University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

STABLE ISOTOPES IN ENVIRONMENTAL RESEARCH

3 credits

MEES 698R
Fall 2019

Course Objectives / Overview

Stable isotopes are a fundamental analytical tool in atmospheric, terrestrial, freshwater and marine ecological sciences, extending earlier applications in geology and geochemistry. In environmental sciences they have proven particularly useful as tracers and integrators of ecological and biogeochemical processes and in assessing responses of such processes to natural and human-induced environmental changes. This course will introduce the theory, nomenclature, methods and applications of stable isotopes in environmental research, with a focus on the stable isotopes of hydrogen, carbon, nitrogen, oxygen, and sulfur. This course is designed for early-career graduate students who potentially have an interest in using these methodologies as part of their research. The course will be comprised of lectures and student-led discussions of the primary literature. At the end of the semester, students will develop a written research proposal and present it to the class. There will also be opportunity to tour the isotope facilities at CBL and AL during the semester.

Expected Learning Outcomes

1. Students will be able to apply theoretical concepts, principles and nomenclature concerning stable isotopes, including use of appropriate terminology, units, and conversions of stable isotope data.
2. Students will be able to explain (written and oral) how stable isotope data are used to address basic and applied scientific questions in the environmental sciences.
3. Students will have practical lab experience and demonstrate the ability to prepare samples, generate data, numerically process data, report data following conventions, and interpret stable isotope data.
4. Students will be able to critically evaluate scientific studies that use stable isotope data.
5. Students will be able to develop a research idea using stable isotope data.

Course Assessment / Grading

INSTRUCTOR DETAILS:

Lee Cooper
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Hali Kilbourne
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David Nelson
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CLASS MEETING DETAILS:

Dates: Tues/Thurs
Times: 9:00-10:20 am
Originating Site: AL/CBL
IVN bridge number: (*******)
Phone call in number: (***)
Room phone number:(*****)

COURSE TYPE:

Check all that apply

☐ Foundation
☐ Professional Development
☐ Issue Study Group
☐ Seminar
x Elective

Prerequisites
N/A

Teaching Assistant
N/A

Course grades will be based on participation in, and leading of paper the discussions (25%), final presentation and paper (25%), midterm exam (25%), and final participation (25%).

Tentative Weekly Course Schedule

Week 1 (Nelson). Introduction and principles of stable isotopes

Historical perspective; principles of isotopic fractionation; Development of modern isotope ratio mass spectrometry, other more recent technologies such as cavity ring-down spectroscopy, membrane-inlet mass spectrometry and isotope dilution methods;

READINGS: Fry. p. 1-20, file in UMD Box folder
DISCUSSION papers: file in UMD Box folder

Week 2 (Nelson). Fractionation, nomenclature, standards

Nomenclature and notations; Rayleigh distillation; kinetic versus equilibrium effects; mass-independent isotopic fractionation; peripheral devices; international and working standards; precision versus accuracy as practical challenges

READINGS: Fry. p. 21-39, file in UMD Box folder
DISCUSSION papers: files in UMD Box folder

Week 3 (Nelson). Carbon isotopes and photosynthesis

Rubsico versus PEP carboxylase as sources of isotopic fractionation, CAM photosynthesis; isotopic composition of atmospheric and soil carbon dioxide; isotopes as a measure of water-use efficiency; isotopic fractionation in aquatic plants (e.g. carbon concentrating mechanisms); tree-ring applications

READINGS: Fry. p. 40-46, file in UMD Box folder
DISCUSSION papers: files in UMD Box folder

Week 4 (Cooper). The hydrologic cycle

Fractionation of oxygen and hydrogen isotopes in the hydrosphere; seasonal, temperature, storm, orographic and latitudinal effects; intro to ice core records; isotopic fractionation of water by plants; Craig-Gordon model for isotopic fractionation from evaporating reservoirs; diffusion effects; applications in groundwater, oceanography, plant physiology; Dole and Suess effects

READINGS: Fry. p. 40-46, file UMD Box folder
DISCUSSION papers: files UMD Box folder

Week 5 (Cooper). Ocean biogeochemistry

Carbon and nitrogen isotope fractionation in organic matter in the ocean; relationship to production rates; calcite and aragonite; fractionation during calcium carbonate production; intro to use of carbon, nitrogen, and sulfur isotopes for foodweb reconstruction and migration paths (covered more extensively on Oct 15/17); sulfur biogeochemistry, denitrification in oxygen-limited zones; nitrous oxide and methane cycling as exemplified by observed patterns of isotopic fractionation.

READINGS: file in UMD Box folder
DISCUSSION papers: files in UMD Box folder

Week 6 (Nelson). Animal diets, migration

Principles of biomagnification, differences in fractionation between carbon, nitrogen and sulfur isotopes; terrestrial examples such as bird migrations as well as feeding in marine and estuarine foodwebs; co-variance of isotopic fractionation with contaminants and trace metals

Week 7 (Kilbourne). Quantitative modeling of stable isotope data

READINGS:
DISCUSSION papers:

Week 8 (Cooper). Methane, nitrous oxide, and other atmospheric gas applications in biogeochemistry

READINGS: file in UMD Box folder
DISCUSSION papers: files in UMD Box folder

Week 9 (Kilbourne). Paleoenvironment reconstruction

Ice cores, including trace gas isotopic composition and water isotopes, variation, marine calcite record, organic material variations in cores and soil profiles

READINGS: file in UMD Box folder
DISCUSSION papers: files in UMD Box folder

Week 10 (Nelson). Forensic applications

Food purity; geographical sourcing of humans

READINGS: file in UMD Box folder
DISCUSSION papers: files in UMD Box folder

Week 11 (Cooper) Clumped isotopes and nitrogen isotopes in plants and soils

READINGS: file in UMD Box folder
DISCUSSION papers: files in UMD Box folder

Week 12 (Cooper). Compound specific isotopes and ^{14}C and a primer on radionuclide applications

READINGS: file in UMD Box folder
DISCUSSION papers: files in UMD Box folder

Week 13 (Nelson) Nitrate $\Delta^{17}O$ and isotope analysis of metals using multi-collector ICP-MS

READINGS: file in UMD Box folder
DISCUSSION papers: files in UMD Box folder

Week 14 Student presentations of individual projects

Required textbooks, reading and/or software or computer needs

Fry, B. (2006). Stable Isotope Ecology. New York, Springer. Available as e-book.

Course Communication

Moodle, phone, or email. Meetings by appointment.

Resources

[Course website: www.moodle.com/xxxxx]

Campus Policies

The University of Maryland Center for Environmental Science has drafted and approved of various academic and research-related policies by which all students and faculty must abide.

Please visit http://www.umces.edu/consolidated-usm-and-umces-policies-and-procedures for a full list of campus-wide academic policies.