of biological interactions (e.g., competition with pterosaurs) that impeded bird ecological divergence. Testing the relative import of these two factors requires extensive modeling efforts. I have run 85,000 simulations using the basal diversification rate

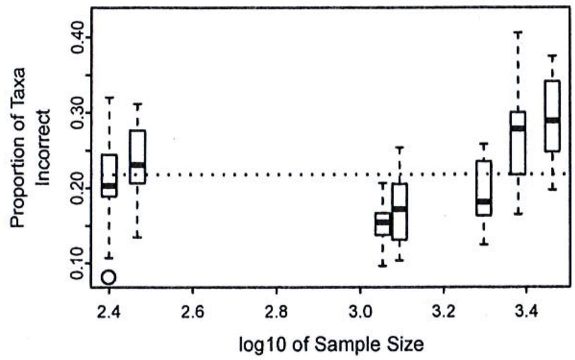

Figure 3: Modified from Figure 3 of Mitchell et al. (2012). Proportion of extinction correctly predicted by CEG for 7 Late Maastrichtian ($\approx$ 66Ma old) sites with $\geq$ 20 tetrapod taxa each, plotted according to the log of the sample size at each site. Dotted line indicates the overall accuracy at a conservative 78%.

for birds (Alfaro et al., 2009) and a rate of morphological evolution drawn from the Baysian posterior distribution of rates computed when accounting for within-lineage variation (Revell, 2012). These simulations show that the disparity in the Jehol biota is actually higher than what would be expected to exist by the Early Cretaceous, suggesting that the radiation of stem birds was accelerated relative to the basal crown bird condition (Mitchell & Makovicky, in prep).

Different ecological settings can beget vastly different functional diversity profiles. These basal birds were radiating and living in an environment filled with competition and predation unlike that seen in the modern realm. These ecological factors likely influenced the ecological diversification of birds, but to tease out their impact requires putting bird-bearing assemblages into the broader context of Mesozoic terrestrial ecosystems. Recently, I have been evaluating a food web model specifically designed to incorporate the uncertainties in fossil data (Roopnarine, 2006). This same model has previously been used to understand the end-Permian mass extinction (Angielczyk et al., 2005) and its empirical predictions were supported in a recent study of fossil occurrences (Irmis and Whiteside, 2011). Using this model to explore the end-Cretaceous extinction, I was able to quantify the extent to which the model successfully predicted extinction at a conservative 78% (Fig 3). My results describing changes seen in the lead up to the extinction in North America are described in a recent publication (Mitchell et al., 2012).

Due to these positive results, I am extending this modeling procedure to the bird lagerstätten I currently have sampled (Jehol Biota, Green River Formation) with the goal of understanding what ecologies non-avian taxa were occupying relative to those occupied by co-occurring birds. I am also extending this modeling approach to modern terrestrial ecosystems, and artificailly 'fossilizing' them, to quantify the impact of data loss on the analyses. However, without funding I will be unable to incorporate the extremely diverse Messel fauna or the Cretaceous London Clay, greatly restricting the temporospatial scale of my results.

Intellectual Merit

Despite a keen interest from both ornithologists and paleoecologists, we still have a poor conception of when and how birds diversified ecologically. My work will compare the structure of bird-bearing ecosystems before and shortly after the end-Cretaceous extinction event, and so will provide a quantitative benchmark for workers in both fields to use when discussing bird macroevolution. Likewise, by combing modern and fossil data with molecular phylogenetics and comparative methods, we can begin to more holistically understand the deep-time history of birds as well as how rates of diversification and morphological evolution may be linked. Even fossil calibration times may be impacted, as the difficulty of identifying members of stem lineages in the Cretaceous may be an artifact of the limited ecological diversification.

My work on understanding fossil food webs also has the potential to help buoy the burgeoning field of predictive conservation biology by setting up a framework and system by which we can test extinction predictions from ecological models (Dunne et al., 2002; Lotze et al., 2011; Srinivasan et al., 2011; de Visser et al., 2011). Further, my work can put our current ecological crisis (de Visser et al., 2011) into a broader geological context, and improve upon the ability of paleobiologists to predict extinction patterns in deep time (Jablonski and Sepkoski, 1996; Jablonski and Raup, 1995; Jablonski, 1986; Krug et al., 2009).

As larger phylogenies (e.g., Jetz et al., 2012) and more sophisticated models of morphological evolution are constructed (e.g., Slater et al., 2012), data collection is likely to be a key limiting factor in the rate of discovery. I will allow my complete morphological dataset to be searched and downloaded via the Field Museum's EMU database, so that future workers will have an easier time amassing large datasets, as well as make the database publically available via dryad and other sources as I publish the pertinent aspects.

Broader Impacts

Fossils are one of the best ways to get the public interested and invested in science. While in graduate school, I have been actively and consistently endeavoring to communicate the impact of my research to the public. Through the City Year program and my own volunteer efforts, I speak to different K-12 classes on the south side of Chicago and in rural North Carolina (over a dozen to date), and I will continue to do so throughout my time in graduate school. I also give public lectures to interested, adult non-scientists, notably at special seminars in both New Mexico and South Carolina. Likewise, because of the broad public interest in dinosaurs, extinction and conservation, I participate in numerous programs in partnership with the Education Department at the Field Museum, leading "behind the scenes" tours of the collections for interested patrons, and helping to foster general perception of the Field Museum as a valuable research institution.

Yet tours and voluntary lectures only reach so many people, so I also help proofread and guarantee the accuracy of educational packets the Field Museum distributes to Chicago Public School teachers. I am involved with the Early Elementary Science Participation (E^2SP) program, where I lead courses providing professional development training in geology and earth history for elementary school teachers, to help them understand the science necessary for revised federal science standards. At the University of Chicago, I participate in the graduate student-led "Ask-a-Paleontologist" program, where we answer questions submitted by south side elementary students.

My work also allows for the direct training of future scientists. Previously, I have helped summer interns for other researchers at the Field Museum and in China with multivariate statistics. I will be recruiting undergraduate and high school students to help me with data collection in the near future, however, as some of my research becomes more focused on generating intraspecific samples (few species in my dataset have more than 10 representatives).

References

Alfaro, M. E., Santini, F., Brock, C., Alamillo, H., Dornburg, A., Rabosky, D. L., Carnevale, G., and Harmon, L. J. (2009). Nine exceptional radiations plus high turnover explain species diversity in jawed vertebrates. *Proceedings of the National Academy of Sciences*, 106(32):13410 –13414.

Amiot, R., Wang, X., Zhou, Z., Wang, X., Buffetaut, E., Lécuyer, C., Ding, Z., Fluteau, F., Hibino, T., Kusuhashi, N., Mo, J., Suteethorn, V., Wang, Y., Xu, X., and Zhang, F. (2011). Oxygen isotopes of East Asian dinosaurs reveal exceptionally cold Early Cretaceous climates. *Proceedings of the National Academy of Sciences.*

Angielczyk, K. D., Roopnarine, P. D., and Wang, S. C. (2005). Modeling the role of primary productivity disruption in end-Permian extinctions, Karoo Basin, South Africa. In *The Nonmarine Permian*, volume 30 of *New Mexico Museum of Natural History and Science Bulletin*, pages 16–23.

Behrensmeyer, A. K. and Hill, A. P., editors (1980). *Fossils in the Making: Vertebrate Taphonomy and Paleoecology.* University of Chicago Press, Chicago.

Behrensmeyer, A. K., Stayton, C. T., and Chapman, R. E. (2003). Taphonomy and Ecology of Modern Avifaunal Remains from Amboseli Park, Kenya. *Paleobiology*, 29(1):52–70. ArticleType: research-article / Full publication date: Winter, 2003 / Copyright © 2003 Paleontological Society.

Bell, A. and Chiappe, L. M. (2011). Statistical approach for inferring ecology of Mesozoic birds. *Journal of Systematic Palaeontology*, 9(1):119–133.

Benson, R. B. J. and Mannion, P. D. (2011). Multi-variate models are essential for understanding vertebrate diversification in deep time. *Biology Letters.*

Brown, J. W. and Van Tuinen, M. (2011). Evolving Perceptions on the Antiquity of the Modern Avian Tree. In *Living Dinosaurs*, pages 306–324. John Wiley & Sons, Ltd.

Butler, R. J., Barrett, P. M., Nowbath, S., and Upchurch, P. (2009). Estimating the effects of sampling biases on pterosaur diversity patterns: implications for hypotheses of bird/pterosaur competitive replacement. *Paleobiology*, 35(3):432–446.

Dalsätt, J., Zhou, Z., Zhang, F., and Ericson, P. (2006). Food remains in *Confuciusornis sanctus* suggest a fish diet. *Naturwissenschaften*, 93(9):444–446.

de Visser, S. N., Freymann, B. P., and Olff, H. (2011). The Serengeti food web: empirical quantification and analysis of topological changes under increasing human impact. *Journal of Animal Ecology*, 80(2):484–494.

Dunne, J. A., Williams, R. J., and Martinez, N. D. (2002). Network structure and biodiversity loss in food webs: robustness increases with connectance. *Ecology Letters*, 5(4):558–567.

Dunning, J. B. (2008). *CRC Handbook of Avian Body Masses.* Taylor & Francis Group, Boca Raton, FL, 2 edition.

Ficken, R. W., Ficken, M. S., and Morse, D. H. (1968). Competition and Character Displacement in Two Sympatric Pine-Dwelling Warblers (Dendroica, Parulidae). *Evolution*, 22(2):307–314. ArticleType: research-article / Full publication date: Jun., 1968 / Copyright © 1968 Society for the Study of Evolution.

Finarelli, J. A. and Flynn, J. J. (2006). Ancestral State Reconstruction of Body Size in the Caniformia (Carnivora, Mammalia): The Effects of Incorporating Data from the Fossil Record. *Systematic Biology*, 55(2):301 –313.

Foote, M. (2010). The Geological History of Biodiversity. In *Evolution since Darwin: The First 150 Years*. Sinauer Associates, Sunderland.

Franzen, J. L. (1985). Exceptional Preservation of Eocene Vertebrates in the Lake Deposit of Grube Messel (West Germany). *Philosophical Transactions of the Royal Society of London. B, Biological Sciences*, 311(1148):181 –186.

Hackett, S. J., Kimball, R. T., Reddy, S., Bowie, R. C. K., Braun, E. L., Braun, M. J., Chojnowski, J. L., Cox, W. A., Han, K.-L., Harshman, J., Huddleston, C. J., Marks, B. D., Miglia, K. J., Moore, W. S., Sheldon, F. H., Steadman, D. W., Witt, C. C., and Yuri, T. (2008). A Phylogenomic Study of Birds Reveals Their Evolutionary History. *Science*, 320(5884):1763 –1768.

Harmon, L. J., Schulte, J. A., Larson, A., and Losos, J. B. (2003). Tempo and Mode of Evolutionary Radiation in Iguanian Lizards. *Science*, 301(5635):961 –964.

Hedges, B. and Kumar, S. (2004). Precision of molecular time estimates. *Trends in Genetics*, 20(5):242–247.

Ingram, T., Harmon, L. J., and Shurin, J. B. (2012). When should we expect early bursts of trait evolution in comparative data? Predictions from an evolutionary food web model. *Journal of Evolutionary Biology*, page no.

Irmis, R. B. and Whiteside, J. H. (2011). Delayed recovery of non-marine tetrapods after the end-Permian mass extinction tracks global carbon cycle. *Proceedings of the Royal Society B: Biological Sciences*.

Jablonski, D. (1986). Background and Mass Extinctions: The Alternation of Macroevolutionary Regimes. *Science*, 231(4734):129 –133.

Jablonski, D. and Raup, D. (1995). Selectivity of end-Cretaceous marine bivalve extinctions. *Science*, 268(5209):389 –391.

Jablonski, D. and Sepkoski, J. J. (1996). Paleobiology, Community Ecology, and Scales of Ecological Pattern. *Ecology*, 77(5):1367–1378. ArticleType: primary_article / Full publication date: Jul., 1996 / Copyright © 1996 Ecological Society of America.

Jetz, W., Thomas, G. H., Joy, J. B., Hartmann, K., and Mooers, A. O. (2012). The global diversity of birds in space and time. *Nature*, advance online publication.

Kissling, W. D., Sekercioglu, C. H., and Jetz, W. (2012). Bird dietary guild richness across latitudes, environments and biogeographic regions. *Global Ecology and Biogeography*, 21(3):328–340.

Krug, A. Z., Jablonski, D., and Valentine, J. W. (2009). Signature of the End-Cretaceous Mass Extinction in the Modern Biota. *Science*, 323:767–771.

Ksepka, D. T. and Boyd, C. A. (2012). Quantifying historical trends in the completeness of the fossil record and the contributing factors: an example using Aves. *Paleobiology*, 38(1):112–125.

Lotze, H., Coll, M., and Dunne, J. A. (2011). Historical Changes in Marine Resources, Food-web Structure and Ecosystem Functioning in the Adriatic Sea, Mediterranean. *Ecosystems*, 14(2):198–225.

Luck, G. W., Lavorel, S., McIntyre, S., and Lumb, K. (2012). Improving the application of vertebrate trait-based frameworks to the study of ecosystem services. *Journal of Animal Ecology*, 81(5):1065–1076.

MacArthur, R. H. (1958). Population Ecology of Some Warblers of Northeastern Coniferous Forests. *Ecology*, 39(4):599–619. ArticleType: research-article / Full publication date: Oct., 1958 / Copyright © 1958 Ecological Society of America.

Mayr, G. (2004). Old World Fossil Record of Modern-Type Hummingbirds. *Science*, 304(5672):861–864.

Mayr, G. (2008). Phylogenetic Affinities of the Enigmatic Avian Taxon Zygodactylus based on New Material from the Early Oligocene of France. *Journal of Systematic Palaeontology*, 6(3):333–344.

Mayr, G., Alvarenga, H., and Mourer-Chauviré, C. (2011). Out of Africa: Fossils shed light on the origin of the hoatzin, an iconic Neotropic bird. *Naturwissenschaften*, 98(11):961–966.

Miles, D. B., Ricklefs, R. E., and Travis, J. (1987). Concordance of Ecomorphological Relationships in Three Assemblages of Passerine Birds. *The American Naturalist*, 129(3):347–364. ArticleType: research-article / Full publication date: Mar., 1987 / Copyright © 1987 The University of Chicago Press.

Mitchell, J. S., Roopnarine, P. D., and Angielczyk, K. D. (2012). Late Cretaceous restructuring of terrestrial communities facilitated the end-Cretaceous mass extinction in North America. *Proceedings of the National Academy of Sciences*.

Morlo, M., Schaal, S., Mayr, G., and Seiffert, C. (2004). An annotated taxonomic list of the Middle Eocene (MP 11) Vertebrata of Messel. *Cour Forsch Inst Senckenberg*, 252:95–108.

Morse, D. H. (1967). Foraging Relationships of Brown-Headed Nuthatches and Pine Warblers. *Ecology*, 48(1):94–103. ArticleType: research-article / Full publication date: Jan., 1967 / Copyright © 1967 Ecological Society of America.

Penny, D. and Phillips, M. J. (2004). The rise of birds and mammals: are microevolutionary processes sufficient for macroevolution? *TRENDS in Ecology and Evolution*, 19(10):516–522.

Revell, L. J. (2012). phytools: an R package for phylogenetic comparative biology (and other things). *Methods in Ecology and Evolution*, 3(2):217–223.

Ricklefs, R. E. and Travis, J. (1980). A Morphological Approach to the Study of Avian Community Organization. *The Auk*, 97(2):321–338. ArticleType: research-article / Full publication date: Apr., 1980 / Copyright © 1980 American Ornithologists' Union.

Roopnarine, P. D. (2006). Extinction cascades and catastrophe in ancient food webs. *Paleobiology*, 32(1):1–19.

Sanchez, M., Green, A., and Dolz, J. (2000). The diets of the White-headed Duck Oxyura leucocephala, Ruddy Duck O. jamaicensis and their hybrids from Spain. *Bird Study*, 47(3):275–284.

Sanz, J. L. and Buscalioni, A. D. (1994). An isolated bird foot from the Barremian (Lower Cretaceous) of Las Hoyas (Cuenca, Spain). *Geobios*, 27, Supplement 1(0):213–217.

Slater, G. J., Harmon, L. J., and Alfaro, M. E. (2012). Integrating fossils with molecular phylogenies imrpoves inferences of trait evolution. *Evolution*, pages no–no.

Spencer, L. M., Van Valkenburgh, B., and Harris, J. M. (2003). Taphonomic analysis of large mammals recovered from the Pleistocene Rancho La Brea tar seeps. *Paleobiology*, 29(4):561–575.

Srinivasan, U. T., Dunne, J. A., Harte, J., and Martinez, N. D. (2011). RESPONSE OF COMPLEX FOOD WEBS TO REALISTIC EXTINCTION SEQUENCES. *Ecology*, 88(3):671–682.

Terry, R. C. (2008). Modeling the Effects of Predation, Prey Cycling, and Time Averaging on Relative Abundance in Raptor-Generated Small Mammal Death Assemblages. *PALAIOS*, 23:402–410.

Webster, A. J. and Purvis, A. (2002). Testing the accuracy of methods for reconstructing ancestral states of continuous characters. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 269(1487):143 –149.

You, H.-l., Lamanna, M. C., Harris, J. D., Chiappe, L. M., O'Connor, J., Ji, S.-a., Lu, J.-c., Yuan, C.-x., Li, D.-q., Zhang, X., Lacovara, K. J., Dodson, P., and Ji, Q. (2006). A Nearly Modern Amphibious Bird from the Early Cretaceous of Northwestern China. *Science*, 312(5780):1640–1643.

Zanno, L. E. and Makovicky, P. J. (2010). Herbivorous ecomorphology and specialization patterns in theropod dinosaur evolution. *Proceedings of the National Academy of Sciences.*

Zhonghe, Z., Fucheng, Z., and Zhou, L. (2009). A new basal ornithurine bird (Jianchangornis microdonta gen. et sp. nov.) from the Lower Cretaceous of China. *Vertebrata PalAsiatica*, 10:299–310.

Zhou, Z., Clarke, J., Zhang, F., and Wings, O. (2004). Gastroliths in *Yanornis*: an indication of the earliest radical diet-switching and gizzard plasticity in the lineage leading to living birds? *Naturwissenschaften*, 91(12):571–574–574.

Zhou, Z. and Zhang, F. (2002). A long-tailed, seed-eating bird from the Early Cretaceous of China. *Nature*, 418(6896):405–409.

Zhou, Z. and Zhang, F. (2006). A beaked basal ornithurine bird (Aves, Ornithurae) from the Lower Cretaceous of China. *Zoologica Scripta*, 35(4):363–373.

JONATHAN STUART MITCHELL

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Fax: (312)-665-7641
email: mitchelljs@uchicago.edu

Professional Preparation

Appalachian State University (Boone, NC)	B.S., Geology	2010
The University of Chicago	M.S., Evolutionary Biology	2012
The University of Chicago	Ph.D., Evolutionary Biology	2015 (expected)

Appointments

Five Related Publications

1) **Mitchell, J. S.**, Roopnarine, P.D., Angielczyk K.D. Late Cretaceous restructuring of dinosaur-bearing communities facilitated the End-Cretaceous mass extinction. In press at Proceedings of the National Academy of Sciences.

Five Other Recent Publications

1) Heckert, A. B., **Mitchell, J. S.**, Schneider, V., and Olsen, P.E. 2012. Diverse new microvertebrate assemblage from the Upper Triassic (Norian) Cumnock Formation, Sanford Subbasin, North Carolina, USA. Journal of Paleontology , 86(2):368-390, doi:dx.doi.org/10.1666/11-098.1
2) **Mitchell, J. S.**, Heckert A. B., and Sues, H-D. 2010. Grooves to tubes: Evolution of the venom delivery system in a Late Triassic "reptile". Naturwissenchaften 97:1117-1121.
3) **Mitchell, J. S.** and A. B. Heckert. 2010. The setup, use and efficacy of sodium polytungstate separation methodology with respect to microvertebrate remains. Journal of Paleontological Techniques , 7: 1-12.

Synergistic Activities

Education and Outreach: Volunteer lecturer for City Year (2010, 2011), Science fair judge for agriculture school (2012), "Dozin' with the Dinos" tour guide (2012), professional development trainer for E2SP teachers (2012), posts for a graduate-student run general science blog (2012).

Educational Resources: Reviewed educational packet distributed by the Field Museum's Education Department to Chicago Public School teachers.

Mentoring of Undergraduate Students: Helped mentor two summer REU-funded interns at the Field Museum (2012).

Professional Service: Travel Grant Review Committee (University of Chicago, 2011 □ 2012), Dean's Council (University of Chicago, 2011-current), Moderator at Society of Vertebrate Paleontology Meeting (2012).

Symposium Organizer:

Collaborators (not including graduate/postgraduate advisors and students/postdoctorates advised)

A. Heckert (Appalachian State University), P. Olsen (Columbia University), P. Roopnarine (California Academy of Sciences), V. Schneider (Smithsonian Institution), H-D. Sues (Smithsonian Institution)

Graduate and Postgraduate Advisors

K. Angielczyk (Field Museum of Natural History), P. Makovicky (Field Museum of Natural History).

Thesis/Postdoctorate Advisor/Co□Advisor for Five Individuals

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University of Chicago

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Kenneth Angielczyk

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**0**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**0**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**1,370**	
2. FOREIGN				**4,741**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**2,809**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**2,809**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**8,920**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Materials and Supplies (Rate: 58.0000, Base: 2809) (Cont. on Comments Page)**					
TOTAL INDIRECT COSTS (F&A)				**3,218**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**12,138**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**12,138**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Kenneth Angielczyk

ORG. REP. NAME*
Denise Dooley

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

** I- Indirect Costs
Travel (Rate: 26.0000, Base 6111)

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University of Chicago

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Kenneth Angielczyk

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**0**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**0**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**0**	
2. FOREIGN				**2,240**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**0**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**2,240**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Travel (Rate: 26.0000, Base: 2240)**					
TOTAL INDIRECT COSTS (F&A)				**582**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**2,822**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**2,822**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME **Kenneth Angielczyk**	FOR NSF USE ONLY		
	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Denise Dooley**	Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION **University of Chicago**	FOR NSF USE ONLY PROPOSAL NO.	DURATION (months)		
		Proposed	Granted	
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Kenneth Angielczyk**	AWARD NO.			

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (**0**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (**0**) GRADUATE STUDENTS				0	
4. (**0**) UNDERGRADUATE STUDENTS				0	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (**0**) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				0	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				0	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				0	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				1,370	
2. FOREIGN				6,981	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				2,809	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				2,809	
H. TOTAL DIRECT COSTS (A THROUGH G)				11,160	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				3,800	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				14,960	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				14,960	
M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME **Kenneth Angielczyk**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Denise Dooley**	Date Checked	Date Of Rate Sheet	Initials - ORG

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

Budget Justification

Funding is requested for two years:

A) Senior Personnel = $0

B) Other Personnel = $0

C) Fringe Benefits = $0

D) Permanent Equipment = $0

F) Travel = $8351 My travel involves four trips: one domestic trip to New York, one domestic trip to Wyoming, one international trip to continental Europe (in the first year of funding; total = $6111), and one international trip to the United Kingdom (in the second year of funding; total = $2240).

Year One:
First domestic trip:

- Economy-class domestic flight to New York = $328
  The American Museum in New York has one of the largest avian skeletal collections in the world, and funding to travel there to measure specimens would greatly increase my sample size for modern birds. Lodging within New York is free for me, as I have spoken with several graduate students at the American Museum who would be willing to host me.

Second domestic trip:

- Economy-class domestic flight to and from Bozeman, MT = $363
- 7 days of lodging in Thermopolis, Wyoming = $403
- 7 day under-25 car rental in Bozeman, MT = $130
- Gas costs associated with rental car = $146
  Thermopolis, Wyoming houses the Wyoming Dinosaur Center, which owns several European Cenozoic bird fossils as well as one of the best preserved skeletons of *Archaeopteryx*. The nearby Fossil Butte National Monument also houses copious Green River bird specimens and casts of specimens otherwise held in private collections. It will take ≈733 miles of driving to go from Bozeman to Thermopolis, Fossil Butte and back (maps.google.com).

First international trip:

- Economy-class Delta flight to and from Berlin = $1062
- EuroRail Global pass (Youth price) for ground transport from Frankfurt to Munich, Brussels, Paris, and Madrid = $1049
- Lodging = $2630 for 32 total days at ≈ $70 per day in Frankfurt, Munich & Madrid (10, 5 and 5 days), ≈ $85 in Brussels (6 days), ≈ $120 in Paris (6 days). Prices estimated from google.com/hotelfinder.

These cities each house an institution with significant Cenozoic fossil bird collections: Forschungsinstitut Senckenberg in Frankfurt am Main & the Palaeontological Museum Munich (Eocene birds of Germany, Oligocene birds of Eastern Europe), Royal Belgian Institute of Natural Sciences in Brussels (Oligocene birds of Belgium), Muséum national d'histoire naturelle in Paris (Oligocene birds of France), and the Unidad de Paleontología, Universidad Autónoma de Madrid in Madrid (Cretaceous birds of Spain).

Year Two:
Second international trip:

- Economy-class United flight to and from London = $1040
- Lodging in London = $1200 (10 days at $120 a day)
  The Natural History Museum in London houses many of the London Clay birds, which represent one of these most significant collections of fossil birds from the early Eocene.

F) Participant Support Costs = $0

G) Other Direct Costs = $2809
1) Materials and Supplies: Equipment will be purchased during year one for research over both years.

- Mitutoyo 12" Calipers 500-196-20 = $160.
  Standard measurement tool for most of my data collection. I currently use a pair on departmental loan, but these need to be available for use by other students, limiting my freedom of use.
- Tresna 40" Calipers 111-607-3 = $1174..
  Many birds (albatross, storks, etc.) are too large to measure with standard calipers. As above, the department currently loans me calipers but these are both old and, since they belong to the department, need to be readily accessible by other students, hampering my ability to travel.
- 18 Megapixel Canon EOS Digital SLR Camera with 60mm macro lens (price from amazon.com) = $1475.
  High resolution macro-lens digital photographs will allow me to document my measurements digitally, and refer back to observed specimens.

H) *Total Direct Costs* = $11160

I) *Total Indirect Costs* = $2171 (off-campus) + $1629 (on-campus) = $3800
Most of my funds are for off-campus travel and research. For my first international trip, more than 30 consecutive days will be spent off-campus, as I will be visiting European institutions to collect data. All other costs will be incurred on campus at the University of Chicago. The University of Chicago has an indirect cost rate of 26% of all modified total direct costs incurred off-campus, and 58% for on-campus

direct costs. The University of Chicago's latest Federal Facilities and Administrative Agreement was approved on April 23, 2012.

J) *Total Indirect & Direct Costs* = \$14960

K) Residual Funds = \$0

L) Amount of this Request = \$14960

Facilities, Equipment, and other Resources

Laboratory

NA

Clinical

NA

Animal

NA

Computer

The PI has two desktops, a Mac and a Linux machine, as well as a Linux laptop. The Co-PI likewise has a Linux laptop and access to two Mac and two PC desktops via the Committee on Evolutionary Biology. The Co-PI also has access to large-scale computing clusters via the University of Chicago.

Office

Both the University of Chicago and the Field Museum provide office space. Office facilities include faxing, scanning, printing and mail delivery.

Other

NA

Major Equipment

Small (12") and large (24") calipers are available via the Committee on Evolutionary biology for measurement of bird specimens. A recently re-calibrated Microscribe MLX is available for three dimensional landmark digitization via the Geology Department at the Field Museum.

Data Management Plan

My research generates a variety of data types: morphological measures of specific specimens, ecological summaries of different taxa, food web compilations of fossil and modern assemblages, simulation outputs and code for processing all of it. All data is stored indefinitely on the PI and CoPI's personal computers. I am working with the Collections Manager in the Bird Division of the Field Museum to get all of my morphological measures attached permanently to specimens in the museum's EMU database, for other researchers to use. For publications, all morphological and ecological data will be uploaded both in supplementary online material and in the data storage service Dryad (http://datadryad.org). Code will be made available by request, or through my personal website (http://home.uchicago.edu/ mitchelljs/).

My ecological data is compiled from various published sources, as per Luck et al. (2012). My morphological data is not dissimilar from what has been collected previously (Miles and Ricklefs, 1984; Bell and Chiappe, 2011; Kissling et al., 2012). I have presented these data in the form of talks at the Geological Society of America meeting last year, and at the Society of Vertebrate Paleontology meeting this year. I intend to continue presenting my data and results at professional conferences to help disseminate my work, as well as eventually publish it (my first dissertation-related paper is out in PNAS, my second is in preparation).

References

Bell, A. and Chiappe, L. M. (2011). Statistical approach for inferring ecology of Mesozoic birds. *Journal of Systematic Palaeontology*, 9(1):119–133.

Kissling, W. D., Sekercioglu, C. H., and Jetz, W. (2012). Bird dietary guild richness across latitudes, environments and biogeographic regions. *Global Ecology and Biogeography*, 21(3):328–340.

Luck, G. W., Lavorel, S., McIntyre, S., and Lumb, K. (2012). Improving the application of vertebrate trait-based frameworks to the study of ecosystem services. *Journal of Animal Ecology*, 81(5):1065–1076.

Miles, D. B. and Ricklefs, R. E. (1984). The Correlation Between Ecology and Morphology in Deciduous Forest Passerine Birds. *Ecology*, 65(5):1629–1640.

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Tuesday, October 23, 2012

To Whom It May Concern:

Jonathan Mitchell has advanced to candidacy for a Ph.D. degree.

Sincerely,

Michael Coates

Michael I. Coates
Professor and Chair

Context for Improvement

Fossil avifaunas are rare, with the most diverse one being from the Eocene of Germany, and with Paleocene Europe having more than any other time or place. Without data from those European birds, my dissertation results would be severely hamstrung. However, funding to travel overseas is difficult to obtain, and this grant would ensure that I was able to complete my research goals in a timely manner. The Doctoral Dissertation Improvement Grant would not only allow me to add vital data on ancient avian fossil deposits from Europe, but it would also allow me to spend more time collecting and analzying data at various U.S. institutions, as I would no longer need to constantly apply for small grants to travel to each isolated institution. Wyoming in particular would be of great use, as the Wyoming Dinosaur Center and Fossil Butte National Monument are two places I have not been able to afford to go. The Wyoming Dinosaur Center houses a spectacular specimen of *Archaeopteryx* as well as various fossil birds from around the world, and Fossil Butte National Monument houses a host of Eocene Green River fossils of all taxa, including birds, as well as casts of specimens that are hard to access (i.e., they are in private collections). Likewise, my gear (small and large calipers, digital camera) are all departmental loans, and so the length of my trips is inherently limited by the need to ensure the other students have sufficient potential access to the equipment. The DDIG would thus allow me to greatly expand my dataset of modern and fossil taxa, and simultaneously allow me to incorporate several more avian assemblages by funding both my trips to collect the requisite data, and by giving me the equipment freedom to go.

My research (JSM's) unites work by my advisor, Kenneth Angielczyk (PI), on ecosystem modeling with work by my co-advisor, Peter Makovicky, on inferring ecomorphology in fossils. However, Dr. Angielczyk works predominantly on ancient mammal-relatives (synapsids) and Dr. Makovicky works on non-avian dinosaurs, while my project is on birds and Mesozoic ecosystems. Further, my research is not a continuation of any project either of my co-advisors have worked on, and as such I have not received fiscal support from either of them. All funding for my data collection has, and will continue to, come from grants awarded directly to me. A National Science Foundation East Asia and Pacific Summer Institute (EAPSI) grant funded my work in China, and various small grants from the Hinds Fund (University of Chicago grant) and the Paleontological Society have funded my museum visits within the United States.

Timetable

- July-August 2013: Travel to Senckenberg Natural History Museum (Frankfurt am Main), Paläontologische Museum München (Munich), Royal Belgian Institute of Natural Sciences (Brussels), Muséum national d'Histoire naturelle (Paris), and Universidad Autónoma (Madrid) to collect data on Eocene & Oligocene birds.

- August 2013: Travel to the American Museum (New York), Wyoming Dinosaur Center (Thermopolis) and Fossil Butte National Monument to collect data on modern & Cenozoic birds.

- September 2013: Travel to the Natural History Museum in London to collect data on birds from the London Clay.

Proposal Status | MAIN

Organization: University of Chicago

Panel Summary #1

Proposal Number: 1311389

Panel Summary:
Panel Summary

Population and Community Ecology Cluster
Doctoral Dissertation Improvement Grants Panel
February 2013

If this is a resubmission, how have previous criticisms been addressed?
This proposal is not a resubmission.

Criterion I: Intellectual Merit
Intellectual Strengths:
The motivation and results to date were clearly articulated and these feed directly into well reasoned arguments for additional funding to improve the project. The three objectives are nicely coupled, each addressing a discrete, but associated question. These objectives, in addition to the focus on birds, which have a long history of study, should lead to novel insights and advancements that would be difficult or impossible to obtain in lesser-known systems.

Intellectual Weaknesses:
It was not clear what the next action steps are for Mitchell's research. For example, the proposal text develops completed or in progress work for the first 6.75 pages. The authors need to allocate more of the proposal text to justify the intellectual advancement that can be made, if they are funded.

Criterion II: Broader Impacts
Strengths:
The broader impacts statement is encouraging since the Field Museum could provide broad exposure for the current and fossil bird collections. In addition, work with Chicago school children would be valuable and would likely add a human divcrsity aspect to the broader impacts as well.

Weaknesses:
There were no Broader Impact weaknesses noted in the panel discussion.

Context for Improvement: The research to be funded by this proposal is the addition of a study site, an extensive fossil location called the Messel Pits of Germany.

Data Management Plan: The data management plan was insufficient. It would benefit from a specific plan to back data up in reliable locales and a plan to make data publicly available. The word "data" is plural.

SYNTHESIS AND RECOMMENDATION

The PIs propose to explore important concepts including using avian morphology to predict ecology, modeling fossil preservation, and modeling ancient food webs to elucidate how modern food webs developed. The research description included discussion of modern conservation and application to it, but gave few specifics about the connection. The proposal was also not hypothesis-driven, which made it difficult to evaluate scientifically. It was also not clear what the next action steps are for Mitchell's dissertation research which is an important component for DDIG proposals.

The panel recommendation is: Not Competitive.

This summary was read by the assigned panelists and they concurred that the summary accurately reflects the panel discussion.

Panel Recommendation: Not Competitive

Proposal Status | MAIN

Organization: University of Chicago

Review #1

Proposal Number:	1311389
NSF Program:	Population and Community Ecology Program
Principal Investigator:	Angielczyk, Kenneth D
Proposal Title:	DISSERTATION RESEARCH: Inferring ecology in fossil terrestrial ecosystems
Rating:	Good

REVIEW:

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to intellectual merit.

While the proposal was enjoyable to read, it was not clear to me what the next action steps are for Mitchell's research. For example, the proposal text develops completed or in progress work for the first 6.75 pages. Only the last paragraph of the text describes that the currently proposed work would be extended to the Messel fauna.

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to broader impacts.

The broader impacts statement is encouraging since the Field Museum could provide broad exposure for the current and fossil bird collections. In addition, work with the school children of Chicago would be valuable and would likely add a human divcrsity aspect to the broader impacts as well.

Please evaluate the strengths and
weaknesses of the proposal with respect to any additional solicitation-specific review criteria, if
applicable

Summary Statement

The proposal contains exciting research, but it is unclear what has already been completed and what is proposed. In addition, the broader impacts would involve a potentially wide cross-section of the public if the Field Museum relationship is developed.

Back to Proposal Status Detail

Proposal Status | MAIN

Organization: University of Chicago

Review #2

Proposal Number:	1311389
NSF Program:	Population and Community Ecology Program
Principal Investigator:	Angielczyk, Kenneth D
Proposal Title:	DISSERTATION RESEARCH: Inferring ecology in fossil terrestrial ecosystems
Rating:	Very Good

REVIEW:

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to intellectual merit.

The research proposed has a high potential to advance our knowledge and understanding of extinct bird ecology. The research explores important concepts including using avian morphology to predict ecology, modeling fossil preservation, and modeling ancient food webs to elucidate how modern food webs came to be. The research description included discussion of modern conservation and application to it, but gave few specifics about the connection. It was also not hypothesis-driven, which made it difficult to evaluate scientifically. The team is highly qualified and has adequate resources to carry out the research.

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to broader impacts.

The researcher is collaborating with the Field Museum to put the data online in a searchable format and in a public outreach context. The researcher has a history of outreach to K-12 students, which makes the potential benefits to society of the project significant. Lastly, the student trains other students and interns as part of his research.

Please evaluate the strengths and
weaknesses of the proposal with respect to any additional solicitation-specific review criteria, if
applicable

Summary Statement

The project looks to: 1) use bird morphology to construct the ecology of ancient birds, 2) model fossil preservation, and 3) use modeling to elucidate ancient food webs and compare them to modern food webs. The research is innovative and a DDIG would increase the sample size to include other geographies. The narrative suffered from not addressing specific research questions and not being hypothesis-driven. The outreach component is particularly strong.

◀ Back to Proposal Status Detail

Proposal Status | MAIN

Organization: University of Chicago

Review #3

Proposal Number:	1311389
NSF Program:	Population and Community Ecology Program
Principal Investigator:	Angielczyk, Kenneth D
Proposal Title:	DISSERTATION RESEARCH: Inferring ecology in fossil terrestrial ecosystems
Rating:	Excellent

REVIEW:

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to intellectual merit.

This research aims to study avian diversification and evolution using comparisons between the fossil record and modern bird assemblages. To account for potential fossilization bias, preservation models would be developed a fit to understand the extent to which observed patterns reflect none-random fossilization versus biology.

In nearly all aspects, this is an exceptionally strong proposal. While much of the proposed work is outside my area of expertise, the motivation and results to date were clearly articulated & these feed directly into well reasoned arguments for additional funding to improve the project. The three objectives are nicely coupled, each addressing a discrete, but associated question. These objective, in addition to the focus on birds, which have a long history of study, should lead to novel insights and advancements that would be difficult or impossible to obtain in lesser-known systems. The authors are well suited to the work and have the necessary resources at their disposal to complete the research.

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to broader impacts.

Broader impacts for this proposal were very good. Fossils are an excellent way to expose diverse groups to science & the authors have used this benefit to great effect and will continue to do so if funded. In addition to reaching school children, teachers, and the public, the work would also support the training of future scientists.

Please evaluate the strengths and
weaknesses of the proposal with respect to any additional solicitation-specific review criteria, if applicable

Summary Statement

This is an excellent proposal that uses creative approaches to address fundamental questions is ecology û namely the processes that drive the evolution and diversification of taxa. The comparisons of fossil and modern assemblages and the analyses of biases in the fossil record are likely to lead to advances within paleontology and beyond. Broader impacts were thoughtful and highly commendable.

Back to Proposal Status Detail