Smithsonian Institution OUSS/MCI Stable Isotope Mass Spectrometry Facility FY09 Report of Activities

Supporting Excellence in Smithsonian Science

Smithsonian Institution

Stable Isotope Mass Spectrometry Advisory Committee

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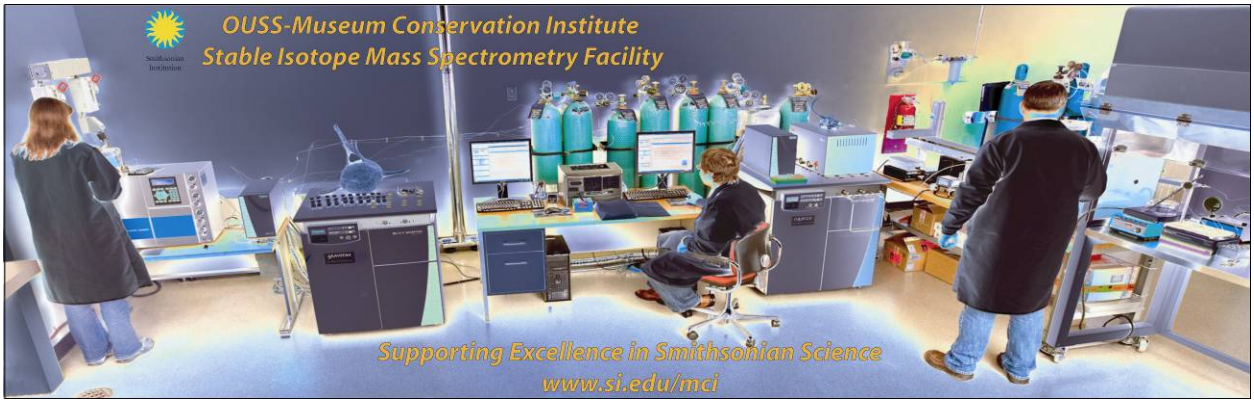
April 2010



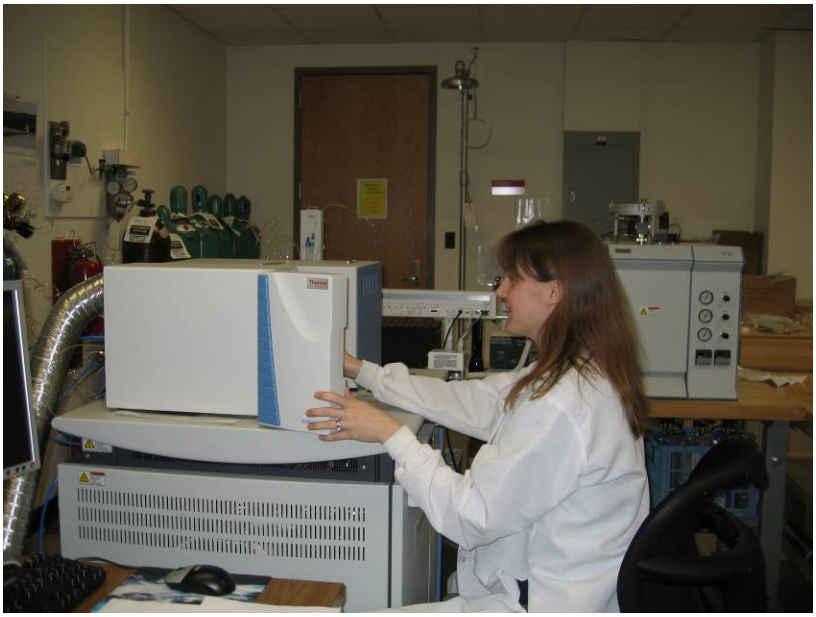
Laboratory Background

During the past twenty years, the development and widespread proliferation of modern mass spectrometers has made the task of measuring the masses and relative concentrations of atoms and molecules at high precision (from both organic and inorganic compounds) a reality at most research institutions throughout the United States. The availability of modern mass spectrometers offers researchers access to a wealth of new scientific knowledge, with much of it based on subtle variations in composition caused by physical and chemical mechanisms in nature. In recognition of this need, the Smithsonian Institution's Office of the Undersecretary for Science (OUSS), in collaboration with the Museum Conservation Institute, formed a Mass Spectrometry Advisory Panel tasked with the goal of identification, acquisition, and development of scientific instrumentation that will meet the research requirements of the broadest segment of SI researchers and their visiting students.

In early discussions with OUSS, MCI, and the Advisory Panel, it was recognized that the most critical and immediate need was a pan-institutional laboratory capable of high-precision measurements of isotopes of carbon, nitrogen, oxygen, hydrogen, and sulfur (C, N, O, H, S). These elements naturally occur as two or more stable (non-radioactive) isotopes. Isotopic variations arising from mass-dependent isotopic fractionation in organic and inorganic substances can be used to trace the pathways and forms that these key elements take as they are transferred and cycled within biological and geochemical systems. Measurements of stable isotope ratios in soils, animal tissues, and plant samples are used to reconstruct past climates and vegetation, evaluate physiological responses of wild and domesticated organisms, characterize energy and material transfers and transformations among plant, animal, and microbial components of ecosystems, and understand atmosphere-biosphere interactions. Stable isotopes record information on biological and physical processes operating across space and time, and thus are useful in integrative studies that span disciplines and levels of biological organization. Rapid and precise stable isotope analysis of solid, liquid, and gaseous materials are fundamental to studies in physiology, ecology, hydrology, earth and atmospheric sciences, archaeology, art history, and conservation.

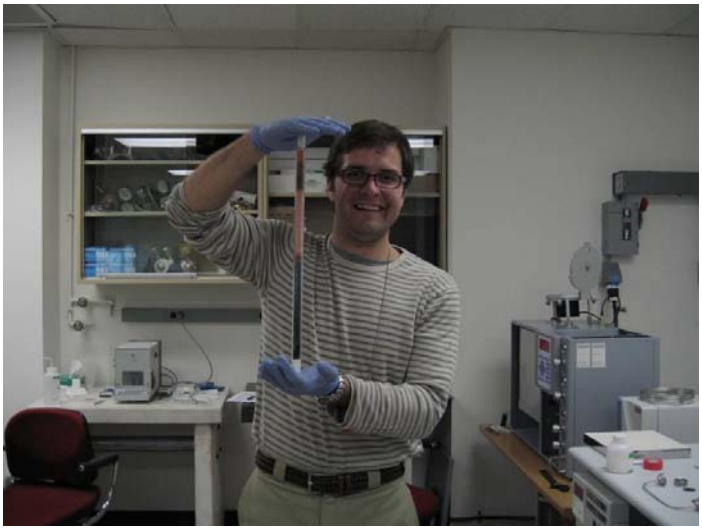
Funding to support the stable isotope initiative was obtained via FY 2007 year-end funding; MCI, with support from OUSS, took the lead in setting up a central laboratory with two stable isotope ratio mass spectrometers and associated peripherals. MCI hired a contractor, Greg Henkes (currently a Ph.D. student at Johns Hopkins) in May 2008 to oversee the installation and initial setup of the instruments. Greg's work was critical for laying the foundation of the laboratory. Both instruments were installed in June 2008, and MCI hired a full time scientist, Dr. Christine France, in November 2008 to manage the day-to-day operation of the laboratory. Upon starting at MCI, Christine (along with MCI management) faced multiple challenges, including advertising the laboratory's capabilities to the SI community, developing partnerships and collaborations, educating potential researchers on details of stable isotope geochemistry, overseeing the analyses, scheduling instrument time, and training multiple SI students and fellows on issues concerning sample preparation and analytic procedures—all while trying to develop and maintain her own research program.

FY09 Accomplishments



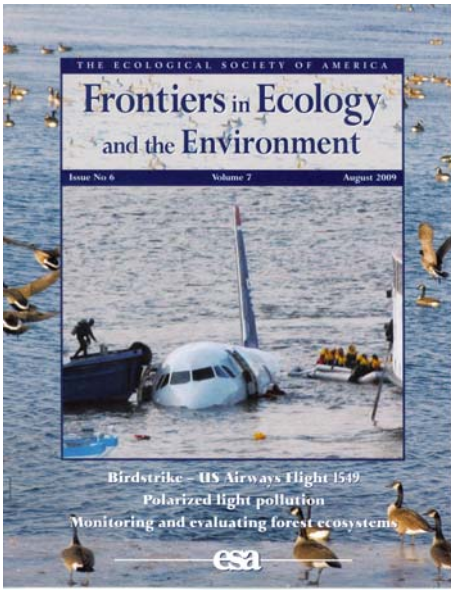
The laboratory has been a phenomenal success. In the first year of operation MCI scientists collaborated on 48 projects that resulted in more than 9,000 analyses, 1 peer-reviewed publication, and 3 professional presentations. Such productivity, in terms of numbers of samples analyzed, is the norm for larger academic-based facilities, but for a brand new laboratory with limited personnel and fiscal resources, this level of productivity is exceptional. In addition to the above mentioned accomplishments, we know of three major grant proposals that were submitted by SI researchers that included data generated at the IRMS laboratory, and we are aware of numerous other papers that have been submitted and are in review or in press. We anticipate that the number of publications will be much higher in FY10. Of the 48 projects initiated in FY09, 15 were based with researchers at **NMNH** (Anthropology and Paleobiology), 10 with **NZP**, 8 with **SERC**, 1 with **SMSFP**, 2 with **STRI**, and 2 with **FSG**. The remaining projects were initiated by **MCI** researchers. These projects also include numerous collaborations with researchers and students at external institutions (such as University of Arizona, NIH, Johns Hopkins University, University of Maryland, Indiana University, Nova Southeastern University, Baylor University, University of Georgia, University of Montana, University of Gronigen, and University of Central Florida) which bring a broader depth of knowledge and unique expertise to Smithsonian projects.

Isotopic research conducted thus far, has, or will contribute to the growing body of research on a multitude of topics such as avian migration, wetland ecology, and African wildlife dietary history. In the future we hope develop novel applications for stable isotope analysis in paleobiology, conservation and archaeological science as well as provide traditional services to those disciplines already heavily based on stable isotope chemistry. If we look at how the current projects are aligned with the Smithsonian's new strategic plan, we count 33 projects that can be thematically classified as **Understanding and Sustaining a Biodiverse Planet**, 7 are classified as **Understanding the Mysteries of the Universe**, 6 are classified as **Valuing World Cultures**, and 2 can be classified as **Understanding the American Experience**. The IRMS Facility is clearly aligned with SI's new strategic plan and making important contributions to Smithsonian Science.



As we look to the future of the laboratory, funding remains a critical issue for sustained maintenance and future growth of the facility. Some success has been made on this front already. In early FY10, OUSS provided funding to support an interdisciplinary postdoctoral fellowship in the area of stable isotope biogeochemistry. In addition, several stakeholders in the laboratory (OUSS, MCI, Peter Marra, and Ed Vicenzi) pooled funds that provided for the purchase of a new microbalance for weighing out samples. While the lab is well equipped, there remain several items that need to be purchased to support daily operations—these include a gas chromatograph for compound specific isotopic research and a micromill for targeted sampling of small areas. The most urgent concern for the immediate future, however, is the continued maintenance and repair of the instruments. The current service contract is set to expire in July 2010. It is critical that the laboratory stakeholders negotiate funding to either renew the contract or identify funds that can be used for instrument repairs on an as-needed basis.

It is equally important to note that since the laboratory opened for business, no fees have been charged for any of the analyses that have occurred and that costs for all consumables and gasses have been borne by MCI. For this laboratory to operate at its maximum potential, hurdles that would limit or preclude access to analytical resources must be minimized. This is especially true given that funding at the unit level oftentimes is limited and access to traditional funding venues, such as the National Science Foundation remain a challenge for SI scientists. It is hoped that at some point in the very near future that MCI and the Stable Isotope Mass Spectrometry Committee can negotiate a dedicated line of funding from SI to support the basic operation of the laboratory. If this is not possible, we unfortunately may be forced to adopt a fee-for-service model to cover costs associated with consumables and repairs.



Finally, it is important to underscore the contributions that the laboratory has already made to support scientific excellence at SI and the synergy that can occur among cross-unit multidisciplinary teams. The very first publication from the laboratory was based, in part, on stable isotope analyses of feathers recovered from the engine of US Airways Flight 1549—also known as *Miracle on the Hudson*. Following the crash, the Federal Aviation Administration contacted Carla Dove (NMNH) about identifying the birds that were sucked into the plane's engine. Carla subsequently initiated a conversation with MCI and Peter Marra (NZP); these discussions formed the foundation for a very strong cross unit collaboration that exemplifies Smithsonian science. The analyses were conducted and isotopic data resulted in the determination of a non-local origin for the Canada Geese that struck the plane specifically that the geese had spent their summer farther north than Labrador. These findings were significant on several fronts. First and foremost were the implications from a wildlife management perspective. Had the geese been determined to be from a local New York population, it is highly likely that the local population would have been culled or exterminated. Determining that these particular geese were migratory requires a completely different management plan to reduce, or prevent, such bird strikes in the future. The use of deuterium isotopes to effectively "source" the geese was a novel application of isotopic research—one that will serve as a model for future avian migration based research. Finally, there is the positive public impact that resulted from the research which was highly publicized both nationally and internationally. A search of the AP headline identified 35,000 hits on Google, hundreds of which were direct coverage of the SI press release. For the public, which traditionally does not associate the SI with science, this research is yet another of several recent and excellent examples of science at the Smithsonian.

Access to the laboratory is available to SI researchers and their students and fellows. For details of specific projects, please contact the primary project PI's; for details concerning the IRMS Facility contact Christine France or Jeff Speakman or visit our Web site: http://www.si.edu/mci/irms. Additional information concerning the instrumentation and sample preparation guidelines are included at the end of this report.

The following section includes summaries provided by PI's for projects initiated in FY09. Although we do not expect all of these projects to necessarily have the same level or type of impact as the Canada Geese research discussed above, we are confident that the research projects described below exemplifies the best of Smithsonian Science and will have far reaching implications both within and beyond the confines of the Institution.

Jeff Speakman
Head of Technical Studies, MCI

IRMS #: 0001
PI: Caroline Salozzo (MCI)
Smithsonian Initiative: *Valuing World Cultures*
Title: Identification of Salish blanket fiber materials
Project Summary: This research seeks to resolve questions concerning the source of protein fiber in blended yarn used by the North West Coast Salish tribes in making blankets, a subject of active debate. The research method involves comparison of provenienced dog and mountain goat hair fibers to unknown fibers from the provenienced Salish blankets, using a range of analytical techniques including proteomics (peptide sequence comparison) and stable isotopic analyses. The results will be of interest to North-American archaeologists and ethnologists first as the use or not of dog hair will change or confirm theories about the Coast Salish and shed new light on Native American weaving and archaeology in general. The second interest is for archaeological sciences: proteomics is a recent discipline, being applied to archeology for the past three years. Its potential is just now beginning to be understood and textile identification can be a huge application for archaeology and conservation. At the same time, it will enlarge the database of provenienced animal fiber sources sequenced by the proteomics methodology.

IRMS #: 0002
PI's: Ilka Feller and Anne Chamberlin (SERC)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Effects of nutrient enrichment and species diversity on ecological stoichiometry
Project Summary: This is a study on how nutrient enrichment alters food webs in the mangroves. These samples cover how different snail species differ their feeding on different species of enriched mangrove leaves.

IRMS #: 0003
PI's: Mary Ballard and Elizabeth Shuster (MCI)
Smithsonian Initiative: *Valuing World Cultures*
Title: Isotope ratio mass spectroscopy (IR-MS) analysis of natural and synthetic indigo
Project Summary: The purpose of this research project is to determine whether isotope ratio mass spectroscopy can aid in the discrimination of synthetic and natural indigo dyes derived from plants incorporated into cultural artifacts. It is hypothesized that natural and synthetic indigo can be identified in cultural artifacts according to

Shuster, E., and Henkes, G., 2009. Isotope Ratio Mass Spectroscopy and Indigo. Second Annual SI-Conservation Conference, Suitland, MD, June 25.

differences in their isotopic makeup, even though their chemical formulas are identical. For example, the carbon isotopes in natural indigo derived from plants and synthetic indigo are likely to be dissimilar because only in natural indigo derived from plants are the isotopes guided by photosynthetic processes. In addition to distinguishing between natural and synthetic indigo, it may be possible to identify the geographic sources of natural indigo used in cultural artifacts, since hydrogen and oxygen isotopes very geographically. In order to test this hypothesis, the tendencies of carbon, nitrogen, oxygen, and hydrogen isotopes toward fractionation in natural and synthetic indigo at various stages of processing will be recorded.

IRMS #: 0004
PI's: Jeff Speakman (MCI) & Greg Henkes (MCI & Johns Hopkins), NZP & National Institutes of Health
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Analysis of *Nautilus pompilius* shell

Project Summary: Nautili are a nocturnal species that undergo a daily, vertical migration. In captivity nautilus require cool water, dark, and deep dedicated aquariums. Even in 'proper' environments, they experience buoyancy problems and are unable to properly grow new shell in captivity. In addition, it appears the mortality rate for captive specimens is quite high. Identifiable chemical differences between the 'new' and 'old' shell growth may help determine the cause of elevated mortality rates in captive nautilus. Inorganic chemical differences will be analyzed using XRF, SEM-EDS, ICP-MS, and IRMS techniques. Changes in organic composition are examined using IRMS and proteomic techniques.

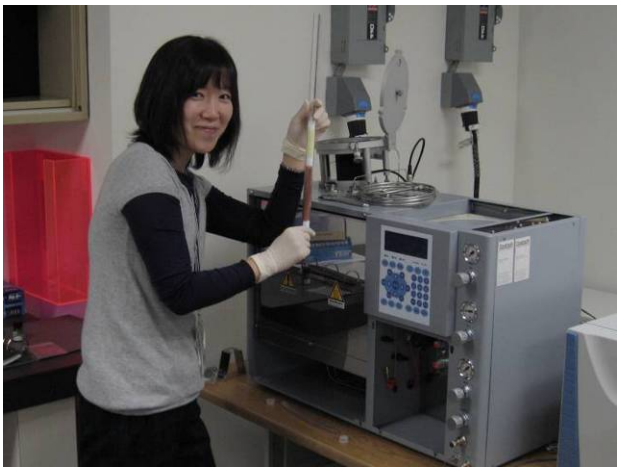
IRMS #: 0005
PI's: Ashley Coutu and Jeff Speakman (MCI)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Tracing the links between elephants, humans, and land use during the 19th century East African caravan trade: a bioarcheological study
Project Summary: This project aims to determine the geographical origins (i.e. source) of ivory traded along 19th century caravan routes in East Africa. It will examine the impacts of the East African ivory trade which reached its peak in the mid 19th century through the use of stable isotope analyses of historic elephants (bone, teeth, and tusk). Isotope analyses of elephant remains will provide a historic proxy of what the elephant was eating (carbon isotopes), what type of climate it lived in (oxygen/nitrogen isotopes), and where it lived (strontium isotopes) in order to build a database of where elephants were exploited. Samples from East African elephants from the 19th and 20th century from the Smithsonian National Museum of Natural History will provide a baseline for the samples in this project. Additional samples from East African animals known to be browsers or grazers (i.e. hippopotamus, giraffe, zebra, and wildebeest) will provide a standard for the carbon isotope values found for the historic elephant populations.

IRMS #: 0006
PI's: Chris Tonra and Peter Marra (NZP)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Patterns of stable carbon isotope variation over the arrival period in a long-distance migratory bird
Project Summary: This was project continues to gather data on how stable carbon isotopes vary over the arrival period for a long-distance migratory bird

IRMS #: 0007
PI's: Sara Rockwell (U. Maryland) and Peter Marra (NZP)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Carry-over effects of winter population limitation in the endangered Kirtland's Warbler

Project Summary: Factors limiting the population size of the Kirtland's warbler (*Dendroica kirtlandii*), an endangered migratory bird, on their Bahamian wintering grounds and how these factors carry over to affect breeding season events remain unstudied, which could undermine conservation efforts. The objectives of this project are to 1) examine whether the consequences of winter habitat and diet affect arrival dates and body condition of Kirtland's warblers on the breeding grounds, and 2) assess the influence of these carry-over effects on the reproductive success. We will do this by monitoring eight 30-ha study plots near Mio, MI for the spring arrival dates of male warblers. Incoming males will be captured and banded, condition measured, and tissue samples will be collected for stable isotope analyses, The $\delta^{13}C$ of crown feather, blood, and claw material will be used as a measure of winter habitat type (wet vs. dry), and $\delta^{15}N$ of these tissues will represent winter diet (proportion of insects vs. fruit). Nests of banded males will be found and reproductive success (number of fledglings per year) will be recorded. Correlations between isotope ratios representing winter habitat and diet and 1) arrival date; 2) body condition; and 3) reproductive success of individual males will be examined. Identifying limiting factors is vital for effective conservation practices, yet the consequences of non-breeding season events on the population dynamics of this species, as well as most Neotropical migratory birds, are not understood. This study will assess the effects of winter population limitation, and increase our understanding of how seasonal interactions shape the fundamental ecology of migratory animals.

IRMS #: 0008
PI's: Yae Takahashi and Blythe McCarthy (FSG)
Smithsonian Initiative: *Valuing World Cultures*
Title: Use and selection of natural versus man-made mercury sulfide in china: development of a method for differentiation



Project Summary: Both natural (cinnabar) and synthetic (vermilion) forms of the red pigment, mercury II sulfide, HgS, are known to have been in use in China where the pigment occurs widely in archaeological contexts. However, differentiation between vermilion from the Chinese dry-process of manufacturing and natural cinnabar is currently not possible. The goal of the research is to develop a method that will discriminate between the two, and possibly identify geological sources of mercury sulfide given sufficient analyses of raw materials. The method will be used to increase understanding of the selection, production and use of mercury II sulfide pigments in China in terms of past human and social dynamics. Specifically, the investigators propose to develop a method by 1) producing vermilion using traditional methods and characterizing it for chemical and physical properties; and by 2) performing sulfur isotope analysis, total mercury analysis (to arrive at mercury to sulfur ratios), and x-ray fluorescence analysis on the vermilion as well as other selected reference materials. The method development will lay the groundwork for more extensive studies of mercury sulfide from archaeological sites in Shaanxi province, China, including a study of HgS used for ritual versus decorative purposes and a study of HgS in wall paintings from the Qin, Han, Sui and Tang dynasties.

Takahashi, Y., McCarthy, B., Henkes, G.A., France, C.A.M., 2009. Analysis of natural and man-made mercury sulfide using sulfur isotope analysis. The Japan society for the conservation of cultural property, 31st conference in Kurashiki, Japan, June 13-14.

IRMS #: 0009
PI: Dennis Whigham (SERC)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: A preliminary analysis of plant and animal ecosystems in Alaska
Project Summary: Plant and soil samples from Alaskan ecosystems will be analyzed in an effort to reconstruct the food webs of the area.

IRMS #: 0010
PI: Ben Turner (STRI)
Smithsonian Initiative: *Understanding the Mysteries of the Universe*
Title: Cross-laboratory comparison and confirmation of standard values for stable isotopic analyses
Project Summary: Standards with accurate known isotopic values are critical to proper data handling and linear correction to internationally calibrated isotopic standards. In this study, organic materials developed at the Smithsonian Tropical Research Institute are tested in an inter-laboratory comparison to confirm stable carbon and nitrogen isotopic values.

IRMS #: 0011
PI's: Christine France and Greg Henkes (MCI)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: IRMS round robin comparison of values for new urea and acetanilide stable isotopic standard materials
Project Summary: This study is a round-robin test of several new urea and acetanilide standards for $\delta^{13}C$ and $\delta^{15}N$ values. The values obtained from multiple labs around the world will be combined and an average value published for purposes of international use. These standards will be used as new calibration points for purposes of correcting data to international standards.

IRMS #: 0012
PI's: Jeff Speakman and Christine France (MCI), Paul Sheppard (U. Arizona)
Smithsonian Initiative: *Understanding the Mysteries of the Universe*
Title: Stable carbon and sulfur isotopic indicators of volcanic eruptions as recorded in tree rings from Central and North America
Project Summary: The identification of past volcanic eruptions as recorded in tree rings is typically accomplished by standard methods of dendrochronology and examination of tree ring morphology. The goal of this study is to add the examination of chemical tracers in the tree rings that may be indicative of an eruption. Specifically, the stable carbon and sulfur isotopic record of the tree rings may reflect an eruption insofar as the isotopic signature of the surrounding atmosphere is often altered by gaseous volcanic input. Tree cores in close proximity to a well dated cinder cone eruption in Paricutin, Mexico will be examined for unique isotopic patterns during the eruption time period. Once a chemical pattern is established, tree cores in proximity to other poorly dated eruptions will be examined in a similar manner. Confirming an exact date for this and other culturally important eruptions will contribute greatly to our understanding of ecologic perturbations as causes for population movements in prehistory.

IRMS #: 0013
PI: Amy Hirons (NMNH)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Identification of water masses through the isotopic signature of marine zooplankton
Project Summary: Marine zooplankton will be used in identifying water masses using the stable carbon and nitrogen isotope signature of different zooplankton taxa. Additional tests will be performed to determine how different preservation techniques affect these zooplankton stable isotope ratios. The potential use of $\delta^{18}O$ and δD analyses will be considered in light of results from carbon and nitrogen isotopic analyses.

IRMS #: 0014
PI: Amy Hirons (NMNH)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Diets of mesopelagic fish
Project Summary: Mesopelagic fish muscle will be used to discern little known aspects about the diets of these fish. Carbon and nitrogen stable isotopic data will help assess what and where these fish are foraging.

IRMS #: 0015
PI: Amy Hirons (NMNH)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Examination of trophic structure of the Northwest Hawaiian Islands throughout the 20th century: evidence from the stable isotope signatures of monk seals

Project Summary: This study looks at the trophic structure of the Northwest Hawaiian Islands throughout predominantly the 20th century in an effort to better understand this species and develop appropriate conservation methods. This study includes monk seal bone collagen as well as vertebrate and invertebrate prey items of these seals which will be used to establish a food web through carbon and nitrogen stable isotope analyses.

IRMS #: 0016
PI: Amy Hirons (NMNH)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Stable isotope signatures of sea otter vibrissae as evidence for temporal/spatial distribution
Project Summary: This study consists of the analysis of sea otter vibrissae. The animals' temporal/spatial distribution will be correlated to the $\delta^{13}C$ and $\delta^{15}N$ values.

IRMS #: 0017
PI: Amy Hirons (NMNH)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Temporal and spatial distribution of Sea otters in the Bering Sea and North pacific: evidence from stable isotopes
Project Summary: This study consists of analyses of Steller sea lion vibrissae for carbon and nitrogen stable isotopes. This is a continuation of our long-term temporal sea lion trophic studies, focused on the western side of the Bering Sea and North Pacific.

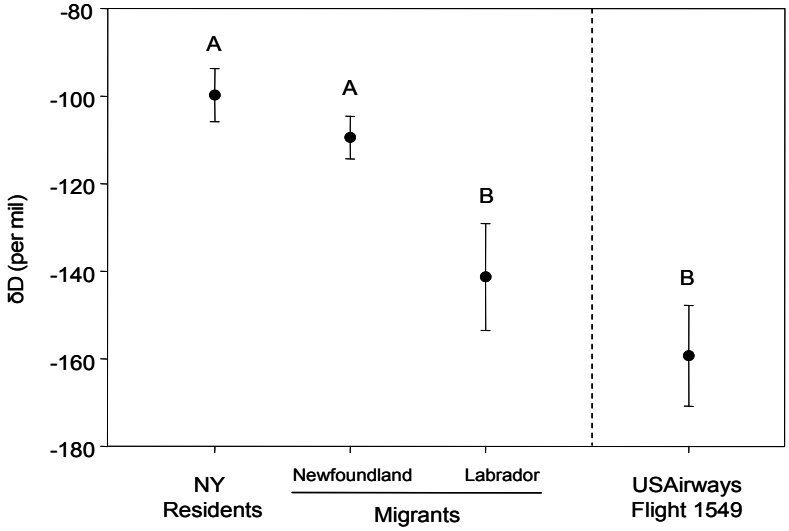
IRMS #: 0018
PI: Amy Hirons (NMNH)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Tracking a turtle's ocean journey using stable isotope signatures
Project Summary: Many species of sea turtles are known to be highly migratory throughout their lifespan. Understanding these migration patterns is crucial for conservation efforts. This project will analyze the stable carbon and nitrogen isotopic signature of several species of sea turtle scute (shell), egg case and bone collagen. This preliminary project will determine if the turtles' ocean journey can be tracked with stable isotopes.

IRMS #: 0019
PI: Amy Hirons (NMNH)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Stable isotopic indications of seagrass contribution to diet and habitat
Project Summary: This project examines seagrass contribution to diet and as habitat. A variety of organisms such as algae, invertebrates and vertebrate muscle will be examined isotopically for their relationship to the seagrass. Additionally, seasonal variability in the seagrass influence will be examined.

IRMS #: 0020
PI: Christine France (MCI)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Thermoregulatory adaptations of *Acrocanthosaurus atokensis* – evidence from oxygen isotopes
Project Summary: The thermoregulatory strategy of *Acrocanthosaurus atokensis* is currently unknown. This study aims to discern the internal temperature patterns of this large theropod dinosaur and determine if it was a homeotherm or a heterotherm. Oxygen isotopes, which are sensitive to variations in body temperature, will be compared across different bones of the same individual. The overall interbone temperature pattern as indicated by the $\delta^{18}O$ values will be compared to the pattern from an ostrich (a known homeotherm and direct descendant of the

dinosaur lineage), an elephant (a known large homeotherm), and an alligator (a known large heterotherm).

IRMS #: 0021
PI's: Peter Marra (NZP) and Carla Dove (NMNH)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Investigation of the migratory nature of Canadian geese causing the crash of US Airways Flight 1549
Project Summary: In January 2009, multiple engine strikes from Canadian geese forced the crash-landing of US Airways Flight 1549 in the Hudson River. Hydrogen isotopic data for the feather remains of the birds were compared to both migratory and local populations of geese in an effort to determine which of these groups was most similar isotopically to the bird remains. Determination of the migratory status of the birds responsible for the crash is critical to future preventative measures.



Marra, P.P., Dove, C.J., Dolbeer, R., Dahlan, N.F., Heacker, M., Whatton, J.F., Diggs, N.E., France, C., and Henkes, G.A., 2009. Migratory Canada geese cause crash of US Airways Flight 1549. Frontiers in Ecology and the Environment 7(6): 297-301.

IRMS #: 0022
PI's: Colin Studds and Peter Marra (NZP)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Connectivity of migratory bird populations wintering in the Caribbean Basin
Project Summary: Natural selection acts on individual animals throughout the annual cycle, and events during each phase of the annual cycle likely influence subsequent events. For migratory animals, understanding these selection processes has been impossible because of our inability to follow individuals year-round and determine where breeding populations' winter and where winter populations breed. In this study, we will construct isotopic basemaps for seven species of Nearctic-Neotropical migratory birds wintering within the Caribbean basin by using stable-hydrogen isotopes in tail feathers grown in North America and collected during the tropical non-breeding season. The final products of this research will include a map linking the breeding and wintering areas of each species. Such data will not only help determine the degree to which migratory bird populations mix between winter and summer, but will also provide an invaluable template for region-specific monitoring efforts.

IRMS #: 0023
PI's: Dennis Stanford (NMNH), Christine France (MCI) and Jeff Speakman (MCI)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Stable isotopic characterization of a mammoth tusk from coastal Virginia and associated fauna on the east coast of North America

Project Summary: A mammoth tusk dredged from the ocean floor off the coast of Virginia represents a unique opportunity to study a mammoth specimen with a known associated spear point. The direct implication of human predation on this species indicates that humans were present in established communities at a time concurrent to this specific animal. Initial carbon dating suggests an earlier than traditionally accepted age for presence of humans on the east coast of North America. Stable isotopic analyses will determine if this particular animal lived on the coast of Virginia or if it was a "wash-out" from upriver. Establishment of this animal as being from local population is central for an argument for a human presence at this early time and location.

IRMS #: 0025
PI's: Dennis Whigham (SERC) & Ryan King (Baylor U.)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Influence of riparian vegetation communities on stream food web structure

Project Summary: This study is focused on how riparian vegetation communities influence stream food web structure, as inferred using hydrogen, carbon and nitrogen stable-isotope ratios. Using samples collected across different wetland geomorphic settings (ecosystems), we will determine if different riparian wetland vegetation along headwater streams differentially support stream food webs. The study will help quantify the hypothesized linkage between uplands, wetlands, and streams in supporting juvenile salmon production. This information will be an important first step for regulators and managers to assess the ecological consequences of development activities in the headwater regions of watersheds on the Kenai Peninsula.

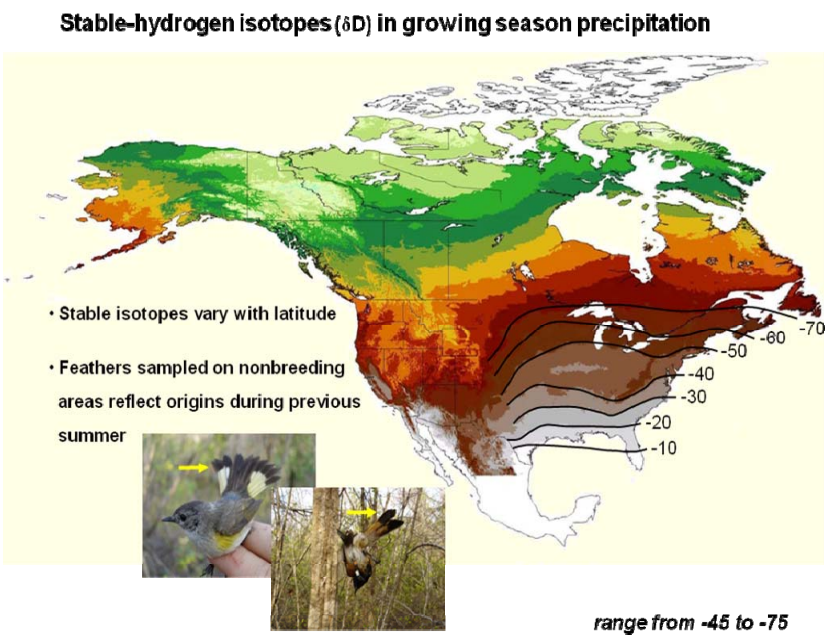
IRMS #: 0026
PI's: Russell Greenberg (NZP) & Patti Newell (U. Georgia)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Evaluating quality of winter feeding grounds for declining Rusty Blackbird
Project Summary: The Rusty Blackbird is one of the fastest declining songbirds in North America. Rates of population decline are estimated at 80-90% over the last 40 years and the cause is unknown. The decline could be occurring on the wintering ground, on breeding sites, or at migration stopover sites. We are studying the bird on the wintering ground to determine high quality habitat sites. It is thought that sites with pecans available may be higher quality than sites without. We are collecting blood samples from the birds we catch in South Carolina and intend to run stable isotope analyses for C and N and correlate them with body condition via indicators of body condition and blood metabolites assays.

IRMS #: 0027
PI: Peter Marra (NZP)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Patterns of stable carbon and nitrogen isotope variation across an urbanization gradient
Project Summary: This was an exploratory project to develop some initial patterns of isotopic variation across an urbanization gradient in the feathers of gray catbirds.

IRMS #: 0028
PI's: Peter Marra (NZP) & Adam Sepulveda (U. Montana)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Trophic structure of several fluvial ecosystems in the western United States
Project Summary: This study aims to reconstruct the trophic structure of several fluvial ecosystems in the western United States. The sample set will include all levels of the food chain from plants to salamanders.

IRMS #: 0029
PI's: Melissa McCormick & Kerry Good (SERC)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Effects of environmental change on the mycorrhizal relationships of the native orchids *Goodyera pubescens* and *Tipularia discolor*
Project Summary: Environmental change poses a many-faceted threat to native orchid species. Not only do habitats threaten to change directly, but the effects these fluctuations can have on necessary mycorrhizal communities also limit the ability of orchids to withstand changing conditions, especially at times of heightened stress when they may be depending on their mycorrhizal partners extensively for nutritional needs. This study incorporates *Goodyera* and *Tipularia* individuals at field sites on the SERC campus. Orchids obtain carbon from photosynthesis and also by digesting their mycorrhizal fungi; carbon can also be transferred from the plant to the fungi. These different nutritional patterns and the different fungal species incorporated into the orchids will be traced using stable carbon and nitrogen isotopes. Additionally, orchids will be exposed to reduced water and light in an effort to estimate the extent to which the orchids rely on their mycorrhizal fungi for nutrition during periods of stress, and whether increased stress induces myco-heterotrophy.

IRMS #: 0030
PI's: Peter Marra (NZP) & Clark Rushing (U. Maryland)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Using stable isotopes to study long-distance dispersal in neotropical migratory birds



Project Summary: Hydrogen isotopes from feathers collected from neotropical migratory bird species will be used to study patterns of long-distance dispersal. Specifically, we have collected samples from ~200 birds representing 6 species during the 2009 breeding season. Because these feathers were grown the previous year on or near the birds' breeding/natal ground, we hope to use H isotopes to determine the likely origin of these individuals, which will allow us to determine patterns of long-distance dispersal and how these patterns differ between ages, sexes and species. Subsequent work will combine these methods with experimental work in order to test hypotheses about the causes and consequences of long-distance dispersal.

IRMS #: 0031
PI's: Bruno Frohlich (NMNH), Christine France (MCI), Jeff Speakman (MCI)
Smithsonian Initiative: *Valuing World Cultures*
Title: Stable isotopic analysis of Bronze Age burial mounds (Khirigsuurs) in Mongolia
Project Summary: This project focuses on the $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$ values from human remains from Bronze Age burial mounds in Mongolia. The stable isotopic values will serve as proxies for reconstructing diet and possibly migratory patterns. These analyses will put into a cultural context to determine status of particular individuals and patterns of movement among separate populations.

IRMS #: 0032
PI's: Doug Owsley (NMNH), Christine France (MCI) & Jeff Speakman (MCI)
Smithsonian Initiative: *Understanding the American Experience*
Title: Stable isotopic analysis of Civil War soldiers from an excavated cemetery in New Mexico
Project Summary: The remains of several Civil War soldiers were unearthed from an abandoned military fort cemetery in New Mexico. The remains consisted of both native and immigrant persons as well as both black and white soldiers. Carbon and nitrogen stable isotopes will be used to determine dietary differences among these different groups. This information will be placed into a cultural context whereby inferences concerning the quality of life of different soldiers will be considered.

IRMS #: 0033
PI's: Christine France (MCI)
Smithsonian Initiative: *Understanding the Mysteries of the Universe*
Title: Development of new in-house standards for isotopic linear correction
Project Summary: Development of in-house working isotopic standards is necessary to reduce the use of certified standards. The project aims to find alternative standards to the limited supply of NIST certified USGS40, USGS41, and others.

IRMS #: 0034
PI's: Anna K. Behrensmeyer (NMNH) and Christine France (MCI)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Incorporating stable isotopic data into the larger biostratigraphic record of the Miocene Siwalik sequence in Pakistan
Project Summary: This project aims to incorporate stable isotopic data into the larger biostratigraphic record of the Miocene Siwalik sequence in Pakistan. Specifically, carbon and oxygen isotopic signatures from *Pila* snail opercula will be examined for climate signals and seasonality. Snails from several stratigraphic levels will be examined to determine changes in seasonality strength over time.

IRMS #: 0035
PI's: Terry Chesser (NMNH) & Camilo Sanin (Columbia U.)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Using stable isotope signatures to examine adaptive radiation of the passerine bird genus *Cinclodes*
Project Summary: This project is a study of the adaptive radiation of the passerine bird genus *Cinclodes*, using an integrated approach involving stable isotopes, phylogeny, and physiology. The genus *Cinclodes* consists of 13 species of ovenbirds, several of which have independently adapted to marine environments. This adaptation is unique among passerine birds, which lack functional salt glands and are constrained by their relative inability to produce concentrated urine. The purpose of the project is to track the pathways that led to the evolution of a marine niche in an evolutionary radiation of passerine birds. We are testing the proposition that *Cinclodes* is an adaptive radiation in which diversification was mediated by changes in osmoregulatory function. We are also examining the hypothesis that the evolution of a marine niche in the marine clades of *Cinclodes* has been accompanied by profound changes in the form

and function of the kidney. Stable isotopes will allow us to determine the relative reliance of the different species on marine and terrestrial-freshwater sources, as well as to determine the spatial and temporal changes in the use of these two types of resources in both individuals and populations.

IRMS #: 0036
PI's: Kenneth Wurdack and James Horn (NMNH)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Evolution of photosynthetic systems in *Euphorbia* (Euphorbiaceae)
Project Summary: *Euphorbia* (Euphorbiaceae) is the second largest genus of flowering plants with nearly 2200 species and contains familiar species such as the ornamental poinsettia. The group contains tremendous adaptive life form diversity (especially rich in xeromorphic species such as diverse succulents and cactiform species) and is the only genus to contain all three photosynthetic systems (C_3, C_4, and CAM). Fewer than 30 species have been examined for C isotope discrimination, but this has revealed significant variation in $\delta^{13}C$ values. A large *Euphorbia* research project has been initiated under the NSF-PBI (Planetary Biodiversity Inventory) program and we are conducting molecular phylogenetic work for this project at LAB. We presently have a large (176 taxa x 9 genes) phylogenetic tree to use for further investigations into the evolution of *Euphorbia*. Our project seeks to understand photosynthetic system evolution by using C isotope analysis of leaf tissue (mostly with the same samples used for DNA extractions), which will be mapped on the phylogeny and correlated with life forms using modern methods of character reconstruction and comparative analysis.

IRMS #: 0037
PI: Ben Turner (STRI)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Nutrients dynamics during ecosystem development
Project Summary: This project examines transformations of nutrients during pedogenesis using a series of soil chronosequences in Australia and New Zealand. Ecosystem development is characterized by a progressive increase in phosphorus limitation of primary productivity, which eventually leads to a reduction in forest biomass (retrogression). Changes in major nutrients (C, N, and P) have been relatively well-studied, but evidence from hydrolytic enzymes from one sequence (the Franz Josef post-glacial sequence in New Zealand) indicates that sulfur may limit productivity during ecosystem development when ample nitrogen and phosphorus are available. I've done some XANES work to identify sulfur compounds in soils along the sequence, and would now like to assess total sulfur concentrations and the isotopic ratios in soil and leaf tissue (from the major species along the sequence). Taken together, this will provide detailed information on sulfur pools and dynamics along the sequence with which to assess the long-term sulfur status of the ecosystem.

IRMS #: 0038
PI's: Doug Owsley (NMNH), Christine France (MCI) & Jeff Speakman (MCI)
Smithsonian Initiative: *Understanding the American Experience*
Title: Stable isotopic analyses of Eastern US (Chesapeake area) historic human remains
Project Summary: Human remains from several North American east coast grave sites spanning time periods from colonization forward will be analyzed for carbon, nitrogen, and oxygen stable isotopes. These analyses will provide insight into diet and migratory patterns. Specifically, isotopic differences between immigrants and native-born citizens as well as among social classes will be examined in an effort to discern patterns that can be applied to individuals of unknown origin.

IRMS #: 0039
PI's: Peter Marra (NZP) & C. Dorcey (UCSB)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Reconstructing food web dynamics in the understory of an eastern deciduous forest
Project Summary: This project uses stable carbon and nitrogen isotopes to reconstruct and understand the trophic relationships of the ground level food web in an eastern deciduous forest. Samples have been collected from a variety of organisms, plant and animals, from rotting roots to insects to ground foraging vertebrates for the assessment of both stable carbon and nitrogen.

IRMS #: 0040
PI's: Peter Marra (NZP) A. Hegemann (U. Gronigen)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Tracking the skylark throughout the annual cycle
Project Summary: This project links detailed information at the individual level with regards to behavior, reproduction, physiology and survival in Skylarks. Since 2006 this research has followed color-ringed birds throughout the year, and focused on identifying seasonal patterns of immune function during the annual cycle, on detecting connectivity between different seasons (using isotopes) and on searching for potential bottlenecks in the annual cycle of this species. Thus, this study will result in a unique dataset, one which connects life history stages and events in the annual cycle with immune function within a population of free-living birds and will contribute to understand how birds in general cope with their environment. Furthermore, it will provide the framework needed to establish a powerful conservation strategy for this rapidly declining species.

IRMS #: 0041
PI's: Amandine Vaslet (SMSFP), Carole Baldwin (NMNH), Ilka Feller (SERC)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Use of isotopic signatures to assess the importance of mangroves as feeding areas for mangrove fish communities in Florida and Belize
Project Summary: The aim of this research is to determine the importance of mangrove ecosystem as fish feeding ground in Florida (Indian River Lagoon – Smithsonian Marine Station in Fort Pierce) and Belize (Twin Cays – Smithsonian Marine Station in Belize). We hypothesize that the importance of mangrove-derived carbon sources in fish food webs may vary on mangrove location (tropical and subtropical latitudes) and physiognomy (offshore islands and

riverine mangrove). Moreover, fish residence times in mangroves (resident, transient) may have an influence on their feeding habits. As stable-isotope composition in a consumer reflects the isotopic ratios of its diet, analyses of the natural abundance of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotopes provide a powerful method to trace sources and transfer of organic matter through food webs. Provided that primary producers and then consumers have distinct isotopic signatures, carbon and nitrogen stable isotopes are proving increasingly useful as tracers in coastal trophodynamics studies. Mangroves are characterized by negative $\delta^{13}C$ values compared with other ecosystems (such as seagrass beds), thus allowing a discrimination of food-source origins. When conducted in conjunction with gut-content analyses to identify prey items, stable-isotopes analyses provide a powerful tool for untangling food webs.

IRMS #: 0042
PI's: Janet Douglas (FSG) & Christine France (MCI)
Smithsonian Initiative: *Valuing World Cultures*
Title: Chinese Buddhist Sculptures in the Freer Gallery of Art
Project Summary: The Freer Gallery of Art holds a major collection of Buddhist sculpture, many of which are from (or thought to be from) the cave sites of Xiangtangshan, Gongxian and Longmen. Little technical research has been done on these materials to date, and our ongoing collaboration aimed at the integration the art historical aspects of the sculpture with scientific data to construct the most complete understanding of our collections, their origin, and history. Several additional object-specific issues will be addressed, such as whether free-standing sculpture is similar in rock type and treatment to those carved in-situ.

IRMS #: 0043
PI's: Matt Tocheri (NMNH), Tosha Dupras (U. Central Florida), & Christine France (MCI)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Stable isotope analysis of faunal remains from Liang Bua, Flores, Indonesia: implications for the disappearance and possible extinction of *Homo floresiensis* and *Stegodon florensis* during the Late Pleistocene
Project Summary: On the Indonesian island of Flores, a well-dated faunal and archaeological sequence has been recovered at Liang Bua cave. This sequence spans the last 100,000 years and includes the only anatomical and behavioral evidence of *Homo floresiensis*, a new species of human first discovered in 2003. From 95 to 17 kyr, the faunal sequence contains a host of endemic mammal, reptile, and bird species, including *H. floresiensis* and *Stegodon florensis*. Both *H. floresiensis* and *S. florensis* disappear from the sequence at approximately 17 kyr, however small endemic fauna such as rats and bats persist. After 11 Ka, modern humans appear in the sequence along with several new introduced animals (i.e., non-endemic to Flores) including *Sus celebensis*, *Sus scrofa*, *Hystrix javanica*, *Paradoxurus hermaphrodites*, and *Macaca fascicularis*. The goal of this project is to reconstruct the local diet and ecosystem surrounding Liang Bua from stable isotope analyses of this incredibly rich 100 kyr faunal sequence. Such data are critical to understanding differences in behavior and diet between *H. floresiensis* and modern *Homo sapiens* as well as for testing hypotheses about the disappearance of *H. floresiensis* and other taxa from the Liang Bua sequence.

IRMS #: 0044
PI: Glen Havelock (SERC)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Environmental controls on diatom distribution in the Patuxent Estuary, past and present: implications for Holocene river discharge and sea-level change
Project Summary: Present models of Holocene estuary evolution are driven largely by changes in relative sea-level with little reference to long-term changes in fluvial regime and regional climate. Recent US studies of estuarine sequences have shown that decadal-centennial scale fluctuations in river discharge and freshwater inflow can be inferred by changes in estuarine paleosalinity and that the timing of these events reflects changes in regional precipitation. It is therefore becoming apparent that estuarine sequences may hold an archive of mid-late Holocene climate change information, as well as being recorders of RSL change. This study will use the contemporary distribution and salinity preferences of diatoms along the inner Patuxent estuary salinity gradient to quantitatively reconstruct paleosalinity in two dated sediment cores. Relationships between diatom distribution and a range of environmental variables will be investigated over a 12 month period so as to incorporate a range of tidal range and seasonal discharge variation. This will enable the development of a robust predictive transfer function, with smaller errors, that calibrates diatom variation to salinity. This will then be applied to the Holocene diatom record. The Patuxent watershed lies in a jet stream transition zone that is particularly sensitive to climatic variability, including the North Atlantic Oscillation. This should enable a sensitive and high resolution precipitation-driven discharge record to be reconstructed for the mid-late Holocene. The resulting climate record will be compared with other proxy climate records from the eastern United States and North Atlantic region. The methodology used in this study can then be applied to other estuarine systems, such as those affected by a Monsoon climate in south-east Asia.

IRMS #: 0045
PI's: Thomas Jordan (SERC) & Thomas Fisher (U. Maryland)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: Assessing denitrification at the watershed scale based on N and O isotopes in nitrate
Project Summary: The goal of this research is to determine the fate of nitrogen (N) added to watersheds by agriculture. Building on previous research, this project will apply new methods to assess denitrification in agricultural watersheds. Denitrification consumes nitrate, the main form of N exported from N-enriched watersheds, and produces dinitrogen and nitrous oxide gases. The project will measure accumulations of dinitrogen and nitrous oxide gases in groundwater and surface soils, and changes in the isotopic composition of nitrate that are indicative of denitrification. The study will identify locations within watersheds where denitrification is hypothesized to be most important: damp areas such as stream buffers and wetlands.

IRMS #: 0046
PI's: Melissa McCormick and Dennis Whigham (SERC)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: The mycorrhizal status of *Epifagus virginiana*
Project Summary: Work in the plant ecology lab has focused on mycorrhizal associations of a variety of plant species. One species that we have studied is the parasitic plant *Epifagus virginiana*. This plant belongs to a plant family thought to be entirely directly parasitic on other plants (Orobanchaceae), yet recent studies have suggested that at least *E. virginiana* may require a mycorrhizal fungus to establish connections with host plants. If the parasitic association is direct, *E. virginiana* $\delta^{15}N$ will resemble the soil environment and host plant. If the parasitic association is mediated via a mycorrhizal fungus, then *E. virginiana* $\delta^{15}N$ will resemble the fungus. Because *E. virginiana* is parasitic on beech trees, potential fungal hosts are ectomycorrhizal and will have very elevated $\delta^{15}N$ (~5-8‰ higher) relative to the tree host or soil. Conducting an isotopic analysis will determine whether mature *E. virginiana* plants use a fungus as an intermediary host.

IRMS #: 0047
PI's: Christine France & Jennifer Giaccai (MCI)
Smithsonian Initiative: *Understanding the Mysteries of the Universe*
Title: The effects of PVA and chemical removal of PVA on stable isotopic signatures in bones and teeth
Project Summary: During excavation, treatment of bones and teeth with PVA solution is a common method to maintain the integrity of highly weathered fossil material. Polyvinyl acetate dissolved in acetone has the potential to exchange carbon and oxygen isotopes with the bone/tooth material. Additionally, the removal of the PVA with various organic solvents may further fractionate isotope signatures and alter them from their original state. This study aims to determine if treatment with PVA and subsequent chemical removal alters isotopic values in fossil bones and teeth. The best strategy for removal will become the recommended standard procedure for handling specimens treated with PVA.

IRMS #: 0048
PI's: Gerhardt Reidel, Eric Johnson, Anson Hines (SERC)
Smithsonian Initiative: *Understanding and Sustaining a Biodiverse Planet*
Title: A novel application of bio-geochemical fingerprinting to evaluate the nursery potential of Chesapeake Bay subestuaries to contribute to the blue crab spawning stock
Project Summary: The objective of this project is to further develop and optimize a novel application of well-studied bio-geochemical tracers (trace elements, stable isotopes) for the blue crab to understand spatial variation in the production of mature female blue crabs among Chesapeake Bay tributaries. This goal is a key step toward providing managers with spatially explicit information about the value of individual tributaries as nursery habitats to contribute to the female spawning stock of blue crabs in Chesapeake Bay. If successful, this promising technique could be employed with other blue crab populations in the U.S., and potentially for other crustaceans that support valuable fisheries worldwide.

Laboratory Instrumentation and Sample Submission Details

Instrument #1 - GRAVITAS

GRAVITAS is a Thermo Scientific Delta V Advantage mass spectrometer coupled with a Costech ECS 4010 elemental analyzer via a Conflo IV gas interface. Its primary task is to provide high-throughput, coupled measurements of carbon and nitrogen stable isotope ratios. With GRAVITAS we are also capable of measuring sulfur stable isotopes from SO2 gas, however, we only do so on a limited basis.

Instrument #2 - ORACLE

ORACLE is a Thermo Scientific Delta V Advantage mass spectrometer coupled directly to a Thermo Gasbench II and a Thermo TC/EA via a Conflo IV gas interface. Its primary task is to provide high-throughput measurements of hydrogen and oxygen stable isotopes as well as carbon and oxygen stable isotope from carbonates. ORACLE also has a dual inlet which is currently set up for high precision stable isotope analysis of N2, CO2, and H2 gases. The dual inlet is used only for externally prepared or special need applications.

Sample Submission Guidelines

1. Contact Christine France (francec@si.edu, 301-238-1261), to discuss your project and sample preparation. Every project and sample set is unique and may require subtle variations to the guidelines listed below. We always strive to obtain the highest quality results for our users, so we ask that you ***please communicate directly with the manager before preparing your samples***!

2. Fill out a project submission request form (available from the lab manager) which includes a brief description of your project and your contact information.

Smithsonian
Museum Conservation Institute

MCI ISOTOPE RATIO MASS SPECTROMETRY
ANALYSIS REQUEST

IRMS #: (Assigned by Lab)

SMITHSONIAN INITIATIVE: (e.g., Understanding and Sustaining a Biodiverse Planet)

PROJECT TITLE:

REQUESTOR:

SMITHSONIAN DEPARTMENT/UNIT:

REQUESTOR ADDRESS, PHONE, EMAIL:

PROJECT SUMMARY:
(Please include a concise one-two paragraph description of the project and identify its connection to the Smithsonian)

PROJECT PI's:
(Please include the SI unit of all Smithsonian PI's; include the institution affiliation of all non-Smithsonian PI's)

OTHER COLLABORATORS:
(Please include the SI unit of all Smithsonian collaborators; include the institution affiliation of all non-Smithsonian collaborators)

REQUEST DATE:

DEADLINE DATE (if unknown use 'ongoing'):

DEADLINE REASON:

ADDITIONAL NOTES REGARDING THIS PROJECT:

3. Discuss the appropriate weights for your samples with the lab manager. The following are some general guidelines for the most common types of samples, but ***please confirm the appropriate weight with the manger before proceeding***. Please note there are other types of samples that we can accommodate that are not listed here.

Animal tissues for C and N (muscle, hair, feather, nails, extracted protein, etc.) 0.5-0.7 mg

Other organic solids for C and N —> 0.4-0.6 mg

Plant tissues for C only —> 0.3-0.4 mg

Plant tissues for C and N —> 3.5-5.0 mg

Soils/sediments for C and N (high organic content) —> 4.0-6.0 mg

Soils/sediments for C and N (low organic content) —> 8.0-10.0 mg

Sulfates and sulfides for S —> 0.4-0.6 mg

Pure organic solids for S —> 0.4-0.6 mg

Soils, sediments, animal tissue, plant tissue for S —> >10 mg

Phosphates and nitrates for O —> 0.4-0.6 mg

Organic solids for O —> 0.3-0.5 mg

Organic solids for H —> 0.3-0.4mg

Pure carbonates for C and O —> 0.3-0.5 mg

Enamel and hydroxyapatite for C and O —> 0.8-1.0 mg

4. For EA and TC/EA analyses, weigh and pack your samples; place them in a 96-well sample tray. Obtain the sample list template (excel format) from the lab manager and record your sample names and weights (in mg to at least 3 decimal places). We can recommend vendors for the tin cups, silver cups, and sample trays if necessary.

Samples for EA carbon, nitrogen, or sulfur isotopes and elemental abundances - Samples should be weighed into tin cups (3.5x5mm, 4x6mm, or 5x9mm) and tightly packed into a ball. Samples for sulfur analysis should have about 0.3-0.5mg of vanadium pentoxide added to the sample before packing the tin cup.

Samples for TC/EA oxygen isotopes - Samples should be weighed into silver cups (3.5x5mm, 4x6mm, or 5x9mm) and tightly packed into a ball.

Samples for TC/EA hydrogen isotopes - Samples for hydrogen analyses must be brought to the isotope lab at least 3 days prior to analysis to allow exchangeable hydrogen to equilibrate with our local atmospheric water vapor. All samples for hydrogen analyses must therefore be weighed and packed at the isotope lab. Contact the lab manager to make arrangements. Samples should be weighed into silver cups (3.5x5mm, 4x6mm, or 5x9mm) and tightly packed into a ball.

5. For carbonate analyses, samples will have to be delivered in bulk to the mass spec lab where they will then be transferred into the appropriate exetainer vials.

6. We can accommodate some gaseous samples for dual inlet analyses. Please communicate with the lab manager for details.

7. Once your samples are prepared, submit your project submission request form and your sample templates electronically to the lab manager. Include a paper copy of the sample templates with your trays. Cover your trays securely and coordinate with the lab manager to either drop off your samples in person or mail them to the lab. ***Please contact the lab manager before you send your samples!*** Internal SI mail can be sent to MRC 534.