Welcome!

Dear Conference Participant:

Welcome to Saskatoon and to our conference *Applications of Stable Isotope Techniques to Ecological Studies*! This meeting involves a unique blend of researchers and students associated with universities, government and industry who share a common interest in learning more about how stable isotope techniques can increase our understanding of ecological processes. Our decision to host this meeting was based on both an appreciation for just how rapidly this field is developing and a realization that presentations of work in this field were typically embedded as workshops within other, larger meetings. With the advent of continuous flow isotope ratio mass spectrometry and several other technological advances, applications of stable isotope analyses to ecological studies are increasing at a tremendous rate. Never before has the need for a dedicated meeting, dealing specifically with both the intricacies of the analytical side and applications involving single organisms through global processes been so great! It is our hope that this meeting will form the basis of a regular event, perhaps every few years, with the venue changing to other centers of isotopic and ecological research.

Our program is an exciting one. We are particularly fortunate to have Dr. Marilyn L. Fogel as our keynote speaker. Dr. Fogel's work truly epitomizes the multidisciplinary nature of research involving naturally occurring stable isotopes. We have several theme sessions in our regular program and an extensive poster session. Finally, we look forward to a wrap-up open forum where you can discuss any aspect of topics covered in the conference.

We hope that you enjoy your stay in Saskatoon, take time to enjoy the Canadian Prairies in spring, and moreover have a productive and rewarding meeting. You will find yourself in a group spanning expertise in the design and manufacture of state-of-the-art analytical equipment to those who are experts in application involving a number of academic disciplines.

Good luck and thank you for helping to make this meeting a success.

Keith A. Hobson and Len Wassenaar

The Scientific Program

The program has 76 papers in total - 40 oral and 36 poster presentations. Thanks to all who have contributed to make this meeting a success!

Dr. Marilyn Fogel of the Carnegie Institution of Washington will present a plenary talk to start the meeting. Her presentation is entitled "*The Marriage of Stables Isotopes and Molecular Biology for Ecological Studies*".

Marilyn Fogel has spent her career studying biological processes using stable isotopic tracers with the goal of understanding reactions that occur in the environment both in modern and in ancient times. Questions that guide her current research include: How do the inorganic and organic nitrogen compounds in atmospheric deposition affect primary and secondary production in coastal environments? What is the mechanism by which nitrogen is immobilized into decomposing plant matter that eventually will enter the fossil record? How far back in time will the isotopic signature of an animal's tissue faithfully record the in vivo signal? Can climatic changes induced by human behavior patterns be studied with stable isotope tracers? All of these studies include aspects that involve compound-specific isotope ratio mass spectrometry. A new area of research for Marilyn will be to combine isotope studies with molecular biological techniques. She plans to set up facilities to investigate the geochemical stability of biochemical macromolecules, including proteins, carbohydrates, and amino acids. She joined the Carnegie Institution of Washington Geophysical Laboratory in 1979.

Oral Presentations

Oral presentations will be in the Adam Ballroom of the Delta Bessborough Hotel. The conference venue has dual slide projectors and dual screens to enhance presentation of data. Use of dual slide projectors is optional. We will also have 30 extra slide carousels for presenters to sign out. Please label your carousels with your surname, and indicate left or right screen on the carousel, if applicable. There will be 3 slide preview booths available at all times outside the conference room for reviewing your presentation. A laser pointer is provided, and a single overhead projector is also available. Presentations are 15 minutes with 5 minutes allowed for questions.

Poster Presentations

Poster presentations will be held in the Convention Floor Foyer, a large area outside the Adam Ballroom on Tuesday evening from 7:30-10:00 p.m. A cash bar and lots of free appetizers will be provided. Posters may be put up on Tuesday morning and must be taken down by Wednesday at 5-6 p.m.

Name Badges

Please wear your name badge at all times during the meeting.

Conference Proceedings

Proceedings (optional to presenters) will be published in *Oecologia* and the *Canadian Journal of Fisheries and Aquatic Sciences*. **The manuscript deadline is May 11**. We will forward bulk submissions to the journals *Oecologia* and the *Canadian Journal of Fisheries and Aquatic Sciences* the week of May 11. Be sure your paper adheres to the guide to authors for the journal you are submitting to.

Student Awards

Students! Two awards will be given - best student oral paper and best student poster. Awards will consist of a framed certificate and $50 cash. Three attending scientists will do the judging. Good luck!

Social Events

Pre-Conference Field Trips - **Sunday, April 19, 9 am - 5pm**

Both trips will leave the hotel north parking lot Sunday at 9:00 am and return by 5 p.m. A description of each trip option follows. Dress accordingly for cool outdoor activity (jacket, walking shoes).

REDBERRY PELICAN PROJECT / WANUSKEWIN HERITAGE PARK

Redberry Lake is the location of a federal Migratory Bird Sanctuary and is home to a colony of American White Pelicans. The project received the Governor General of Canada's Conservation Award for 1991, and has been awarded a Tourism for Tomorrow Award by British Airways. Redberry Lake is a 6,000 hectare closed basin lake in the heart of Saskatchewan's Aspen Parkland belt. Wildlife, including numerous species of migratory geese, ducks, and shorebirds, are abundant on the lake's shores. Nine bird species found at Redberry Lake are classified as "endangered, threatened, or rare" including the Whooping Crane, Peregrine Falcon, and Piping Plover. The importance of Redberry Lake to migratory birds has long been recognized. In 1986 the numerous islands in the lake were declared a Provincial Wildlife Refuge. Because the lake is becoming increasingly saline, it contains no game or commercial fish species. As a result, it has remained relatively undeveloped.

Wanuskewin Heritage Park is a unique National Historic site. Located in a river valley that people have been using for almost 6000 years, it contains 19 sites that predate the arrival of Europeans in this Prairie region. As a result, the park is a rich resource for archaeologists. Exhibits and programming focus on the cultures of the Plains Indians, who inhabited lands stretching from northern Saskatchewan and Alberta south to the state of Texas. Products sold through the gift shop include a wide range of items made by artisans from tribes such as the

Cree, Dakota (Sioux), Assiniboine, and Blackfoot. Wanuskewin emphasizes that Plains' cultures are living ones that continue to change.

LAST MOUNTAIN LAKE REGIONAL RESERVE

Mixed grassland habitat including potholes, springs, fen bogs and saline wetland complexes. The site also contains shallow marshy bays and inlets separated by numerous points and islands, all surrounding a large freshwater lake. This site is recognized as a Migratory Bird Sanctuary under the RAMSAR convention and is also a National Historic Site. The lake provides critical fish spawning and nursery habitat and is considered to support the most productive fish population in Saskatchewan. This site is an important stopover for many species of migratory birds. This is one of the Prairie Provinces most important waterfowl staging areas and is a crucial refueling stop for waterfowl on their way from the Arctic to the southern United States. Over 250 species of birds have been recorded here and over 100 of these species have been documented as breeding in the area. Also, a number of rare and endangered species that use the area at some point during the year include the Peregrine Falcon, Burrowing Owl, Ferruginous Hawk, and the Whooping Crane. (this site is about a 2.5 hour drive from Saskatoon).

Wine And Cheese Mixer **Sunday, April 19, 8pm - 10pm**

Sponsored by *Micromass, Europa Scientific, and Finnigan-MAT*

Held in the Terrace Lounge from 8 p.m. -10:00 p.m., Sunday April 19. Free food and drinks sponsored by your favorite isotope mass spectrometer manufacturers - a great chance to get acquainted.

Banquet **Wednesday April 22, 6:15-10:30pm**

The conference will be concluded with a banquet and awards ceremony. This is held in the Adam Ballroom. After dinner there will be lots of time to visit and enjoy the music of Eileen Laverty

6:15 p.m.	Pre-Dinner Cash Bar
7:00 – 8:30	Dinner
	Awards and Presentations
	Best Student Paper
	Best Student Poster
	Closing Remarks
8:30-10:30	Entertainment
	Featuring *Eileen Laverty*

Eileen Laverty, originally from Belfast, retains a strong attachment to her Celtic roots. She possesses sterling vocal quality and an ability to convey powerful emotion through song, whether traditional Irish ballads, contemporary or original material.

(cash bar provided after dinner)

OVERVIEW OF EVENTS

Sunday, April 19

9:00a.m. Pre-Conference Field Trips

- Redberry Pelican Project / Wanuskewin Heritage Park
- Last Mountain Lake Regional Reserve

Terrace Lounge

8:00-10:00 p.m. Pre-Conference Wine and Cheese Mixer
Sponsors: *Micromass, Europa Scientific, Finnigan-MAT*

Monday, April 20

Adam Ballroom

8:30-9:00 Final Program Pickup

9:00-9:15 **Welcome and Introductions**

Keith Hobson and Len Wassenaar - Conference Organizers
Joseph Culp - Acting for John Carey, Director of National Water Research Institute, Environment Canada
Bill Gummer - Chief of Ecological Research Division, Environment Canada Prairie and Northern Region

9:15-10:15 **Keynote Address** - *Dr. Marilyn Fogel*

10:15-10:45 *Break*

10:45-4:30 Session - **Stable Isotope Applications to Animal Ecology and Migration**

12:05-1:15 *Luncheon* - served in the Adam Ballroom

2:55-3:30 *Refreshment Break* - (serving environmentally friendly "shade coffee")

4:30 *Closing Remarks*

5:00-6:30 p.m. Optional Stable Isotope Laboratory tours (please sign up by noon)

Tuesday, April 21

Adam Ballroom

8:30-11:50 Session - **Stable Isotope Applications to Aquatic Ecosystems: Foodwebs, Pollutants and Natural Tracers**

10:10-10:30 *Refreshment Break*

11:50-1:00 *Luncheon* - served in the Adam Ballroom

1:40-4:00 Session - **New Methods and Developments in Stable Isotope Ecology**

3:00-3:20 *Refreshment Break*

4:00 *Closing Remarks*

Tuesday Evening, April 21

Convention Floor Foyer (cash bar and complimentary appetizers provided)

7:30-10:00 p.m. **Poster Sessions**

- *Stable Isotope Applications to Animal Ecology and Migration*
- *Stable Isotope Applications to Aquatic Ecosystems: Foodwebs, Pollutants and Natural Tracers*
- *New Techniques and Methods Development in Stable Isotope Ecology*
- *Paleoecology and Forensics*
- *Soil and Microbial Processes*
- *Large-scale Ecosystem Processes*
- *IRMS Manufacturer Product Displays*

Wednesday, April 22

Adam Ballroom

9:00-1:20	Session - **Large Scale and Ecosystem Processes**
10:20-10:40	*Refreshment Break*
12:00-1:00	*Luncheon* - served in the Adam Ballroom
1:20-2:00	Session - **Paleoecology and Forensics**
2:00-3:00	**Panel Discussion**
	Brian Fry, Marilyn Fogel, Keith Hobson, Roy Krouse, Chuck Douthitt
3:00-3:30	*Closing Remarks and Refreshments*

Wednesday Evening, April 22

Adam Ball Room

6:15 – 10:30	**Banquet**
6:15 p.m.	Pre-Dinner Cash Bar
7:00 – 8:30	**Dinner** **Awards and Presentations** (including "Best Student Paper" and "Best Student Poster")
	Closing Comments
9:00-10:00	**Live Music** (cash bar)

THE PROGRAM

Person presenting indicated in **bold**

Sunday, April 19

Terrace Lounge

8:00-10:00 p.m.	Pre-Conference Wine and Cheese Mixer Sponsors: *Micromass, Europa Scientific, Finnigan-MAT*

Monday, April 20

Adam Ballroom

8:30-9:00	Final Program Pickup
9:00-9:15	Welcome and Introductions
9:15-10:15	**Keynote Speaker** *The Marriage of Stable Isotopes and Molecular Biology for Ecological Studies* **Dr. Marilyn Fogel**
10:15-10:45	*Refreshment Break*

Stable Isotope Applications to Animal Ecology and Migration

Session Chair:	***Dr. Keith Hobson***
10:45-11:05	Why don't elephants eat grass? **Thure E. Cerling**, J. M. Harris, M. G. Leakey
11:05-11:25	Nutritional ecology of bears **G.V. Hilderbrand**, M.E. Jacoby, C.C. Schwartz, C.T. Robbins, T.A. Hanley, S.M. Arthur, and C. Servheen

11:25-11:45	Trophic relationships in an Antarctic seabird community **Peter Hodum** and Keith Hobson
11:45-12:05	The importance of marine food sources to a cyclic population of arctic foxes **J.D. Roth**
12:05-1:15	*Luncheon* - served in the Adam Ballroom
Session Chair:	***Dr. Jim Ehleringer***
1:15-1:35	Using GIS and stable isotopes to characterize foraging strategies for wood storks **Chris Romanek**, K.F. Gaines, A.L. Bryan Jr., I.L. Brisbin, J. Gariboldi and C.H. Jagoe
1:35-1:55	Stable isotopes indicate the extent of freshwater feeding by cormorants *Phalacrocorax carbo* from inland fisheries in England **Stuart Bearhop**, David Thompson, Susan Waldron, Ian C. Russell, Gavin Alexander and Robert W. Furness
1:55-2:15	Tracking origins and migration of migratory wildlife using stable isotope analysis - a review. **Keith Hobson** and Len Wassenaar
2:15-2:35	A stable isotope (δ^2H, δ^{13}C) investigation of the eastern North American Monarch Butterfly (*Danaus Plexippus*) migration phenomenon **Len Wassenaar** and Keith Hobson
2:35-2:55	Using δD and δ^{13}C as markers of endogenous nutrients in migrating waterfowl: implications for determining nutrient allocations in eggs **Lisa Atwell**, Keith Hobson and Len Wassenaar
2:55-3:30	*Refreshment Break* - (serving environmentally friendly "shade coffee")
Session Chair:	***Dr. Susan Waldron***
3:30-3:50	Use of stable isotopes to infer diet and movements of Snow Geese during winter and spring migration **Ray T. Alisauskas**, Keith Hobson

3:50-4:10	The effects of spawning migration on the nutritional status of adult Atlantic salmon: insights from biochemistry and stable C, N, and S isotope ratios **Richard Doucett**, R.K.Booth, R.S. McKinley, and G. Power
4:10-4:30	Application of pyrolysis-IRMS $\delta^{18}O$ analyses as a new tool to evaluate animal migration patterns **John Morrison**, Francois Fourel, Len Wassenaar, and Keith Hobson
4:30-4:50	Seasonal patterns of *Salix* carbon and water relations: effects of browsing and hydrologic condition. **Karrin Alstad**, S. Williams, Trlica, J.M., and Welker, J.
4:50	*Closing Remarks*
5:30-8:30 p.m.	**Stable Isotope Laboratory tours** (please sign up by noon) **Environment Canada Stable Isotope Laboratory** (Micromass CF-IRMS) for demonstration of online ^{18}O analyses of organic samples. Hosted by John Morrison, Francois Fourel and Len Wassenaar. **University of Saskatchewan Department of Soil Science Stable Isotope Facilities** (Europa CF-IRMS). Hosted by Garth Parry. **University of Saskatchewan Department of Geological Sciences Stable Isotope Laboratory** (Finnigan IRMS). Hosted by Chris Holmden

Tuesday, April 21

Adam Ballroom

Stable Isotope Applications to Aquatic Ecosystems: Foodwebs, Pollutants and Natural Tracers

Session Chair:	***Dr. Joseph Culp***
8:30-8:50	Riverine inputs into estuaries: using stable isotopes to separate effects of riverine nutrients vs. particulates in supporting estuarine food webs **Brian Fry**
8:50-9:10	A stable isotope (^{13}C, ^{15}N) based quantitative assessment of the impact of land-based discharges of organic matter and trace metals on the sediment characteristics in Table Bay, Cape Town **P. Montiero** and S. Woodborne
9:10-9:30	Spatial and temporal variation in MeHg transfer in lakes: effects of vertical migration by invertebrate predators **Peter Leavitt,** K. Kidd, M.D. Graham and R. Hesslein
9:30-9:50	Diet differences of northern pike in lakes with different fish assemblages - a stable isotope study **Catherine Beaudoin**, W.M. Tonn, E.E. Prepas, L.I. Wassenaar
9:50-10:10	Use of stable isotopes in inferring food web relationships and contaminant bio-magnification pathways in northern lake ecosystems: a Great Slave Lake focus **Marlene S. Evans**, Derek Muir, Gary Stern
10:10-10:30	*Refreshment Break*
Session Chair:	***Dr. Brian Fry***
10:30-10:50	Changes in carbon and nitrogen stable isotope signatures of benthic invertebrates and fish associated with development of hydroelectric facilities **Andrea Farwell**, K.R. Munkittrick, M.R. Servos, K.R. Solomon

10:50-11:10 An experimental study on variations in stable carbon and nitrogen isotopes fractionation during growth of *Mysis mixta* and *Neomysis integer* (Crustacea, Mysidacea)
Elena Gorokhova and Sture Hansson

11:10-11:30 Complementary use of stable isotope and gut-pigment analyses to determine zooplankton trophic positions in prairie lakes
Mark Graham, Peter .R. Leavitt and Ray Hesslein

11:30-11:50 Use of stable isotopes to determine origin of drifting organic matter in the Colorado River during the 1996 spike flow from Glen Canyon Dam
Joseph P. Shannon, Dean W. Blinn, Peggy L. Benenati and Kevin P. Wilson

11:50-1:00 *Luncheon* - served in the Adam Ballroom

Session Chair: ***Dr. Marilyn Fogel***

1:00-1:20 Mapping spatial variability in marsh redox conditions in the Florida Everglades using biomass stable isotopic compositions
Carol Kendall and Steve Silva

1:20-1:40 Investigation of PCB and pp'DDT concentrations and stable nitrogen ratio in the arctic char (Salvelinus alpinus) from Lake Geneva
Elise Dufour, D. Gerdeaux, C. Corvi, S. Khim-Heang, H. Bocherens, A. Mariotti

New Methods and Developments in Stable Isotope Ecology

1:40-2:00 Compound-specific isotope correlation of fatty acids: a novel approach in population dynamic studies
Michael Whiticar, R.J. Veefkind, J.N.C. Whyte and R.I. Perry

2:00-2:20 Group-specific isotope ratios in ecological research - determination of source materials and processes of humification
Gerd Gleixner and Hanns-Ludwig Schmidt

2:20-2:40 Food web dynamics of the juvenile blue crab, *Callinectes sapidus*: whole tissue and compound-specific stable isotope techniques
Matthew Fantle, A.I. Dittel, S. Schwalm, C. E. Epifanio, D. Kirchman and M. Fogel

2:40-3:00	Preservation of biosignatures in museum herbarium collections **Mark Teece**, M. Fogel and Tuross
3:00-3:20	*Refreshment Break*
Session Chair:	***Dr. Anette Giesemann***
3:20-3:40	Requirements for hydrogen isotopic measurements in continuous flow mode - application to migration patterns of animals using EA-pyrolysis-IRMS **Francois Fourel**, Tom Merren and John Morrison
3:40-4:00	On-line $\delta^{18}O$ measurement of organic and inorganic compounds **Barbara E. Kornexl**, Matthias Gehre and Reiner Hoefling
4:00	*Closing Remarks*

Tuesday Evening Poster Session (7:30-10:00 p.m.)

Convention Floor Foyer (cash bar and complimentary appetizers provided)

Stable Isotope Applications to Animal Ecology and Migration

1. *Assessment of marine resources in the diet of the Alexander Archipelago wolf using stable isotope analysis.* **Michele M. Szepanski**, James M. Peek
2. *Feeding habits of detritivorous termites in the decomposition process.* **Ichiro Tayasu**
3. *Linking breeding and wintering grounds of neotropical migrant songbirds using stable hydrogen isotopic analyses of feathers.* **Keith Hobson** and Len Wassenaar
4. Stable isotope analysis reveals importance of introduced rats (*Rattus* sp.) as predators of burrow-nesting seabirds on Langara Island: implications for the protection of island fauna. **Keith Hobson**, Mark C. Drever and Gary Kaiser.
5. *Using hydrogen isotope analyses to identify breeding latitudes of sparrows migrating through the Middle Rio Grande of New Mexico, USA* . **Jeffrey F. Kelly**, Deborah M. Finch, and Keith A. Hobson
6. *Nutritional stress in Arctic ground squirrels: can ^{15}N be used as an indicator*? Merav Ben-David, C.J. McColl, R. Boonstra, and T.J. Karels.
7. *Social behaviour and ecosystem processes: effects of river otters' latrine sites on nutrient dynamics of terrestrial vegetation.* Merav Ben-David, R.T. Bowyer, L.K. Duffy, D.D. Roby, D.M. Schell.
8. *The trophic status of marine turtles as determined by stable isotope analysis.* Brendan J. Godley, David R. Thompson, **Susan Waldron**, and Robert W. Furness
9. *Stable-carbon and nitrogen dynamics in plasma and milk of free-ranging female polar bears and cubs.* **Susan Polischuk**, Keith Hobson and Malcolm Ramsay
10. *What does a mite bite? Insights on carbon and nitrogen movement through soil food webs under altered climates.* **Paul .T. Rygiewicz**, E.A. Hobbie, A.E. Moldenke, and W.L. Griffis
11. *Influence of drinking water and diet-tissue fractionation on δD values of avian tissues*. **Lisa Atwell**, Keith Hobson and Len Wassenaar
12. *Stable isotope study of the biosphere on a Coral Cay, Great Barrier Reef*. H.K. Herbert and **H. Roy Krouse**
13. *Stable isotope ecology and raptor diets.* **Jason Duxbury** and Geoff Holroyd

Stable Isotope Applications to Aquatic Ecosystems: Foodwebs, Pollutants and Natural Tracers

14. *Stable Nitrogen and Carbon Isotopic Composition of Seston and Sediment in Two Adirondack Lakes*. **Jeffery S.Owen**, M.J.Mitchell, and R.H.Michener
15. *A glimpse into important ecosystem relationships on the southeast Australian shelf using stable isotopes*. **Stevie Davenport** and N. Bax

16. *Effects of pike additions on pollutant accumulation and food web structure in an eutrophic and oligotrophic lake.* **Karen Kidd**, M.J. Paterson, R.H. Hesslein, and D.C.G Muir
17. *Analysis of material flow from aquatic ecosystem to terrestrial ecosystem mediated by the great Cormorant by using stable isotope techniques.* **Kayoko Kameda**, Hiroshi Mizutani, Keisuke Koba
18. *Tidal currents and the control of energy flow in a marine foodweb.* **Jeannette E. Zamon**
19. *Patterns of stable isotopes of C, N, and S in riparian food chains on rivers receiving pulp mill effluents.* **Mark Wayland** and Keith Hobson
20. *Stable isotope analysis of the Lake Superior fish community.* **Chris Harvey** and J. Kitchell
21. *Tracing changes in littoral fish communities using stable isotope analyses.* **Tamara Yankovitch**, R.J. Cornett, and S. Casselmann
22. *Categorization of trophic grouping for littoral organisms using a quantitative statistical model.* **Tamara Yankovitch**, and R.J Cornett
23. *Seasonal changes in carbon and nitrogen stable isotope signatures in the eastern basin of Lake Erie.* **Mark Servos**, M. Leggett, M. Burley, R. Hesslein and O. Johannsson
24. *Natural nitrogen isotope variations in Pinus sylvestris as indicator of environmental stress.* **Klaus Jung**, G. Gebauer, M. Gehre, L. Weissflog, D. Hofmann, G. Schuurmann

New Techniques and Methods Development in Stable Isotope Ecology

25. *Carbon isotope ratios of ecosystem respiration along an Oregon conifer transect: preliminary observations based upon small-flask sampling.* **Jim Ehleringer**
26. *Continuous flow ^{34}S measurements and combustion deviltry.* Steve Silva and **Brian Fry**
27. *The effects of acid washing and lipid extraction on the simultaneous analysis of carbon and nitrogen isotopes in benthic macroinvertebrates.* **Jim Neary**, Joseph Culp, Keith Hobson, and Len Wassenaar
28. *The effects of preservatives and acidification on the stable isotope ratios of marine animals.* **Keith .L. Bosley** and Sam C. Wainright
29. *Analysis of stable isotope data – A K Nearest-Neighbors Randomization test.* **M.N. Rosing,** Merav Ben-David, and R.P. Barry

Paleoecology and Forensics

30. *Intra-tooth isotopic variation (^{13}C, ^{18}O) in herbivores - implications for paleoenvironmental reconstruction.* **Felicitas Wiedemann**, H. Bocherens, A. van den Driesch, G. Grupe, and A. Mariotti
31. *Stable isotope composition of human hair and nails.* L. Guo, S. Iyer, **H. Roy. Krouse**, B. K. Jankowska, D.R. Krouse and M. Minagawa

Soil and Microbial Processes

32. *Biogeochemical characteristics of peat swamp forests in Thailand inferred from carbon and nitrogen stable isotope analyses.* **Takeshi Matsubara**, E. Wada, N. Boontanon, S. Ueda
33. *^{2}H and ^{18}O of plant and soil water in a subtropical savanna parkland: Vertical stratification of soil water acquisition and plant response to rainfall.* **Andy .J. Midwood**, T.W. Boutton and S.R. Archer
34. *Isotope effects during microbial conversions of organic sulfur compounds in soils.* **Bernhard Mayer**, C. Heinzer and K. Knief
35. *Applications of Dual-Isotopes to Studies of Carbon Fluxes in Forest Ecosystems.* **Guanghui Lin**

Large-scale Ecosystem Processes

36. *Determination of stable sulphur isotope composition in tree rings - a possibility for retrospective evaluation of an influence through anthropogenic S emissions.* **Anette Giesemann**, F. Hofmann, U. Schlechtriemen and H.J. Weigel

IRMS Manufactuers Display Booths

A. *Finnigan - MAT* - Chuck Douthitt and Nik Binder
B. *Micromass Ltd.* - John Morrision and Francois Fourel
C. *Europa Scientific* - Jon Hartman

Wednesday, April 22

Adam Ballroom

Large Scale and Ecosystem Processes

Session Chair:	***Dr. Michael Whiticar***
9:00-9:20	Ecosystem-Atmosphere Carbon Dioxide Exchange: Insights from Stable Isotope Analyses **Larry B. Flanagan**, D.S. Kubien and J.R. Ehleringer
9:20-9:40	Source tracing of atmospheric sulfur using stable isotopes and epiphyte lichen D.M. Blake and **Moire A. Wadleigh**
9:40-10:00	Assessment of atmospheric S input into terrestrial ecosystems **Anette Giesemann**
10:00-10:20	Isotopic tracing of lake water balance and related processes in low-relief boreal forest terrain: A sustainable forest management NCE study **John Gibson**, Terry D. Prowse and Ellie Prepas
10:20-10:40	*Refreshment Break*
Session Chair:	***Dr. Carol Kendall***
10:40-11:00	Interpretation of Nitrogen Isotope Signatures Using a NIFTE Model **Erik A. Hobbie** and Stephen A. Macko
11:00-11:20	Variability in the C isotope composition of selected VOCs in an urban environment **Ann-Lise Norman**, J.F. Hopper, J. Rudolph, D.E. Ernst, E. Czuba, B. Kieser
11:20-11:40	Decline of Pinniped Populations in the North Pacific Ocean: An Indication of Environmental Change? **Amy Hirons** and Don Schell
11:40-12:00	Stable isotope differentiation of marine and continental foodwebs in the arctic **H. Roy. Krouse**, R. Harrison, M.A. Katzenburg, W.W. Nassichuk, J.E. Motz, D.M. Schell, N.K. Vereschagin

Withdrawn

12:00-1:00	*Luncheon* - served in the Adam Ballroom
Session Chair:	***Dr. Roy Krouse***
1:00-1:20	From ecological patterns to processes in coastal waters: the utility of light stable isotope techniques in an estuarine setting **Thomas A. Schlacher** and Tris H. Wooldridge

Paleoecology and Forensics

1:20-1:40	When whales left the beach: isotopic insights into a physiological transition in the fossil record **Lois J. Roe**, J.G.M. Thewissen, Jay Quade, James R. O'Neil, Sunil Bajpai, Ashok Sahni and S. Taseer Hussain
1:40-2:00	Integrating ecology and archaeology: Reconstructing prehistoric human diet in an arid coastal environment **Theresa Schober**
2:00-3:00	**Panel Discussion** Panelists : **Brian Fry, Marilyn Fogel, Keith Hobson** **Roy Krouse, Chuck Douthitt, Michael Whiticar**
3:00-3:30	*Closing Remarks and Refreshments*

Wednesday Evening Banquet (6:15-10:30 p.m.)

Adam Ball Room

6:15 p.m.	Pre-Dinner Cash Bar
7:00 – 8:30	**Dinner** **Awards and Presentations** (including "Best Student Oral Paper" and "Best Student Poster") **Closing Comments**
8:30-10:30	**Live Music** - Eileen Laverty (cash bar)

ABSTRACTS

Person presenting in **bold**; student presentations indicated by an asterisk *

Oral Presentation

USE OF STABLE ISOTOPES TO INFER DIET AND MOVEMENTS OF SNOW GEESE DURING WINTER AND SPRING MIGRATION.

Ray T. Alisauskas *and Keith A. Hobson,*

Prairie and Northern Wildlife Res. Centre, Canadian Wildlife Service, Saskatoon, SK, and Dept. Biol., Univ. of Saskatchewan, SK.

We studied variation in $\delta^{13}C$ and $\delta^{15}N$ values in the muscle tissue and principal foods of lesser snow geese concurrently in 3 winter landscapes and during subsequent spring migration. Principal winter foods were (1) corn and sorghum in northern agricultural areas in Iowa, Missouri or Kansas, near the Missouri River Valley (MRV) (2) *Spartina patens* rhizomes and *Scripus olneyi* tubers in coastal brackish marshes of Louisiana along the Gulf of Mexico, and (3) a mix of forbs, grasses and small "weed" seeds in agricultural areas in Texas dominated by rice about 100 km inland from coastal marshes. Corn agricultural diets were most different in $\delta^{13}C$ from foods found in both marsh and rice agriculture near the Gulf Coast. Most variance in foods from brackish marsh and rice agricultural areas was in $\delta^{15}N$. Mean isotopic signatures of goose *pectoralis* muscle tissue generally reflected these differences, suggesting low movement among the 3 landscapes during winter. Early in spring migration, geese from rice and marsh landscapes along the Gulf Coast, migrated to and mixed with geese that had wintered near the MRV. Samples of geese from the MRV after the influx showed a bimodal distribution in $\delta^{13}C$ reflecting corn/sorghum-based diets of winter residents, and diets of geese from the Gulf Coast. After spring departure from the MRV, geese were sampled in agricultural areas of southern Manitoba and from coastal marshes along southern Hudson Bay in northern Ontario. As geese migrated north through agricultural areas, $\delta^{13}C$ in goose muscle was correlated with body fat, suggesting the importance of corn for spring fat storage by geese. Adequate storage of body fat during spring migration is essential to successful reproduction in the arctic.

Oral Presentation*

SEASONAL PATTERNS OF SALIX CARBON AND WATER RELATIONS: EFFECTS OF BROWSING AND HYDROLOGIC CONDITION

***Alstad, K.P.**, Williams, S., Trlica, J.M., Welker, J.*

In this study, we investigated the carbon and water relations of *Salix* spp. in elk winter range of Rocky Mountain National Park where portions of these riparian habitats were exposed to different levels of winter browsing by elk and different hydrologic conditions. Leaf gas exchange, leaf $\delta^{13}C$ and $\delta^{18}O$-values of plant xylem water were measured on *Salix* plants over two growing seasons and the isotopic measures were collected an additional year. Exclosures were used to prevent elk browsing, while adjoining areas were browsed by elk in winter. To simulate increases in beaver ponding activity and a change in surface water condition, stream water was artificially dammed in half the sites, while in the other sites, stream channels were left free flowing. *Salix* plants used for physiological measures were stratified into plants that were streamside and those that were located away from streams in upland positions.

Snow pack was 25% greater than the long-term average in both years, but the peak snowpack of 1995 occurred nearly 30 days later than normal resulting in high levels of run-off late in the summer. In 1996, peak snowpack occurred in late April and early May, similar to the long-term average. This pattern of peak snow resulted in peak stream levels occurring approximately two weeks later in 1995 (early July) than in 1996 (mid June).

The water potentials of *Salix* plants were lower in 1996 when peak snowpack occurred early as compared to 1995. In both years there was a seasonal decrease in total stem water potential from -0.5 MPa to -1.5 MPa. On average, streamside plants had higher leaf $\Delta^{13}C$-values (20.4λ) compared to plants that were away from streams (19.8λ). Instantaneous leaf CO_2 assimilation was similar throughout the summer, and in July, plants browsed by elk the preceding winter had significantly higher rates of carbon assimilation, than unbrowsed plants. Leaf nitrogen was, in general, high (>2.3%) and decreased only slightly from early- to late- season.

Plant water potentials were higher in browsed *Salix* plants compared to unbrowsed plants in the drier second. In addition, photosynthetic rates in July and the leaf $\Delta^{13}C$-values were significantly higher in browsed *Salix* plants in both years. Together, these physiological traits indicate that *Salix* plants, which were browsed by elk the previous winter, experienced more favorable plant water status and had greater rates of carbon gain.

Water sources of *Salix* plants and grass species were evaluated by measuring the $\delta^{18}O$-values of summer rain, snow, stream water, and groundwater. The $\delta^{18}O$-value of snow (-17λ) was depleted by up to 9λ compared to summer rain (-8λ). The $\delta^{18}O$-value of stream water consistently mimicked the $\delta^{18}O$-value of snow, averaging -16λ. The similarity in the $\delta^{18}O$-values of snow and stream water indicates the dependence of these riparian systems on high altitude snowfields that are at the headwater of the watersheds. The $\delta^{18}O$-values of *Salix* xylem water were consistently close to that of stream water, averaging -14λ, indicating that stream water is the dominant source of water used by *Salix* plants in these riparian zones. The $\delta^{18}O$-values of grass and grasslike species were generally more enriched than the xylem water of *Salix* and demonstrated a seasonal shift in $\delta^{18}O$-values such that late season values were more enriched and similar to summer rain values.

Poster Presentation*

INFLUENCE OF DRINKING WATER AND DIET TISSUE FRACTIONATION ON δD IN AVIAN TISSUES: IMPLICATIONS FOR TRACING FEEDING ORIGIN AND DIET

***Lisa Atwell*[1]*, Keith Hobson*[2]*, and Leonard Wassenaar*[3]

[1]Department of Biology, University of Saskatchewan, Saskatoon, SK, S7N 0W0
[2]Prairie and Northern Wildlife Research Center, 115 Perimeter Rd, Saskatoon, SK, S7N 0X4
[3]National Hydrology Research Institute, 11 Innovation Blvd., Saskatoon, SK S7N 3H5

Recent ecological studies using stable hydrogen isotopes (δD) have identified the need for basic information on trophic fractionation and the contribution of drinking-water hydrogen to the non-exchangeable δD values of consumer tissues. We examined δD values of blood, liver, muscle, nail and abdominal fat from two groups of Japanese quail (*Coturnix japonica*). Each group was raised on the same homogenous diet, but with isotopically distinct drinking-water sources (+196.3 ± 4.4λ and –129.6 ± 3.1λ, VSMOW). All like tissues had significantly different δD values between the two groups, indicating that drinking-water hydrogen contributed to the non-exchangeable δD values of tissues. A drinking-water δD difference of 325λ produced differences in quail tissues ranging from 57-87λ, suggesting that drinking water contributed up to 20-30% of the non-exchangeable hydrogen in these tissues. We derived diet-tissue fractionation factors for tissues of quail raised on food and drinking water from the same geographic location. Diet-tissue fractionations ranged from –32λ for nail to –120λ for abdominal fat. Our study indicates that the influence of drinking water must be considered in ecological studies using measurements of naturally abundant stable hydrogen isotopes, and possibly those energetics studies involving the use of doubly-labeled water.

Oral Presentation*

USING δD AND δ^{13}C AS MARKERS OF ENDOGENOUS NUTRIENTS IN MIGRATING WATERFOWL: IMPLICATIONS FOR DETERMINING NUTRIENT ALLOCATIONS TO EGGS

***Lisa Atwell*[1]*, Keith Hobson*[2]*, and Leonard Wassenaar*[3]

[1]Department of Biology, University of Saskatchewan, Saskatoon, SK, S7N 0W0
[2]Prairie and Northern Wildlife Research Center, 115 Perimeter Rd, Saskatoon, SK, S7N 0X4
[3]National Hydrology Research Institute, 11 Innovation Blvd., Saskatoon, SK S7N 3H5

We are exploring the utility of measuring δD and δ^{13}C values in the tissues of breeding migratory waterfowl to determine whether they are effective markers of endogenous tissues accumulated on wintering grounds. Muscle and abdominal fat tissues of female redhead ducks (*Aythya americana*) arriving on their breeding grounds in southern Manitoba should reflect enriched marine values characteristic of their estuarine wintering grounds off the Gulf coast of Texas and Mexico. We found measurements of both δD and δ^{13}C in muscle to be effective markers of overwintering habitat, becoming progressively more 'dilute' as redheads assimilated the more depleted terrestrial δD and δ^{13}C signatures of the breeding-ground food web. δD values in abdominal fat, however, became more enriched after arrival on the breeding grounds, a pattern opposite to that expected for a shift from southern marine to northern terrestrial diet, and opposite to that of δ^{13}C values in abdominal fat. Since tissue δD and δ^{13}C values of arriving ducks were very different than δD and δ^{13}C values of the breeding ground diet we examined egg components for evidence of a marine signal from maternal endogenous reserves. δD values in egg albumen, yolk lipid, and lipid-free yolk did not reflect laying female tissue δD values. δ^{13}C values in egg components were distinctly more depleted than δ^{13}C in tissues of laying females, being closer to tissue values of females that had two months to assimilate local diet, suggesting that resources for egg formation in these ducks came primarily from local, breeding-ground diet and not from stored endogenous reserves. Due to the potentially confounding influence of drinking water on tissue δD values, measurements of δD may not provide the clearest picture of endogenous nutrient transfer to eggs. While stable hydrogen isotopes may still provide a useful marker of endogenous reserves for migrants crossing a large isotopic gradient, carbon stable isotopes appear to be a more distinct marker for those migrating between marine and terrestrial/freshwater biomes.

Oral Presentation*

STABLE ISOTOPES INDICATE THE EXTENT OF FRESHWATER FEEDING BY CORMORANTS *PHALACROCORAX CARBO* FROM INLAND FISHERIES IN ENGLAND.

Stuart Bearhop[1], *David Thompson*[1], *Susan Waldron*[2], *Ian C. Russell*[3], *Gavin Alexander*[4] & *Robert W. Furness*[1].

[1]Applied Ornithology Unit, Institute of Biological Life Sciences, University of Glasgow, Glasgow, G12 8QQ, United Kingdom. email: sbearhop@udcf.gla.ac.uk

[2]Scottish Universities Research and Reactor Centre (SURRC), East Kilbride G75 0QF, United Kingdom. email s.waldron@surrc.gla.ac.uk

[3]Centre for the Environment, Fisheries and Aquatic Science, Lowestoft Laboratory, Suffolk NR33 OHT, United Kingdom

[4]Institute of Terrestrial Ecology, Banchory, Aberdeenshire AB31 4BY, United Kingdom.

The rapid increase in the European great cormorant (*Phalacrocorax carbo*) population over the last 20 years has lead to attention being focused upon the possible impact they are having on freshwater fisheries. In Britain conflict occurs mainly during the winter and the concern among fishery managers and anglers has been so great that the issue has been discussed in both parliament and the national press. With this in mind the Ministry of Agriculture, Food and Fisheries (MAFF) has commissioned an extensive research programme into the feeding ecology of British great cormorants. In this study we have assessed the extent of freshwater feeding in this species by analysing the isotopic composition of different feathers. Three feathers were analysed, each representing a different time scale. The carbon isotope ratio obtained from body feathers suggested that cormorants had a 50% freshwater diet between June and November. This fits with the idea that the coastal breeding cormorants move inland gradually as the winter progresses. However, the isotope signature from growing and freshly grown feathers suggested a diet that comprised exclusively freshwater prey. The birds are therefore probably spending around six months of the year feeding entirely in freshwater systems and so the impact they are having may be considerable. Fractionation factors for three piscivorous bird species are also presented and the utility of the two-source mixing model in such studies will be discussed.

Oral Presentation*

DIET DIFFERENCES OF NORTHERN PIKE IN LAKES WITH DIFFERENT FISH ASSEMBLAGES: A STABLE ISOTOPE STUDY.

***Catherine Beaudoin*[1]*, W.M. Tonn*[1]*, E.E. Prepas*[1]*, and L.I. Wassenaar*[2]

[1]Department of Biological Sciences, University of Alberta, Edmonton, AB, T6G 2E9;
[2]Environmental Sciences Division, National Hydrology Research Center, 11 Innovation Blvd, Saskatoon, SK, S7N 3H5.

In small lakes of north-central Alberta, northern pike are typically found with other large-bodied fish or as the only species present. I used stable carbon and nitrogen isotope analysis (SIA) and stomach content analysis (SCA) to determine the diets of northern pike (*Esox lucius*) in five lakes, three "pike-only" lakes and two lakes that contained northern pike along with yellow perch (*Perca flavescens*) and/or white sucker (*Catostomus commersoni*). SIA and SCA were also used to assess differences in diet and trophic level as pike increased in length. SIA provides information about a fish's long-term assimilated diet, whereas SCA complements SIA by showing what a fish has recently ingested. Based on SIA, invertebrates appeared to be a large component of pikes' diet in all lakes. Not surprisingly, fishes were also important prey items in lakes that contained other fish species, and in one of the "pike-only" lakes, where cannibalism occurred. There was evidence that trophic level increased as pike length increased in "pike-only" lakes, but not in lakes with other fish present. Also, in two "pike-only" lakes, where only invertebrates were consumed, a shift in diet from pelagic to littoral invertebrates occurred as pike grew larger. The feeding habits of pike are appear to be flexible, and change as their prey base changes.

Poster Presentation

NUTRITIONAL STRESS IN ARCTIC GROUND SQUIRRELS: CAN $\delta^{15}N$ BE USED AS AN INDICATOR?

M. Ben-David[1], C. J. McColl[2], R. Boonstra[2], and T. J. Karels[2]

[1]Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks AK 99775, USA.
[2]Division of Life Sciences, University of Toronto, Scarborough, Ontario, Canada M1C 1A4.

Studies using stable isotope analysis have documented an enrichment in values of $\delta^{15}N$ in nutritionally stressed animals. Investigators suggested that changes in $\delta^{15}N$ measured in urine, hair, and blood may be good indicators of lean tissue losses. During investigations on the effects of population density on reproduction and body condition of female Arctic ground squirrels (*Spermophilus parryii plesius*) near Kluane Lake, Yukon, Canada, we examined the relation between body condition and values of $\delta^{15}N$ in 20 live-trapped female ground squirrels. Reproductive females from a population with moderate density and low food availability experienced nutritional stress. In contrast, those from a population which failed to reproduce successfully and had high density and low food availability experienced no nutritional stress. Similarly, those from a high density population with high food availability (i.e., supplemented food) which successfully reproduced, suffered no noticeable nutritional stress. Values of $\delta^{15}N$ did not show a decline with increasing body weights, and animals in poor and excellent body condition had similar $\delta^{15}N$ values. In addition, female ground squirrels from the same group with similar types of available food (natural or supplemented), similar body weights, similar values of BUN and glucose showed a difference in $\delta^{15}N$ values of up to 2.5‰. Thus, $\delta^{15}N$ can not be used as an indicator for nutritional stress. We recommend that field ecologists studying animal diets using stable isotope analysis will attempt to evaluate the body condition of their subjects using alternative techniques.

Poster Presentation

SOCIAL BEHAVIOR AND ECOSYSTEM PROCESSES: EFFECTS OF RIVER OTTERS' LATRINE SITES ON NUTRIENT DYNAMICS OF TERRESTRIAL VEGETATION

M. Ben-David[1], R. T. Bowyer[2], L. K. Duffy[3], D. D. Roby[4], and D. M. Schell[5]

[1]Alaska Cooperative Fish and Wildlife Research Unit and the Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks AK 99775, USA.
[2]Institute of Arctic Biology and the Department of Biology and Wildlife, University of Alaska Fairbanks, Fairbanks AK 99775, USA.
[3]Institute of Arctic Biology and Department of Chemistry, University of Alaska Fairbanks, Fairbanks AK 99775, USA.
[4]Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, Corvallis, OR 97331-3803, USA.
[5]Institute of Marine Sciences and Water Research Center, University of Alaska Fairbanks, Fairbanks AK 99775, USA.

River otters (*Lutra canadensis* Schreber) inhabiting coastal environments scent-mark specific locations along the coast, known as latrine sites. In this study, we investigated the effects of this scent-marking behavior on terrestrial vegetation at the terrestrial-marine interface using stable isotope techniques. Our analysis of stable isotope ratios of fur and feces indicated that river otters fed mainly on intertidal and subtidal fish. Eight different species of plants, growing in latrine sites of river otters, had significantly higher values of $\delta^{15}N$ compared with the same plant species growing on non-latrine sites. Elevated N concentrations occurred only in grasses and mosses growing in latrine sites. Our results indicate that through their scent-marking behavior, coastal river otters transfer marine-derived nitrogen into the beach-fringe forest and thus fertilize the terrestrial vegetation in the terrestrial-marine interface.

Oral Presentation

SOURCE TRACING OF ATMOSPHERIC SULFUR USING STABLE ISOTOPES AND EPIPHYTIC LICHEN

*D.M. Blake and **M.A. Wadleigh***

Department of Earth Sciences, Memorial University of Newfoundland, St. John's, NF, A1B 3X5

Atmospheric sulphur at any site potentially contains contributions from natural and anthropogenic, local and remote sources. Natural emissions to the atmosphere include seaspray, dimethyl sulphide (DMS), hydrogen sulphide and sulphur dioxide. Anthropogenic emissions consist mostly of SO2 generated by industrial processing of native suphur, sulphide ores, coal and petroleum. Depending on the geographic area of the sampling site, there will be greater or lesser ratios of local-to-remote sulphur contributions. A proper assessment of anthropogenic input to the atmosphere requires the ability to differentiate between sulphur derived from these two kinds of sites. Stable isotopic signatures can achieve this differentiation. d34S measurements of sulphates show a wide range, but commonly quoted average values for continental aerosols and rain in central and eastern North America fall between +3λ and +6λ. Seaspray sulphate has d34S = +21λ giving coastal rains a higher average isotopic composition. However, it is not always easy or convenient to directly sample the atmosphere via precipitation. Epiphytic lichens have been demonstrated to be effective bioindicators of pollution, being sensitive to both sulphur and trace metal concentrations in the atmosphere. They are slow growing and extremely effective in absorbing soluble and insoluble mineral nutrients from ambient air and precipitation with little subsequent loss. There is little or no fractionation of sulphur in which they grow. Sulphur isotopic measurements made on lichens have been found to correlate with measurements of dissolved sulphate in precipitation.

The overall objective of the work was to measure the spatial variation of sulphur isotopic composition in the atmosphere across Newfoundland in order to assess the degree to which it has been affected by long-range transport of anthropogenic sulphur from eastern North America. Over one hundred samples of lichen species *alectoria sarmentosa* have been collected throughout Newfoundland over the past four years as an indirect method of sampling the atmosphere. In addition, detailed sampling was carried out near the Come By Chance oil refinery to determine the effect of this large, local point source of sulphur dioxide. Lichens were sampled along a transect away from the refinery according to the direction of prevailing winds. Newfoundland samples of *alectoria sarmentosa* have been analyzed for sulphur and chloride concentration and sulphur isotopic composition. Results indicate that average isotopic compositions are related to sulphur content and are consistent with proximity to coastal and pollutatn sulphur sources. A contour map illustrating the spatial distribution of sulphur isotopic composition of the Newfoundland atmosphere as recorded in *alectoria* shows a gradient from the coast to the interior of the island as well as local anomalies corresponding to the city of St. John's, the oil refinery, and pulp and paper industries. The transect shows a pattern of increasing sulphur isotopic composition and decreasing sulphur concentration away from the point source. Based on the isotopic composition of the lichen, samples collected up to 30 km away showed evidence of impact from the refinery.

Poster Presentation*

EFFECTS OF PRESERVATIVES AND ACIDIFICATION ON THE STABLE-ISOTOPE RATIOS (^{15}N:^{14}N, ^{13}C:^{12}C) OF MARINE ANIMALS

K. L. Bosley *and S. C. Wainright*

Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Road, New Brunswick, New Jersey 08901-8521, USA

We investigated the effects of three preservatives, two acidification methods and two types of analysis boat on stable-isotope ratios of N and C in mud shrimp (*Crangon septemspinosa*) and juvenile winter flounder (*Pleuronectes americanus*). All three preservatives (formalin, formalin followed by transfer to ethanol, and saturated mercuric chloride solution) produced significant increases in $\delta^{15}N$ values and decreases in $\delta^{13}C$ values of *P. americanus*. Similar results were obtained for *C. septemspinosa*, but the effects were not as clear. *P. americanus* $\delta^{15}N$ values were enriched by 1.2 ± 0.14 s.e. per mil by formalin, 1.4 ± 0.12 per mil by form/EtOH and 0.7 ± 0.26 per mil by $HgCl_2$, while *C. septemspinosa* was enriched by 0.5 ± 0.58, 1.2 ± 0.15 and 0.6 ± 0.15 per mil respectively, compared to frozen samples. *P. americanus* $\delta^{13}C$ values were depleted by 0.7 ± 0.15 per mil by formalin, 2.2 ± 0.62 per mil by form/EtOH and 0.6 ± 0.27 per mil by HgCl2, while *C. septemspinosa* was depleted by 2.3 ± 0.40, 0.9 ± 0.55 and 0.7 ± 0.22 per mil respectively, compared to frozen samples. Acidification (to remove carbonates) with neither concentrated HCl fumes nor 1.0 N HCl containing 1.0% $PtCl_2$ had a significant effect on $\delta^{15}N$ or $\delta^{13}C$ values for either species. Samples of *C. septemspinosa* that were frozen or freeze-dried had $\delta^{15}N$ and $\delta^{13}C$ values that were not significantly different from ones that were dried fresh immediately after sacrificing. $\delta^{15}N$ and $\delta^{13}C$ values of shrimp samples that were analyzed in silver boats were not significantly different from those of samples that were analyzed in boats made of tin. The results show that freezing is the only means of preserving samples that will not have a significant effect on nitrogen and carbon stable isotope ratios. Additionally, acidification may be an unnecessary sample preparation step and silver boats may be used, if necessary, since they appear to have no effect on nitrogen and carbon stable-isotope ratios.

Oral Presentation

WHY DON'T ELEPHANTS EAT GRASS?

***T.E. Cerling**, J.M. Harris, M.G. Leakey*

The diet of extant elephants (*Loxodonta* in Africa, *Elephas* in Asia) is dominated by C3 browse. This is particularly noteworthy because high-crowned elephantid cheek teeth represent adaptation to an abrasive grazing diet and because isotopic analysis demonstrates that C4 vegetation was the dominant diet for *Elephas* in Asia 5 to 1 Ma and for both *Loxodonta* and *Elephas* in Africa between 5 to 1 Ma. Other probiscideans in Africa and southern Asia, except deinotheres, also had a C4 dominated diet from ca. 7 Ma (when the C4 biomass radiated in tropical and subtropical regions) until their subsequent extinction.

Poster Presentation

A GLIMPSE INTO IMPORTANT ECOSYSTEM RELATIONSHIPS ON THE SOUTH EAST AUSTRALIAN SHELF USING STAVLE ISOTOPE ANALYSIS

Stevie Davenport *and Nik Bax*

The stable isotopes of carbon and nitrogen were used in an ecosystem study on the continental shelf (25-250 m) of south eastern Australia in 1993-1997.

Faunal samples analysed included 86 species of teleosts and elasmobranchs, invertebrates from 8 phyla, 10 species of marine mammal and one species of bird. Algal samples, particulate organic carbon and sediment data were also examined. Preliminary analyses indicated that the primary source of nutrients on the shelf was oceanic, with little or no detectable terrestrial input. Continuing analyses will compare detailed isotopic signatures for fish with their stomach contents and functional morphology to describe major trophic pathways.

Oral Presentation*

THE EFFECTS OF SPAWNING MIGRATION ON THE NUTRITIONAL STATUS OF ADULT ATLANTIC SALMON: INSIGHTS FROM BIOCHEMICAL AND STABLE-C AND N-ISOTOPE ANALYSES.

***[1]Doucett, R.R.**, [2]Booth, R.K., [2]Mckinley, R.S., and [1]Power, G.*

[1]Department of Biology, University of Waterloo, Waterloo, ON, N2L 3G1
[2]Waterloo Biotelemetry Institute, 200 University Ave. W., Waterloo, ON, N2L 3G1

Adult Atlantic salmon (*Salmo salar*) were collected during their annual migration run along the Exploits River, Newfoundland, and analyzed for stable-C and N-isotope ratios, as well as other biochemical parameters. This collection of fish represents both a temporal and spatial gradient that followed the salmon for approximately 120 km over a 5-month period. $\delta^{13}C$ values from 48 fish became enriched by 4-5‰ during the upstream migration. However, the degree of enrichment was dependent on tissue type, with liver and red muscle undergoing greater enrichment than white muscle. Similar patterns were observed in $\delta^{15}N$, as fish collected at sea (10‰ to 13‰) were less ^{15}N-enriched than those captured at, or near, the spawning grounds (15‰ to 16‰). Changes in stable-isotope ratios of migrating salmon appear to result from the significant loss of lipid and protein due to the cessation of feeding upon entering freshwater. Utilization of ^{13}C-depleted lipid during upstream migration shifted tissue $\delta^{13}C$ toward more positive values. Loss of ^{14}N, and recycling of ^{15}N from body protein, resulted in higher tissue $\delta^{15}N$. This study suggests that the measurement of stable-isotope ratios in anadromous fishes is affected by a "starvation process" and that collection of these fishes should be carried out in seawater if the goal is to obtain accurate information regarding their marine-feeding histories.

Oral Presentation*

INVESTIGATION OF PCB AND PP'DDE CONCENTRATIONS AND STABLE NITROGEN RATIO IN THE ARCTIC CHAR (*SALVELINUS ALPINUS*) FROM LAKE GENEVA.

***Elise Dufour*[1], *Daniel Gerdeaux*[2], *Claude Corvi*[3], *Sophal Khim-Heang*[3], *Hervé Bocherens*[1] *and André Mariotti*[1]**

[1] Laboratoire de Biogéochimie Isotopique UMR 162, CNRS-INRA-Université Paris VI, [4] place Jussieu, 75 252 Paris cedex 05, France
[2] Laboratoire d'Hydrobiologie lacustre INRA, 75 avenue de Corzent, 74 203 Thonon-les-Bains, France
[3] Service du Chimiste Cantonal, CP 166, CH 1211, Genève 4, Switzerland

Annual surveys of PCB and pp'DDE concentrations performed on muscle tissue of arctic char, (*Salvelinus alpinus*) from Lake Geneva show that fish of the same cohort, sampled within the same place of the lake can exhibit a wide range of pollutant concentrations. Measurements of nitrogen isotopic and C/N ratios, as well as that of pollutant concentrations were carried out on 60 specimens in order to test whether a relationship exists between the trophic position of fish and the pollutant content.
A first sample was made in February 1996 on 20 fish which are at the beginning of their 4th year of life. A second sample of 40 fish was then made in December on 20 fish at the end of the 4th year of life, and 20 fish at the end of the 5th year of life.
As expected the range of variation of PCB and pp'DDE concentrations are high for all specimens. This variability increases significantly with age but there is no relationship between mean pollutant concentrations and age. Besides, the range of variation of $\delta^{15}N$ is low and only two samples exhibit very different values. The ^{15}N content of fish do not increase with age. Moreover, the stable isotopic ratios and pollutant concentrations are not correlated.

Nevertheless, a correlation is found between pollutant concentrations and nitrogen isotopic ratio when only fish in their 4th year of life are considered. The PCB and pp'DDE concentrations increase with the $\delta^{15}N$ but these correlations are not very strong.

A correspondance analysis shows that the 3 different samples of fish are well separated by the isotope and C/N ratios, but pollutant concentrations do not separate these samples. It should be noticed that the time scale recorded by these parameters are not the same. The PCB concentrations may vary seasonally with the physiology of the fish, while the isotopic ratio are not so variable.

Then, it seems that one part of the inter-individual variations may be correlated with the trophic level of the diet of the fish from a cohort. But, the rest of the variation is

caused by the life history of each individual depending on whether it fed polluted food during its life or not.

Poster Presentation*

STABLE ISOTOPE ECOLOGY AND RAPTOR DIETS

Duxbury, J.*[1]*, *Geoff Holroyd*[2]

[1]Department of Renewable Resources, 751 General Services Building, University of Alberta, Edmonton, AB, Canada T6G 2H1.
[2]Canadian Wildlife Service - Prairie and Northern Region, Environment Canada, Room 200, 4999 - 98 Ave, Edmonton, AB, T6B 2X3

One of the most recent developments in stable isotope ecology is its use in avian ecology. The use of stable isotope ratio analysis (SIRA) to determine the type of ecosystem and the relative trophic level in which raptors are feeding is a new domain. Analysis of heavily studied raptor species along with the more unknown species may help develop associations that can provide insights into the more unknown diets of certain raptors. The bioaccumulation effects of ^{15}N was used to study trophic relationships. Feathers from 27 species of raptors commonly found in Alberta were analyzed. The results indicated that the raptor samples originating in the prairie ecoregion of Alberta had relatively higher $\delta^{15}N$ values than samples obtained in the parkland or boreal regions. Until the degree of how all species are affected by the enrichment factor has been determined, it is recommended that raptor isotope values not be compared between ecoregions. This study also demonstrated that SIRA detected interesting aspects of Broad-winged Hawk, Cooper's Hawk and Great Gray Owl diets. Traditional methods should now be used to examine why the isotope values are indicating that in Alberta, these species are eating at potentially different trophic levels than what the literature suggests. Taking into account the causes of isotope ratio variability, biological aspects of raptor diets can be studied at the individual, species, and ecoregion guild levels using a combination of stable isotope ratio analysis and more traditional methods. A holistic approach using as many methods as possible will result in the most accurate conclusions about raptor diets.

Poster Presentation

CARBON ISOTOPE RATIOS OF ECOSYSTEM RESPIRATION ALONG AN OREGON CONIFER TRANSECT: PRELIMINARY OBSERVATIONS BASED UPON SMALL-FLASK SAMPLING

Jim Ehleringer
University of Utah

Isotope ratio analyses of atmospheric CO2 at natural abundance levels have significant potential for contributing to our understanding of photosynthesis and respiration processes in forest ecosystems. Recent advances in isotope ratio mass spectrometry allow for rapid, on-line analysis of small volumes of CO2 in air and open new opportunities at the ecophysiological, whole organism, and atmospheric levels. The routine analysis of carbon dioxide in total air volumes of approximately 50-300 microliters is accomplished by linking a commercially-available, trace gas condenser and gas chromatograph to an isotope ratio mass spectrometer operated in a continuous-flow mode. Among the immediate applications are the carbon and oxygen isotope ratio analyses of carbon dioxide in atmospheric air. Samples collected in the field are stored in either gas-tight syringes or 100-ml flasks. The small sample volume required makes it possible to sample the ar flasks for carbon dioxide and then to sample the remaining air volume for the analysis of the isotopic composition of either methane or nitrous oxide.

When linked with an infrared gas analyzer, pump and flask sampling system, it is feasible to sample CO_2 extensively in remote forest locations. The air-sampling system was used to measure the isotope ratios of atmospheric CO_2 and to conduct a regression analysis of the relationship between these two parameters. From this we calculated the $\delta^{13}C$ of ecosystem respiration of four coniferous ecosystems along a precipitation gradient in central Oregon USA. The ecosystems along the coast-to-interior Oregon gradient (OTTER) are dominated by spruce-hemlock forests at the wet, coastal sites (> 200 cm precipitation annually) through juniper woodlands (20 cm precipitation) at the interior, dry end of the transect. The differences in $\delta^{13}C$ values of ecosystem respiration along this transect differed by only 1.3 λ (range of -25.2 to -23.9 λ) during August at the peak of the summer drought. Following autumn rains in September, the $\delta^{13}C$ of ecosystem respiration in these four stands decreased; overall the difference in the carbon isotope ratio of ecosystem respiration among sites increased to 3.9 λ (-26.8 to
-22.9 λ).

The use of smaller air volumes (and therefore smaller flasks) for the measurement of ecosystem level gas exchange processes appears feasible, making greater sampling frequencies possible in isolated field conditions. Reliable $\delta^{13}C$ and $\delta^{18}O$ values can be obtained from samples collected and stored for 1-3 days. Longer-term storage, on the order

of weeks, is possible for $\delta^{13}C$ measurements without drift in the isotope ratio signal, and should also be possible for $\delta^{18}O$ measurements.

Oral Presentation

USE OF STABLE ISOTOPES IN INFERRING FOOD WEB RELATIONSHIPS AND CONTAMINANT BIOMAGNIFICATION PATHWAYS IN NORTHERN LAKE ECOSYSTEMS: A GREAT SLAVE LAKE FOCUS.

***Marlene S. Evans*[1]**, *Derek Muir*[2] *and Gary Stern*[3]
[1]National Hydrology Research Institute, Saskatoon, Saskatchewan S7N 3H5;
[2]National Water Research Institute Burlington, Ontario L7R 4A6;
[3]Freshwater Institute, Winnipeg, Manitoba R3T 2N6.

Stable isotope studies are a valuable component of baseline limnological studies, providing useful information on carbon and nitrogen pathways. Examples of the usefulness of this approach are illustrated from our research on Great Slave Lake and Waskesiu Lake.

Great Slave Lake, located in the subarctic region, consists of two major regions. The first is the West Basin which is strongly influenced by the Slave River inflow. The Slave River is formed by the confluence of the Peace and Athabasca Rivers which drain an extensive watershed in Alberta, British Columbia, and Saskatchewan. The Slave River is a major source of nutrients, suspended sediments, organic debris, and various inorganic and organic contaminants to the West Basin. The East Arm, located on the Precambrian Shield, is fed by smaller, nutrient-poor, clear-water rivers. Most of the contaminant input to the East Arm is believed to be from the atmosphere. We have been conducting studies investigating contaminant biomagnification, primarily organochlorine compounds such as PCB, toxaphene, and DDT, in the Slave River delta region and a second site in the East Arm. Stable isotope investigations have been a central part of this research.

Carbon stable isotope studies suggest that there are two major sources of primary production in the East Arm: water column phytoplankton production and production associated with littoral zone macrophytes. In the Slave River delta region, there is a single carbon source which is believed to originate from the phytoplankton community. Nitrogen stable isotope studies have illustrated the major features of the food web in the two regions of Great Slave Lake. Despite greater contaminant inputs in the West Basin than the East Arm, organisms inhabiting the East Basin tend to have higher concentrations of organic contaminants. This is believed to be due, in part, to the greater bioavailability of organic contaminants to the biota in the East Arm than West Basin. Other important factors may be related to regional differences in lipid content, growth rates, and fish age.

Less intensive stable isotope and contaminant studies have been conducted in Waskesiu Lake, located in the boreal region of Saskatchewan. These studies suggest that two carbon sources fuel the food web: phytoplankton and periphyton growth on littoral zone macrophytes. Contaminant biomagnification was similar to that observed in Great Slave Lake.

Some limitations in the use of stable isotope studies were encountered and are discussed in this presentation. Overall, however, the approach provided useful insight into important limnological processes in our study systems and will assist in future study design.

Oral Presentation*

FOOD WEB DYNAMICS OF THE JUVENILE BLUE CRAB, *CALLINECTES SAPIDUS* : WHOLE TISSUE AND COMPOUND-SPECIFIC STABLE ISOTOPE TECHNIQUES

Matthew S. Fantle[1], *Ana I. Dittel[2], Sandra M. Schwalm[2], and Charles E. Epifanio[2], David Kirchman, Marilyn L. Fogel[1]*

[1] Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Branch Road, N.W., Washington, D.C. 20015
[2] University of Delaware, College of Marine Studies, 700 Pilottown Rd., Lewes, DE 19958

In the Middle Atlantic coastal region, the blue crab is a commercially–important species, valued at approximately nine million dollars per year, and its dietary habits during the early juvenile stage determine in no small part the success of the fishery. As the blue crab migrates inland within the estuarine ecosystem of the Delaware Bay, metamorphosing from its larval stage to its early juvenile stage, it is hypothesized that the crab changes its diet. This study examines this change in diet by determining the primary food source or sources of the early juvenile blue crab. In this way we can assess the degree of importance of the estuarine ecosystem in the lifecycle of the juvenile blue crab.

We have measured, by mass spectrometry, the carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope ratios of representative members of the blue crab food web at each trophic level, including potential diets such as phytoplankton, zooplankton, meiofauna, and *Spartina alterniflora*, as well as experimentally-cultured and field-collected samples of *Callinectes sapidus.* In addition, we have analyzed the $\delta^{13}C$ of individual amino acids in these samples by gas chromatography/combustion–isotope ratio mass spectrometry (GC/C–IRMS).

Whole tissue measurements indicate that the blue crab feeds primarily on zooplankton during its early juvenile stage. These analyses also have food web scale implications, suggesting that isotope fractionation of dietary nitrogen and carbon by the blue crab depends on the relative abundance of nitrogen and carbon in the diet, as well as net growth of the crab over time. The trend in $\delta^{13}C$ of amino acids in the blue crab and other estuarine organisms such as zooplankton mirrors that of terrestrial organisms. Glycine and threonine are among the heaviest amino acids while essential amino acids such as valine, leucine, isoleucine, and phenylalanine are the lightest. Analyses of experimentally-cultured samples show enrichments in $\delta^{13}C$ between diet and crab in the amino acids lysine, serine, and glycine.

Successful ecosystem management depends heavily upon understanding the relationships between various types of primary production and higher organisms. Consequently, the insight into food web dynamics obtained from this study allows for the effective management of the economically–important ecosystem of the blue crab.

Oral Presentation*

CHANGES IN CARBON AND NITROGEN STABLE ISOTOPE SIGNATURES OF BENTHIC INVERTEBRATES AND FISH ASSOCIATED WITH DEVELOPMENT OF HYDROELECTRIC FACILITIES.

***A.J. Farwell*[1]*, K.R. Munkittrick*[2] *M.R. Servos*[2] *and K.R. Solomon*[3]

[1]Department of Environmental Biology, University of Guelph, Guelph, ON, Canada
[2]Environment Canada, Burlington, ON, Canada
[3]Centre for Toxicology, University of Guelph, Guelph, ON, Canada.

Carbon and nitrogen stable isotopes have been used to characterize nutrient enrichment in benthic fish species (white sucker, *Catostomus commersoni*) collected downstream of pulp mill effluent discharge. Stable isotope assessment of the impact of pulp mill effluent is complicated by the presence of a hydroelectric dam located immediately upstream of the pulp mill. The objective of this study is to assess changes in nutrient cycling described by stable carbon and nitrogen isotope signatures in a river with only hydroelectric development. Study sites were located upstream and downstream of the hydroelectric dam constructed on the Groundhog River, a major tributary of the Moose River system in northeastern Ontario, Canada. The isotope signatures of different tissues (muscle, liver, gonad) are compared for white sucker collected at upstream and downstream sites. The operculi of upstream samples were analyzed by grinding individual annuli in order to distinguish between enriched pre-impoundment signatures and depleted post-impoundment signatures for stable carbon isotopes. Benthic invertebrate species were analyzed to determine the isotopic variability associated with water depth and flow rate at upstream sites for less mobile organisms. Possible explanations for the depletion in stable carbon isotope signatures will be presented. The importance of separating the impact of hydroelectric dams on stable isotope signatures of benthic fish will be discussed with respect to the stable isotope assessment of combined impacts of hydroelectric dams and pulp mill effluent.

Oral Presentation

ECOSYSTEM-ATMOSPHERE CARBON DIOXIDE EXCHANGE: INSIGHTS FROM STABLE ISOTOPE ANALYSES

***Lawrence B. Flanagan*[1]**, *David S. Kubien*[2], *James R. Ehleringer*[3]

[1]Department of Biological Sciences, University of Lethbridge, Lethbridge, Alberta
[2]Department of Botany, University of Toronto, Toronto, Ontario
[3]Department of Biology, University of Utah, Salt Lake City, Utah

The stable isotope composition of atmospheric CO_2 is an important tool used in studies of the global carbon cycle. For example, carbon dioxide uptake and release from the ocean causes different changes in the $^{13}C/^{12}C$ ratio of atmospheric CO_2 than does carbon dioxide exchange with the terrestrial biosphere. Therefore the $^{13}C/^{12}C$ ratio of atmospheric CO_2 can be used as a tracer to separate oceanic and terrestrial carbon dioxide exchange processes. The $^{18}O/^{16}O$ ratio of atmospheric CO_2 is primarily controlled by carbon dioxide fluxes between the terrestrial biosphere and the atmosphere. Therefore the ^{18}O signal has the potential to be used to separate and study CO_2 fluxes associated with photosynthesis and respiration on large spatial scales in terrestrial ecosystems. This information can be used to determine changes in the carbon dioxide sink strength of the terrestrial biosphere.

Interpretation of the stable isotope signal recorded by atmospheric CO_2 requires a detailed understanding of isotope effects that occur during ecosystem gas exchange processes. We have conducted a series of studies to examine factors influencing the stable isotope ratio of atmospheric CO_2 in boreal forest ecosystems in northern Canada. Our stable isotope measurements have been conducted during time periods when simultaneous ecosystem-level CO_2 and water vapour flux measurements were made using eddy covariance techniques in association with the BOREAS project. The combination of stable isotope and flux measurements have allowed us to determine the relative influence of photosynthesis, respiration and turbulent exchange processes on the stable isotope ratio of atmospheric CO_2 within the vegetation canopy. Since the processes controlling the ^{13}C composition of atmospheric CO_2 are completely independent from those affecting the ^{18}O composition, measurements of both isotopes can be used to provide independent information about large scale CO_2 exchange processes. Use of the ^{18}O signal in carbon cycling studies is potentially great, but it requires a great deal more understanding of hydrological processes that influence the ^{18}O content of water in plant leaves and soils. In particular, more knowledge is required of the fractionation processes that occur during CO_2 - H_2O exchange in soils.

Oral Presentation

REQUIREMENT FOR HYDROGEN ISOTOPIC MEASUREMENTS IN CONTINUOUS FLOW MODE - APPLICATION TO ANIMAL MIGRATION USING EA PYROLYSIS - IRMS

***Francois Fourel*[1]*, Tom Merren*[1]*, John Morrison*[1]*, Leonard Wassenaar*[2] *And Keith Hobson*[3]

[1] Micromass UK Ltd , Floats Road, Wythenshawe , Manchester M23 9LZ UK
[2] Stable Isotope Hydrology and Ecology Laboratory Environment Canada 11 Innovation Blvd. Saskatoon, Canada S7N 3H5
[3] Canadian Wildlife Service 115 Perimeter Road Saskatoon, SK Canada, S7N 0X4

The performance of a current analyser has been extended to achieve high precision measurement of the isotopes of hydrogen in continuous flow mode using helium as carrier gas.

The H3 correction factor is calculated and applied to hydrogen chromatographic peaks providing numbers corresponding to those measured in dual inlet mode.

Samples with different levels of deuterium depletion have been measured successfully using the new system.

The system has been successfully used to measure δD from butterfly wings to trace migration patterns from North American Monarch butterflies. These δD are very comparable to those obtained with classical techniques and show correlation with δD of precipitation waters from the butterfly's growing areas. The δD also show correlation with $\delta^{18}O$ measured with EA-Pyrolysis-IRMS on the same samples comparable to the Craig correlation in precipitation waters.

This provides an automated easy technique to have access to organic hydrogen using EA-Pyrolysis technique.

Oral Presentation

RIVERINE INPUTS INTO ESTUARIES: USING STABLE ISOTOPES TO SEPARATE EFFECTS OF RIVERINE NUTRIENTS VS. PARTICULATES IN SUPPORTING ESTUARINE FOOD WEBS

Brian Fry

U.S. Geological survey, Mailstop 434, 345 Middlefield Road, Menlo Park CA 94025
(Currently on leave at the USGS from Florida International University)

Riverine inputs to estuaries are quite important for sustained coastal productivity, but in many areas of the world, freshwater diversions are diminishing historical riverine inputs. If current models are correct, reduced riverine inflows should lead to reduced estuarine fish and shellfish production, but the exact mechanism of this reduction is not known. One obvious linking mechanism is delivery of riverine foodstocks to estuaries in the form of particulate organics; delivery of nutrients that stimulate within-estuary phytoplankton production could be another important link. Stable isotopes of nitrogen and sulfur, but probably not carbon, can be helpful in discerning the relative contributions of these two food-related riverine subsidies for estuarine food webs. This talk will review several estuarine studies that suggest a strong ^{15}N link between estuarine food webs and riverine nutrients, with a much more minor role for riverine particulates.

Oral Presentation

ISOTOPIC TRACING OF LAKE WATER BALANCE AND RELATED PROCESSES IN LOW-RELIEF BOREAL-FOREST TERRAIN: A SUSTAINABLE FOREST MANAGEMENT NCE STUDY

***J.J. Gibson*[1]**, *T.D. Prowse*[1], *and E. Prepas*[2]

[1]National Hydrology Research Institute, 11 Innovation Blvd. Saskatoon, SK S7N 3H5,
Tel: (306) 975-5744; Fax: (306) 975 5143; email: john.gibson@ec.gc.ca
[2]Department of Biological Sciences, University of Alberta, Edmonton AB T6G 2E9

Lake water balance and related ecosystem processes are being studied in reference, burn, and cut watersheds in northern Alberta as contribution to research conducted within the Sustainable Forest Management Network of Centres of Excellence (SFM-NCE). Due to several factors such as the large scale of the study, which includes observations in over 70 lakes, the complex hydrology, and limited hydroclimate data, use of a non-conventional hydrological approach is essential for differentiating the degree of watershed runoff to lakes, lake residence times, lake outflows, and associated nutrient fluxes. This paper describes the basis for application of a stable isotope mass balance method using oxygen-18 and deuterium developed to provide such information in remote, under-monitored areas [1]. The method relies on partitioning of water discharge by evaporation and liquid outflow pathways based on evaporative isotopic enrichment measured in the lakes, and supplementary hydroclimate data. Results of the isotopic analysis will be presented, including comparisons with physical watershed characteristics which demonstrate fundamental controls on the hydrology and related ecosystem processes in lakes of the boreal plain of Alberta. Further research is underway to develop and test the method as a versatile field-based management tool with considerable potential for identification of lakes with delicate hydrologic-nutrient balances.

[1] Gibson, J.J., Edwards, T.W.D., Bursey, G.G., and Prowse, T.D., 1993. Estimating evaporation using stable isotopes: quantitative results and sensitivity analysis for two catchments in northern Canada, *Nordic Hydrology*, 24, pp. 79-94.

Oral Presentation

ASSESSMENT OF ATMOSPHERIC S INPUT INTO TERRESTRIAL ECOSYSTEMS

Dr. A. Giesemann

Institute of Agro-Ecology, Federal Agricultural Research Centre
Bundesallee 50
D - 38116 Braunschweig

In the 1980s, atmospheric S input into terrestrial ecosystems was rather high in Germany due to exhaust fumes from factories and power plants. It was of major interest to evaluate the role of S in spruce tree damage and forest decline, which occurred at locations subjected to high atmospheric S impact.

Stable S-isotope analysis proved to be a valuable tool to determine how high the contribution of atmospheric S compounds to S in an ecosystem compartment was. Supposed atmospheric S and S present in the ecosystem differ in their S-isotopic composition, this method allows to differentiate between S either origin.

A comparative study was carried out at four locations in former West Germany, which were known to have different atmospheric S input. The location with low atmospheric S input (Black Forest) showed, that the S isotopic composition in spruce needles was close to identical to the S isotopic composition observed in the plant available sulphate fraction of the soil. At places with mediate (Harz) to high (Fichtelgebirge and Bavarian Forest) atmospheric S input the S-concentration of the needles had increased and their S isotopic composition changed towards the S isotopic composition of atmospheric S. The more airborne S was present, the more expressed were these changes. However, some needles harvested from severely damaged spruce trees at places with very high atmospheric S-input contained low amounts of S. They were comparable to such needles originating from the location with very low S input. As their S-isotopic composition was close to the S-isotopic composition of atmospheric S, this indicated that S derived from the atmosphere rather than from soilborne S.

Due to the introduction of technical equipment reducing the emission of S compounds into the atmosphere starting in the mid 80s, atmospheric S concentrations decreased markedly. S is present at subnecrotic levels, which might interfere the plant's metabolism. An approach was carried out to correlate S from traffic exhaust fumes in plants growing in the close vicinity of motorways to plant S-metabolism. First results will be presented showing the feasibility of stable S isotope analysis even for approaches where very low atmospheric S concentrations are to be traced, supposed the difference in S-isotopic composition of source and sink is high enough.

Poster Presentation

DETERMINATION OF STABLE SULPHUR ISOTOPE COMPOSITION IN TREE RINGS - A POSSIBILITY FOR A RETROSPECTIVE EVALUATION OF ATMOSPHERIC S INPUT INTO ECOSYSTEMS

Dr. A. Giesemann[1]*, F. Hofmann*[2]*, U. Schlechtriemen*[3]

[1]Institute of Agro-Ecology; Federal Agricultural Research Centre
Bundesallee 50; D-38116 Braunschweig
[2]Ökologiebüro Hofmann; Wielandstr. 25; D-28203 Bremen
[3]Forstsachverständigenbüro; Im Sacke 2; D-37176 Nörten-Hardenberg

Research on the influence of anthropogenic sulphur (S) emission on vegetation has been carried out for many years. Gaseous S species like SO_2 and H_2S can result in severe damage if S is not readily incorporated into the plant's metabolism or detoxified.
S is an essential nutrient and taken up from both soil and atmosphere. In order to distinguish between these different S sources, stable S isotope analysis of source and sink compounds has been shown to be a useful tool.

For example fossil fuels, as a major source of anthropogenic S from the atmosphere, often are enriched in ^{34}S compared to S naturally present in ecosystems. As trees grow by building up one tree ring per year, they can be expected to reflect the respective S input situation over time. The S isotopic composition of tree rings therefore could provide information on changes in the S impact on forest ecosystems within the past years.

Tree ring samples from an oak tree (*Quercus robur*) - 120 years old - at a rural forest site in North Germany were analysed for their S isotope composition. Sequences covering periods of five years were cut out of a stem disc, homogenised, divided into 3 sub samples and analysed for total S concentration and S isotope composition. Results gave obvious trends over time: S concentration was at a constant level first and increased from about 1945 onwards, while the S isotope composition decreased first and increased again starting about 1945 too. These trends could be clearly interpreted to reflect changes in the S impact on the ecosystem.

Additional investigations on tree ring width, elemental composition of the tree rings (Ca/Al- and the Mn/Ba - ratio), soil analysis and bark monitoring all support the trends seen with S isotope composition.

The results proved the feasibility of the S isotope analysis in tree rings as a tool to get information about changes in S impacts on an ecosystem. Distinguishing the sources of the S-pollution is possible.

Oral Presentation

GROUP SPECIFIC ISOTOPE RATIOS IN ECOLOGICAL RESEARCH DETERMINATION OF SOURCE MATERIALS AND PROCESSES OF HUMIFICATION

Gerd Gleixner[1] *and Hanns-Ludwig Schmidt*[2]

[1]Max-Planck-Institut für Biogeochemie, Jena, Germany
[2]Technische Universität München, Freising, Germany.

Bulk isotope ratios of organic matter provide relevant information about the sources and processes involved in their synthesis. In the course of the humification isotopic shifts of biomass can be caused by selective preservation of individual compounds, e. g. lignin, which is isotopically depleted relative to carbohydrates, or by secondary metabolic reworking of the material (trophic level effect). Corresponding information on humification steps can be obtained from the intermolecular and intramolecular distributions of isotopes in individual parts of humic material. However, the chemical degradation of organic matter is very laborious, time consuming and needs relative large amounts of sample. Furthermore most structural elements of biomass, e. g. carbohydrate- and lignin-moieties, are not volatile and needfor separation in gas chromatographs additional derivatizations. These steps imply isotopic fractionations and introduce foreign carbon.

On the other hand much information can already be obtained from the isotopic analysis of fragments obtained by partial thermal degradation of bulk material. We have used a system for the controlled pyrolysis of small amounts of organic matter by a Curie point pyrolyzer (Py) on line connected to a gaschromatograph- combustion-isotope ratio mass spectrometer (GC-C-IRMS) device. Individual peaks were identified in an Py-GC/MS using the same column and identical conditions for separation. The system was applied to refractory organic acids from aquatic ecosystems yielding peaks with characteristic δ-value differences. The assignment of some pyrolysis products and their δ^{13}C-values relating to cellulose (average mean -23.5 ‰ ± 1.0 ‰) and lignin (average mean -29.4 ‰ ± 5.8 ‰) revealed plants as source material. The high enrichment of some other pyrolysis products suggests secondary (bacterial or fungal)sources. Furthermore results are presented for the primary steps of the humification process in soil organic matter. Additionally possible scope and limitations for the determination of δ^{15}N-values of pyrolysis products are outlined.

Poster Presentation

THE TROPHIC STATUS OF MARINE TURTLES AS DETERMINED BY STABLE ISOTOPE ANALYSIS.

*Brendan J. Godley[1,2], David R. Thompson[1], **Susan Waldron**[3] & Robert W. Furness[1]*

[1]Marine Turtle Research Group, Division of Environmental and Evolutionary Biology, University of Glasgow, Glasgow G12 8QQ, United Kingdom. email: B.Godley@udcf.gla.ac.uk
[2]Dept. of Veterinary Anatomy, University of Glasgow Veterinary School, Glasgow G61 1QH, United Kingdom.
[3]Scottish Universities Research and Reactor Centre (SURRC), East Kilbride G75 0QF, United Kingdom. email: s.waldron@surrc.gla.ac.uk

Stable isotope ratios of nitrogen and carbon were determined in bone collagen, egg proteins and keratin from epidermal carapace scutes of loggerhead *Caretta caretta*, green *Chelonia mydas*, and leatherback *Dermochelys coriacea* turtles from the Mediterranean Sea and the European Atlantic Ocean. Isotope ratios in protein from loggerhead turtles indicate this species occupies a higher trophic position that green turtles. leatherback turtles are apparently intermediate in trophic status. Both carbon and nitrogen isotopic ratios from loggerhead turtles correlated positively with body size, indicating a trend of increasing trophic level with age. Within the size range of turtles sampled, there was apparently no change in trophic level in relation to body size. In absolute terms, isotopic signatures of egg proteins were markedly different from those of bone collagen. However, interspecific differences in isotope values were consistent with those in bone protein. The novel application of this technique to marine turtles generally confirmed dietary information collected conventionally in these species, and has afforded additional insights into shifts in diet and trophic status as turtles mature.

Oral Presentation

AN EXPERIMENTAL STUDY ON VARIATIONS IN STABLE CARBON AND NITROGEN ISOTOPES FRACTIONATION DURING GROWTH OF MYSIS MIXTA AND NEOMYSIS INTEGER (CRUSTACEA, MYSIDACEA)

Elena Gorokhova *& Sture Hansson*

Stockholm University, Sweden

Isotopic composition of M. mixta and N. integer was studied in field and under laboratory conditions using natural abundances of stable isotopes (^{13}C and ^{15}N).

1. Delta (13)C and delta (15)N of two species in the field samples were similar and ranged from -23.1 to -21.51‰ and from 10.2 to 12.6‰ respectively. Animals collected from the field showed a significant increase in delta (15)N with size (biomass range for M. mixta was 1.09 to 16.48 and for N. integer 0.21 to 5.45 mg of dry weight). No such increase was detected for carbon isotopes.
2. Feeding experiments were done with two diets of different origin (newly hatched Artemia and detrital Enteromorpha) which had considerably different stable isotope ratios. The isotopic composition of body (abdominal muscle tissue), exoskeleton and feces were monitored.
3. There were a general shifts in body delta (13)C towards the composition in the diets, however muscle tissue of M. mixta did not reach an isotopic equilibrium with their diet during 12 weeks. Delta (13)C of exoskeleton approached that of the diet immediately and came in equilibrium in 2 weeks. The muscle tissue of M. mixta was enriched in ^{15}N relatively to its diet. The differences in delta (15)N between this tissue and the diets were diet dependent; +3.6‰ for Artemia and +2.7‰ for Enteromorpha.
4. The following fractionation for field and laboratory maintained animals was obtained: $\delta^{13}C_{feces} > \delta^{13}C_{diet} > \delta^{13}C_{molt}$ and $\delta^{13}N_{feces} > \delta^{13}N_{diet} > \delta^{13}N_{molt}$.
5. Six weeks of starvation of N. integer resulted in insignificant changes in delta (13)C and delta (15)N.
6. Experimental data were consistent with those from the Baltic Sea with regard to isotopic differences between muscle tissue, exoskeleton and feces of M. mixta. This will provide an essential calibration for the use of the stable isotopes in food web studies. Also, metabolic turnover of carbon and nitrogen can be calculated and incorporated into bioenergetics model.

Oral Presentation*

COMPLEMENTARY USE OF STABLE ISOTOPE AND GUT PIGMENT ANALYSES TO DETERMINE ZOOPLANKTON TROPHIC POSITIONS IN PRAIRIE LAKES

Mark D. Graham[1], *Peter R. Leavitt[1] and Ray H. Hesslein[2]*

[1]Department of Biology, University of Regina, Regina, Saskatchewan, S4S 0A2, Canada
[2]Department of Fisheries and Oceans, Central and Arctic region, Freshwater Institute, 501 University Crescent, Winnipeg, Manitoba, R3T 2N6, Canada

δ^{15}N-inferred zooplankton trophic positions can exhibit both spatial and temporal variation as functions of lake productivity and time of year, respectively. Sources of variance may include changes in resource base, selective herbivory and omnivory by zooplankton. This study examines how gut-pigment analysis using HPLC may be combined with stable isotope analysis to construct more accurate pelagic food webs.

δ^{15}N-inferred trophic position of zooplankton species differed both temporally and along a lake production gradient. δ^{15}N λ values of individual plankton were consistent across time in the oligotrophic lakes. In contrast, the δ^{15}N λ values of zooplankton species declined throughout the summer in the eutrophic lakes. Despite this decline, Daphnia (*D. galeatamendotae*, *D. retrocurva*) occupied one trophic level above phytoplankton, consistent with their role as herbivores. Unlike in oligotrophic lakes, predacious copepods and *Leptodora kindtii* occupied a trophic level intermediate to true herbivores and carnivores suggesting that omnivorous feeding was common. Dietary gut-pigment analysis generally corresponded with the δ^{15}N method. As well, the gut-pigment technique provided a reliable estimate of selectivity for algal items and the proportion of animal prey in the diets of these invertebrates. This study demonstrates that knowledge of invertebrate feeding behaviours through gut analyses improves the resolution of trophic relations provided by the stable isotope technique.

Poster Presentation

STABLE ISOTOPE COMPOSITION OF HUMAN HAIR AND NAILS

*L. Guo[1], S. Iyer[1], **H.R. Krouse[1]**, B.K. Jankowska[1], D.R. Krouse[2], M. Minagawa[3]*

[1]Dept. of Physics and Astronomy, University of Calgary, Calgary, Alberta Canada T2N 1N4
krouse@acs.ucalgary.ca
[2]218 Farmington Dr. Lakeside Park, KY, USA 41017
[3]Grad. School of Environmental Earth Science, University, Sapporo 060, Japan Hokkaido

Thousands of stable isotope data have been determined for hair and nail specimens from different parts of the world. The frequencies of analyses in descending order are C, N, S, O, and H with occasionally Pb, Sr, and B. Data for all elements reflect diet and place of residence. The influence of these two parameters are better inter-related near the equator and in remote regions. In industrialized cities at higher latitudes, the isotopic compositions of diets depart from those of the natural surroundings through pollution and import of foods from lower latitudes. Cultural differences may influence diet. The D, ^{13}C, and ^{15}N values for hair of nursing infants are slightly higher than those of adults at a given location.

Isotopic data for different elements are complimentary because of different fractionation processes. For carbon, the relative influence of the recognized photosynthetic pathways on diet determines the isotope composition of hair. Whereas, carbon isotope compositions display geographical trends including a latitude dependence, these are more pronounced for H and O isotopes because photosynthesis involves environmental water which is in turn meteorologically fractionated. In South America below the equator, all three elements become isotopically lighter with increasing latitude. Whereas H and O isotope data for a native Indian community follow the same trend as found for cities, the ^{13}C values are a few per mil more negative reflecting dietary availability. Hair from Calgary and three cities in China were found to have the relationship D=12.7 $^{18}0$-126 compared to the global meteoric water line, D=8.1 $^{18}0$+11. Evapotranspiration enriches foliage water in the heavier isotopes of both hydrogen and oxygen. In contrast, photosynthesis favours the lighter H-isotope but the heavier O-isotope. Hence, the D values of vegetation and consequently hair may be higher or lower whereas the $^{18}0$ values for vegetation and hair are about 15 per mil higher than those of environmental water.

Sulphur isotope data compliment carbon and nitrogen isotope data in determining marine vs terrestrial composition of diet. Continental ^{34}S values tend to be lower than those of marine sources (^{34}S =+17$^{0}/_{00}$) but are more locally dependent because sulphur in plants derive sulphur from the atmosphere and soil. The latter has a lithogenic component from weathering processes whereas pollution can alter the isotopic composition of any sulphur available to plants. Changes in the isotopic composition of hair with migration of individuals has been documented. The isotopic composition of hair has proved useful in many applications such as paleodietary reconstruction, paleoclimate, environmental studies, and forensic science.

Poster Presentation*

STABLE ISOTOPE ANALYSIS OF THE LAKE SUPERIOR FISH COMMUNITY

Chris J. Harvey *and James F. Kitchell*

Center for Limnology, University of Wisconsin, Madison, WI 53706, USA

Lake Superior is the largest of the Laurentian Great Lakes, and also the least studied. Many questions of both ecological and managerial nature can be addressed using stable isotope analysis. We are conducting ^{15}N and ^{13}C analyses of Lake Superior food webs to explore several hypotheses. First, urban effluent from Duluth/Superior, the major port in U.S. waters, may produce a ^{15}N signal in the pelagic and demersal fish community that will indicate the influence of anthropogenic nutrients and migratory characteristics of key species. Initial analysis supports this hypothesis; slimy sculpin (*Cottus cognatus*) near Duluth/Superior were enriched by 2-3‰ ^{15}N. Second, the two principal races of lake trout (*Salvelinus namaycush*), leans and siscowets, may have different ^{13}C signatures, owing to differences in diet, age, and bathymetric distribution. Third, sea lamprey (*Petromyzon marinus*) ^{15}N signatures may change as lampreys increase in size because of ontogenetic shifts in growth rate and preferred host species. Results from this work should provide greater knowledge of trophic linkages and life history characteristics of Lake Superior fishes, and also provide useful information for fisheries managers, whose objectives include restoration of native fish stocks, maintaining stocks of desirable exotics (rainbow smelt *Osmerus mordax* and Pacific salmon *Oncorhynchus* spp.), and controlling sea lamprey populations.

Poster Presentation

STABLE ISOTOPE STUDY OF THE BIOSPHERE ON A CORAL CAY, GREAT BARRIER REEF

H.K. Herbert[1], ***H. Roy Krouse***[2]

[1]H.K.Herbert & Associates Pty Ltd, Toowoomba Mall Center, Queensland, Australia 4352
[2]Department of Physics and Astronomy, University of Calgary, P.O.Box 7810, Calgary, Alberta Canada T2N 1N4

Heron Island on the Great Barrier reef is about 700m long and 300m wide. Human intrusion is relatively minor with a resort at one corner of the island and the presence of the University of Queensland Research Station.

C, N, and S isotope abundance determinations were made on leaves, fruit, and twigs from *Argusia argentea, Pandanaus heronensis, Celtus paniculata, Casurina equiseifolia, Melanthera biflora incana, Ficus opposita, Scaevola sericea, Abutilon albescens, Suriana maritima, Pipturus argenteus,* and *Pisonia grandis*. ^{13}C values ranged from -24 to -31 per mil consistent with C3 photosynthesis. *Thuarea involuta* had a ^{13}C value of -12 per mil attesting to a minor C4 grass component.

The ^{34}S values of vegetation were found to be remarkably uniform at about +18 per mil consistent with sulphur being derived from sulfate of marine salt and oxidized excrement from the large bird population. There are subtle indications that emissions from a fossil fuel fired generator lower the ^{13}C and ^{34}S values of nearby trees by a few per mil.

Regardless of whether birds are tree top dwellers, ground nesters, waders, or fish eaters, the ^{34}S values of their feathers are markedly consistent, $+17.9\pm0.4^{0}/_{00}$. In contrast, there is a range of over $12^{0}/_{00}$ in their ^{13}C values. The most negative ^{13}C values near -22 per mil are identified with the Silver-eyes (*Zosterops lateralis)* who nest high in the trees and consume insects, larvae, and fruit such as wild figs. Hence the ^{13}C values in the realm of C_3 plants are quite reasonable.

In contrast, the Banded Land-Rail (*Rallus philippensis*), while capable of flight, prefers a walking habit. Its diet is mainly grubs and insects found in the leaf litter of the interior. Considering the presence of C_4 grasses, their ^{13}C values near $-17.5^{0}/_{00}$ represent a C_3-C_4 mixture. The ^{13}C values near $-15^{0}/_{00}$ for Noddy Tern (*Anons minutus*) and gulls (*Larus novaehollandiae*) are consistent with their predominantly fish diet. The high ^{13}C values near $-10^{0}/_{00}$ for egret feathers while surprisingly different from those of gulls and terns, reflect their wading habitat and near shore diet.

Data found for insects, fish, etc. are consistent with the above conclusions but the isotope compositions of some birds, particularly railers and gulls are influenced by food provided by tourists.

Oral Presentation*

APPLICATIONS OF STABLE ISOTOPE ANALYSES: NUTRITIONAL ECOLOGY OF BEARS

***G.V. Hilderbrand*[1]**, *M.J. Jacoby*[1], *C.T. Robbins*[2], *C.C. Schwartz*[3], *S.M. Arthur*[3], *T.A. Hanley*[4], *C. Servheen*[5]

[1]Department of Zoology, Washington State University, Pullman, WA 99163
[2]Departments of Zoology and Natural Resource Sciences, Washington State University, Pullman, WA 99163
[3]Alaska Department of Fish and Game, 34828 Kalifornsky Beach Road, Suite B, Solodotna, AK 99669
[4]Pacific Northwest Research Station, United States Forest Service, 2700 Sherwood Lane, Suite 2A, Juneau, AK 99801
[5]United States Fish and Wildlife Service, University Hall, University of Montana, Missoula, MT 59812

Stable isotope analyses have been used to investigate the ecology of individual bears as dietary shifts reflect seasonal variation in available resources and nutritional requirements as well as the bear's reproductive and social status. The nutritional requirements of a bear population as a whole have been estimated through a combination of demographic and isotopic studies. Additionally, comparisons of diet composition have been made across North American brown bear populations which differ in their available nutritional resources. Lastly, nutritional resource partitioning between sympatric black and brown bear populations has been assessed. Information on the nutritional ecology of bears at the level of the individual, population, and species is vital to ecosystem management and bear conservation on local and regional scales.

Oral Presentation*

DECLINE OF PINNIPED POPULATIONS IN THE NORTH PACIFIC OCEAN: AN INDICATION OF ENVIRONMENTAL CHANGE?

Amy C. Hirons *and Donald M. Schell*

The numbers of Steller sea lions (Eumetopias jubatus), northern fur seals (Callorhinus ursinus) and harbor seals (Phoca vitulina) have declined dramatically in the Bering Sea and Gulf of Alaska for more than two decades. Decreasing food availability and/or changing to prey of lower nutritional value have been hypothesized as possible links in the declines. Archived and recent pinniped and prey tissues were analyzed for stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope ratios as a way to test for shifts in trophic level and carrying capacity. Multiple tissues were collected from seals and sea lions of the Gulf of Alaska and Bering Sea from 1950-1996. Vibrissae were used from animals sampled during the 1990s and frozen muscle tissue was collected from animals in the 1970s and 1980s. Bone collagen was extracted from skeletal remains in museum collections from 1950 to 1996. No significant differences in $\delta^{15}N$ were found in any of the species and areas during the 47 year period that samples were available and indicate no trophic shift occurred as a result of changes in diet. A decrease of almost 2ppt in the $\delta^{13}C$ did occur from the late 1960s to 1996 in Steller sea lions and was less apparent in the northern fur seals and harbor seals. The decline was a probable result of decreasing seasonal primary productivity. The time of the isotope shift corresponds to similar shifts in physical and biological properties measured in the North Pacific Ocean and signal that environmental changes may be a factor in the declines of these pinniped populations.

Oral Presentation

INTERPRETATION OF NITROGEN ISOTOPE SIGNATURES USING A NIFTE MODEL

Erik A. Hobbie and Stephen A. Macko*.

Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia, 22903, USA.
*Current address: National Research Council, National Health and Environmental Effects Research Lab, Corvallis, Oregon, 97333, USA.

Because nitrogen is often the limiting nutrient for forest growth, the cycling of nitrogen has been intensively studied for many years. Attempts to use natural abundances of nitrogen isotopes to study nitrogen (N) dynamics have been inconclusive however because of the great complexity of the interactions between soil, microbes, and plants and the consequent inability to correlate $\delta^{15}N$ changes with biologic processes. During an investigation of N dynamics along the 250-year-old successional sequence in Glacier Bay, Alaska, several puzzling isotopic patterns were observed, including a consistent decline in $\delta^{15}N$ of the late successional dominant Picea, high $\delta^{15}N$ for mycorrhizal fungi, and a lack of agreement between foliage $\delta^{15}N$ and ammonium $\delta^{15}N$. In order to understand the mechanisms creating these patterns, we developed a model of N dynamics and N isotopes (NIFTE: Nitrogen Isotope Fluxes in Terrestrial Ecosystems) which simulated the major transformations of the N cycle and predicted isotopic signatures of different plant species and soil pools. Comparisons with field data from six sites along the successional sequence indicated that NIFTE can duplicate observed patterns in soil, foliage, and mineral N $\delta^{15}N$ over time.

Different scenarios that could account for the observed isotopic patterns were tested in model simulations. Possible mechanisms included increased isotopic fractionation on mineralization, fractionation during the transfer of nitrogen from mycorrhizal fungi to plants, variable fractionation on uptake by mycorrhizae compared to plants, no fractionation on mycorrhizal transfer, and elimination of mycorrhizae as a pool in the model. A net fractionation during mycorrhizal transfer of nitrogen to vegetation provided the best fit to isotopic data on mineral N, plants, soils, and mycorrhizal fungi. Enzymatic reactions within the mycorrhizae that involve the movement of amino groups among amino acids are the most probable cause of this fractionation. The model and field results indicate that the importance of mycorrhizae to N uptake is less under conditions of high N availability.

Use of this model should encourage a more rigorous assessment of isotopic signatures in ecosystem studies and provide insights into the biologic transformations which affect those signatures. This should lead to an enhanced understanding of some of the fundamental controls on nitrogen dynamics.

Oral Presentation

TRACKING ORIGINS AND MIGRATION OF MIGRATORY WILDLIFE USING STABLE ISOTOPE ANALYSES - A REVIEW

Keith A. Hobson[1] and Len Wassenaar[2]

[1]Canadian Wildlife Service, 115 Perimeter Road, Saskatoon, SK, S7N 0X4
[2]National Hydrology Research Institute, 11 Innovation Boulevard, Saskatoon, SK S7N 3H5.

Annual migration or movement between distinct biomes is an important aspect of the ecology of many species. Understanding patterns of movement or migration is particularly important to the conservation of species that move over large geographical regions or across political boundaries. The ability to link breeding and wintering grounds of migratory birds, mammals and insects is of particular interest since conservation efforts can be focused more appropriately at these areas and at possible stopover sites. To date, tracking migration movements has largely been restricted to game species large enough to mark with conspicuous tags, radio or satellite transmitters, and the large recovery rate of such marked animals has provided very useful information. However, for smaller and less conspicuous species, banding and tagging programs have generally not been successful in providing such information. Stable-isotope techniques can provide important insights on movements of animals that were previously unavailable. Those species that move between biomes involving foodwebs with characteristic isotopic profiles may maintain that isotopic information in their tissues long enough to be traced at recovery sites. In this paper, we review studies that have used isotopic tracing of animal movements. Such studies have made use of animals moving between C-3 and C-4 based foodwebs or between marine and terrestrial biomes. However, the recent use of deuterium measurements in animal tissues that can ultimately be related to rainfall patterns, has provided a more general tool for inferring breeding origins in North America. In addition to a review, this paper will present new examples of latitudinal patterns in deuterium in feathers of breeding Red-winged Blackbirds (*Agelaius phoeniceus*) and on linking breeding and wintering sites of Loggerhead Shrikes (*Lanius leudovicianus*).

Poster Presentation

STABLE ISOTOPE ANALYSIS REVEALS IMPORTANCE OF INTRODUCED RATS (RATTUS SP.) AS PREDATORS OF BURROW-NESTING SEABIRDS ON LANGARA ISLAND, BRITISH COLUMBIA: IMPLICATIONS FOR THE PROTECTION OF ISLAND FAUNA

Keith A. Hobson[1], *Mark C. Drever[2], Gary Kaiser[3]*

[1]Prairie and Northern Wildlife Research Center, Canadian Wildlife Service, 115 Perimeter Road, Saskatchewan S7N 0X4, Canada. [2]Department of Biology, Simon Fraser University, Burnaby, British Columbia V5A 1S6, Canada. [3]Pacific Wildlife Research Center, Canadian Wildlife Service, RR 5421, Delta, British Columbia V4K 3N2, Canada.

Introduced species to oceanic islands can cause tremendous declines and extinctions of native fauna. On Langara Island, British Columbia, the burrow-nesting Ancient Murrelet (*Synthilobramphus antiquus*) has declined from an estimated original population of 200,000 pairs to 14,600 pairs in 1993. Previously, causes of this decline were unknown but the introduction of Norway rats (*Rattus norvegicus*) has been implicated as a major factor and has resulted in a recent rat eradication program. A major obstacle in the investigation of the effects of rats on seabirds, here and elsewhere, has been our inability to accurately assess the importance of seabirds to the diets of rats that are known to also consume a variety of plant and invertebrate foods. We used stable-carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$), and sulfur ($\delta^{34}S$) isotope analyses of muscle and liver tissues of rats and prey organisms from three regions of Langara Island in order to evaluate evidence for marine foods including seabirds in the diets of rats. Rats were segregated into three isotopic groups corresponding to upland, (liver mean $\delta^{15}N$: 10.9‰, mean $\delta^{13}C$: -22.4 ‰ , n= 7; muscle mean $\delta^{15}N$: 12.3 ‰, mean $\delta^{13}C$: -19.8 ‰, n=6) littoral (liver mean $\delta^{15}N$: 13.7‰, mean $\delta^{13}C$: -18.3 ‰ , n= 24; muscle mean $\delta^{15}N$: 13.7 ‰, mean $\delta^{13}C$: -16.8 ‰, n=25) and seabird nesting(liver mean $\delta^{15}N$: 16.6/‰, mean $\delta^{13}C$: -18.6 ‰ , n= 21; muscle mean $\delta^{15}N$: 13.7 ‰, mean $\delta^{13}C$: -16.8 ‰, n=23) areas on the island. We interpret these groups to represent individuals consuming predominantly C-3 terrestrial foods (mean $\delta^{15}N$: 5.4 ‰, mean $\delta^{13}C$: -24.9 ‰, , n= 24), intertidal invertebrates (mean $\delta^{15}N$: 8.9‰, mean $\delta^{13}C$: -14.3 ‰ , n=21), and Ancient Murrelet adults, chicks or eggs (mean egg $\delta^{15}N$: 13.2 ‰, mean $\delta^{13}C$: -17.6 ‰ , n=8). We found strong correlations between liver and muscle isotope values for both ^{13}C and ^{15}N suggesting that dietary preferences within individuals remained relatively constant. Stable-sulfur isotope values of rat liver were less useful in segregating marine and terrestrial dietary inputs, possibly because sources of sulfur to the terrestrial foodweb was of marine origin (pooled mean $\delta^{34}S$ value:17.8 ‰, , n=20). Our measurement of liver and muscle tissues gave dietary estimates based on relatively short- and long-term integrations and revealed that the three groups of rats remained isotopically segregated at least over the two month period of ancient murrelet breeding on Langara Island. Our results have important ramifications for dietary investigations of introduced fauna and their impacts on native seabirds on oceanic islands.

Poster Presentation

LINKING BREEDING AND WINTERING GROUNDS OF NEOTROPICAL MIGRANT SONGBIRDS USING STABLE HYDROGEN ISOTOPIC ANALYSES OF FEATHERS

Keith A. Hobson[1] *and Len. I. Wassenaar*[2]

[1]Canadian Wildlife Service, 115 Perimeter Road, Saskatoon, SK, S7N 0X4.
[2]National Hydrology Research Institute, 11 Innovation Boulevard, Saskatoon, SK S7N 3H5.

Recent studies have shown that stable-hydrogen isotope ratios (δD) in the tissues of animals can be correlated with δD values in local precipitation. We expand on these findings to examine the δD relationships between feathers and precipitation where feathers were grown for neotropical migrant songbirds breeding along a continent-wide isotopic gradient in precipitation. δD values were determined for feathers of 140 individuals of 6 species of wild insectivorous forest songbirds (*Setophaga ruticilla, Empidonax minimus, Vermivora pregrinus, Catharus ustulatus, Seiurus aurocapillus, Hylocichla mustelina*) from 14 breeding locations across North America. The δD values of feathers were strongly correlated with growing season δD values in precipitation at their breeding sites. Distributions of δD values in the feathers of 64 individuals representing 5 species of wintering migrants (*Helmitheros vermivorus, Wilsonia citrina, Hylocichla mustelina, Dumetella carolinensis, Seirus aurocapillus*) at a single site in Guatemala were also consistent with those expected from known breeding ranges of these species in North America. Our results indicate the potential for using hydrogen isotopes for linking breeding and wintering grounds of neotropical migrant songbirds and other migratory species moving between isotopically distinct regions. Using red-winged blackbirds (*Aegolius phoeniceus*) raised in captivity on a constant diet, we determined that the δD values of bird feathers also reflected that of their diet with little apparent isotopic fractionation.

Oral Presentation*

TROPHIC RELATIONSHIPS IN AN ANTARCTIC SEABIRD COMMUNITY

Peter J. Hodum[1], *Keith A. Hobson*[2]

[1]Dept. of Avian Sciences, University of California, Davis, California 95616 USA, pjhodum@ucdavis.edu
[2]Canadian Wildlife Service, 115 Perimeter Road, Saskatoon, Saskatchewan, S7N OX4 CANADA

We employed stable isotope analyses to investigate marine trophic relationships among the Antarctic fulmarine petrel community breeding on Hop Island, Prydz Bay, Antarctica. We measured stable-carbon (δ ^{13}C) and nitrogen (δ^{15}N) isotopes from blood samples from breeding adults and chicks during the 1994-95 (n = 123) and 1995-96 (n = 160) breeding seasons and from representative prey items. δ^{13}C was not a useful indicator of trophic position but did indicate that all four species foraged pelagically rather than inshore. In contrast, δ^{15}N was a useful indicator and showed step-wise trophic enrichment. δ^{15}N values ranged from 3.98 ± 0.21 ^{o}/oo for Antarctic krill to 11.98 ± 0.64 ^{o}/oo for snow petrel chicks. Trophic positions of petrels overlapped extensively, suggesting considerable dietary overlap. Consistent with known dietary information, snow petrel chicks occupied the highest trophic level. Breeding adults of all four species selectively provisioned their chicks with higher trophic level diets than they consumed themselves. Antarctic fulmars and snow petrels showed within season variation in trophic level while only Antarctic petrel adults showed inter-annual variation. Results suggest a higher proportion of zooplankton in the diet than conventional dietary studies indicate. Petrels occupied trophic levels 3.9 (Antarctic petrel adults) through 4.7 (snow petrel chicks) in this marine ecosystem. Elucidation of seabird community trophic relationships contributes to our understanding of marine ecosystem processes and dynamics.

Poster Presentation

NATURAL NITROGEN ISOTOPE VARIATIONS IN *PINUS SYLVESTRIS* AS AN INDICATOR OF ENVIRONMENTAL STRESS

***K Jung*[1]**, *G Gebauer*[3], *M Gehre*[2], *L Weißflog*[1], *G Schüürmann*[1]

[1]Department of Chemical Ecotoxicology, [2]Department of Analytical Chemistry, UFZ Centre for Environmental Research, P.O. Box 2, D-04301 Leipzig, Germany
[3]Department of Plant Ecology, University of Bayreuth, D-95440 Bayreuth, Germany

In the heavily industrially polluted region Leipzig-Halle (Germany) natural nitrogen isotope variations ($\delta^{15}N$ values) and N concentrations were determined in needles from 7-12year old pines *(Pinus sylvestris)* on 27 different sites. At three selected locations measurements were repeated over a period of five years.
One-year-old pine needles varied in the $\delta^{15}N$ values from +0.4λ to -9.6λ and N concentrations between 0.71 and 1.38 mmol eq Ng dw^{-1} depending on their specific location.

Pine stands with positive or slightly negative $\delta^{15}N$ values and high N concentrations were found in the industrial areas and around the cities. More negative $\delta^{15}N$ and lower N concentrations were found in the low polluted forested parts.

From three sites the specific differences in the $\delta^{15}N$ values of the nitrogen in the humus layer were similar to those found in the needles. The $\delta^{15}N$ values of the hot water soluble nitrogen fraction of the mineral soil show no sites specific differences.

Poster Presentation

ANALYSIS OF MATERIAL FLOW FROM AQUATIC ECOSYSTEM TO TERRESTRIAL ECOSYSTEM MEDIATED BY THE GREAT CORMORANT BY USING STABLE ISOTOPE TECHNIQUES

***Kayoko Kameda*[1]**, *Hiroshi Mizutani*[2], *and Keisuke Koba*[3]

[1]Lake Biwa Museum, [2]Senshu University of Ishinomaki, [3]Kyoto University

The Great Cormorant *Phalacrocorax carbo* has been increasing in Lake Biwa in Japan in the last fifteen years. They feed on fish in the sea, lakes, or rivers, and return to the colony in the forest, where their droppings damage the fauna and flora. In other words, the Cormorant exports some material, such as fish, from aquatic areas and imports it as droppings to terrestrial areas. Thus, the Cormorant is thought to play an important role in the flow from aquatic ecosystems to terrestrial ecosystems. Although the material flow can partly be proven by the amount of fish they eat in the lake and their droppings on the forest floor calculated from field observations of cormorants, stable-isotope analysis will be a good support for this because of the high nitrogen-stable isotope ratio in Lake Biwa. We outline the data of carbon and nitrogen stable-isotope ratios from the lake ecosystem and cormorants from previous studies, and show the possibility of the application of stable-isotope techniques to an analysis of material flow mediated by cormorants from the lake to a forest ecosystem at a colony.

Poster Presentation

USING δD ANALYSES OF FEATHERS TO IDENTIFY BREEDING LATITUDES OF SPARROWS MIGRATING THROUGH THE MIDDLE RIO GRANDE OF NEW MEXICO, USA.

Jeffrey F. Kelly, *Deborah M. Finch*[1], and *Keith A. Hobson*[2]

[1]USDA-FS, Rocky Mountain Research Station, Albuquerque, NM, USA
[2]Canadian Wildlife Service, Saskatoon, SK, Canada

A chronic problem in the study of migrant birds has been our inability to link the breeding, wintering, and migration areas used by individuals or populations. The recently established relationship between hydrogen isotope ratios (δD) in feathers and latitudinal trends in δD may be useful in linking breeding birds to migration stopover sites. We propose to use analyses of δD to delineate the breeding latitudes of sparrows (Emberizidae) migrating through the Middle Rio Grande Valley of New Mexico, USA. Over the past four years, we have intensively studied bird migration in the Middle Rio Grande Valley. These studies have confirmed that this region is an important stopover for Neotropical and short-distance migrants; including 19 species of sparrows. Of these 19 species, at least 6 (Clay-colored Sparrow, Chipping Sparrow, Vesper Sparrow, Brewers Sparrow, Savannah Sparrow, Lark Sparrow) have been identified as species of high concern, or in need of status assessments in the U.S. In addition, general concern over population trends of grassland and shrubland birds has been on the rise among conservation biologists. To address these rising concerns, it will be necessary to improve our understanding of the relationships between breeding, wintering, and migration habitats used by these species. We think that using δD analyses to identify the breeding latitudes of sparrows migrating through the Middle Rio Grande will contribute new insights to our basic understanding of migration biology and improve our ability to manage habitats for these migrants.

Oral Presentation

MAPPING SPATIAL VARIABILITY IN MARSH REDOX CONDITIONS IN THE FLORIDA EVERGLADES USING BIOMASS STABLE ISOTOPIC COMPOSITIONS

Carol Kendall *and Steve Silva*

USGS, 345 Middlefield Road, MS 434, Menlo Park CA 94025 USA

The Everglades was once a pristine, free-flowing sea of grass extending from Lake Okeechobee S-SW to Florida Bay. Since 1990, agricultural activities south of the lake have severely restricted the flow and added large quantities of agricultural chemicals to the marshes. This massive ecosystem change has also resulted in large increases in methyl mercury (MeHg) production by sulfate-reducing bacteria, with consequent bio-accumulation of Hg up the food chain from bacteria to fish to panthers. The potential risk to human and animal health has recently focused attention on understanding the linkage between ecosystem changes and MeHg cycling.

As part of a collaboration between the USGS and the USEPA, plant and fish samples were collected during both the wet and dry seasons in 1996 at over 100 marsh sites throughout the Everglades to assess the local and regional ranges in their C, N, and S stable isotope ratios. Additional samples were analyzed for water chemistry and mercury content. Both plants and fish show wide ranges in isotopic composition throughout the marshes. However, the spatial contour plots of the isotopic compositions show intriguing regional patterns that show little change with time or species. In general, the compositions of all the isotopes show a general correspondence with peat thickness, with the lowest ^{13}C values and highest ^{34}S values along the major axis of the flow system. The ^{15}N values are highest in the same general area where ^{13}C values are lowest, but the ^{15}N values appear to be more locally variable. Areas with high MeHg contents often have high ^{15}N and ^{34}S values.

The compositions and spatial distributions of the C, N, and S isotopic compositions suggest that the values reflect spatial variability in reducing conditions in the marshes that favor methane production, sulfate reduction, and (perhaps) denitrification. The isotopic compositions of aquatic plants appear to integrate the temporal variability in water-column isotopic composition produced by these redox reactions (and other factors), and these same patterns are incorporated throughout the food chain. These compositions are relatively stable over time because the biomass remains in the system and is actively recycled without significantly affecting the isotopic compositions of the residual material. Therefore, zones frequently dominated by particular redox reactions appear to be labeled by the C, S, and N isotopic compositions of local organisms. Isotopic compositions of biomass may prove to be more cost-effective and reliable indicators of prevailing environmental conditions that favor MeHg production than other parameters currently being considered because biomass isotopic compositions are much more difficult to perturb than the more transient concentrations of aqueous species. Hence, the spatial isotope patterns are likely to provide a valuable integration of long-term environmental conditions in the Everglades.

Poster Presentation

EFFECTS OF PIKE ADDITIONS ON POLLUTANT ACCUMULATION AND FOOD WEB STRUCTURE IN AN EUTROPHIC AND AN OLIGOTROPHIC LAKE

Kidd, K.A.[1], *M.J. Paterson*[1], *R.H. Hesslein*[1] *and D.C.G. Muir*[2]

[1]Department of Fisheries and Oceans, 501 University Crescent, Winnipeg, MB, R3T 2N6;
[2]Environment Canada, 867 Lakeshore Road, Burlington, ON, L7R 4A6.

Concentrations of persistent and bioaccumulating pollutants in fishes vary with the length of the underlying food web, and the trophic status of the lake. We examined the effects of changing food web structure on pollutant concentrations in biota in two cyprinid-dominated lakes that were subjected to the additions of a piscivorous fish species. In May 1993, tagged pike were added to eutrophic L227 (Chl a 25.7 $mg.m^{-3}$) and oligotrophic L110 (Chl a 3.2 $mg.m^{-3}$) at the Experimental Lakes Area in northwestern Ontario, and the lakes were sampled for zooplankton, *Chaoborus* (an invertebrate predator), fathead minnows, northern redbelly dace, and pike in 1992 through 1994. Changes in food web relationships in these lakes were monitored using stable carbon and nitrogen isotope analyses of invertebrates (including monthly samples of zooplankton and *Chaoborus*) and fishes. Biotic concentrations of several persistent organochlorines and Hg were also measured over this period; results for a main metabolite of DDT, *p,p*'-DDE, are reported herein.

From the spring to the fall of 1993, weight and lipid content of individual pike increased by two- and three-fold respectively in both lakes, yet their fall tissue concentrations of *p,p*'-DDE, (L110 - 0.84±0.45; L227 - 1.22±0.68 $ng.g^{-1}$ wet weight) were comparable to pike from spring sampling (1.24±0.72). However, mean concentrations of *p,p*'-DDE in pooled minnow samples decreased by up to two times in both lakes after pike additions, and these decreases were not related to changes in fish lipid content. After pike additions, the densities of cyprinids decreased significantly and the mean $\delta^{15}N$ and $\delta^{13}C$ values of these fishes shifted, suggesting a predator-induced change in dietary habits. Fathead minnows from both lakes and northern redbelly minnows from L227 became enriched in ^{13}C and depleted in ^{15}N. This shift was most pronounced in L110 (fatheads $\delta^{15}N_{Spring93}$-$\delta^{15}N_{Fall93}$= ~2‰; $\delta^{13}C_{Spring93}$-$\delta^{13}C_{Fall93}$= ~-7‰). Tissue $\delta^{15}N$ and $\delta^{13}C$ of zooplankton and *Chaoborus* varied considerably over the season, and it was not possible to determine whether this variability was attributable to food web manipulations. Pollutant concentrations in the cyprinids were not consistently related either to their tissue $\delta^{15}N$ or $\delta^{13}C$, suggesting that factors other than changes in food web structure, such as increased growth efficiency due to reduced intraspecific competition, were causing the lower levels of contaminants in these fishes.

Oral Presentation

ON-LINE $\delta^{18}O$ MEASUREMENT OF ORGANIC AND INORGANIC COMPOUNDS

Barbara E. Kornexl, *Matthias Gehre and Reiner Höfling*

UFZ Umweltforschungszentrum Leipzig-Halle GmbH, Permoserstr. 15, D-04318 Leipzig

The natural oxygen-18 stable isotope abundance can reveal important informations on geographic and biochemical origin of the analyzed compound as well as on climatic conditions and reaction mechanisms during its (bio-)synthesis. Modern on-line techniques for the determination of $\delta^{18}O$-values have been limited to organic compounds so far [1-3]. For the $\delta^{18}O$ measurement of inorganic substances still laborious and time-consuming off-line techniques are used, as was shown by recent papers on sample preparation and isotope ratio measurement of nitrate [4, 5].

A universal method for the automated sample conversion and on-line oxygen isotope ratio determination has been developed using an elemental analyzer directy coupled to an IRMS. CO is produced by a sudden high temperature pyrolysis in a helium carrier gas stream. The method is applicable for organic and inanorganic compounds, as will be shown for carbohydrates, nitrates and sulfates. Calibration of the system was performed by measuring standard materials from different laboratories. First results for $\delta^{18}O$-values of some organic and inorganic international reference materials will be presented. A standard deviation of better than 0.5 ‰ has been observed.

1. Werner RA, Kornexl BE, Roßmann A, Schmidt H-L: Anal. Chim. Acta 319 (1996) 159-164
2. Koziet J: J. Mass Spectrom. 32 (1997) 103-108
3. Farquhar GD, Henry BK, Styles JM: Rapid Comm. Mass Spectrom. 11 (1997) 1554-1560
4. Revesz K, Böhlke JK, Yoshinari T: Anal. Chem. 69 (1997) 4375-4380
5. Bräuer K, Strauch G: Annual Meeting German Stable Isotope Community, Oct. 6-8, 1997, Proceedings

Oral Presentation

STABLE ISOTOPE DIFFERENTIATION OF MARINE AND CONTINENTAL FOOD WEBS IN THE ARCTIC

H. Roy Krouse[1], *R. Harrison[2] M.A. Katzenberg[2], W.W. Nassichuk[3], J.E. Motz[4], D.M.Schell[5], N.K.Vereschagin[6],*

[1]Dept. of Physics and Astronomy, University of Calgary, Calgary, Alberta, Canada, T2N 1N4 krouse@acs.ucalgary.ca
[2]Dept. of Archaeology, University of Calgary, Calgary, Alberta, Canada, T2N 1N4
[3]Geological Survey of Canada (Calgary), 3303 -33rd. St.NW., Calgary, Alberta, T2L 2A7
[4]Dept. of Earth Sciences, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1
[5]Institute of Marine Science,University of Alaska, Fairbanks, Alaska, USA 99775
[6]Zoological Institute, Russian Academy of Sciences, 1, University Embankment, 199034, St. Petersburg, Russia

C, N, S, and O isotope abundances were determined as appropriate for sporadically obtained specimens at different trophic levels in Arctic locations. The isotope composition of all 4 elements proved diagnostic of the relative amounts of marine and continental dietary components.

Most data were obtained for hair, flesh, and feathers with one study addressing the C and N isotope composition of collagen extracted from bones. The hair of most land animals had $\delta^{13}C$ values near $-24^0/_{00}$. Polar bears had higher values, near $-14^0/_{00}$ consistent with consumption of seals and lower members of the marine web. The $\delta^{13}C$ values of salmon flesh fall between marine and continental distributions, with some overlap with freshwater fish presumably reflecting its life cycle in both riverine and oceanic environments. The $\delta^{13}C$ values for grizzly bears were found to be slightly less negative than those of black bears but significantly more negative than those of polar bears. This implies a dominantly continental diet for the former.

Polar bears have $\delta^{34}S$ values from +16 to $+18^0/_{00}$ because of seals in their diet. Lower $\delta^{34}S$ of values flesh and trace -S in teeth of salmon also reflect a minor continental component. Continental animals and birds, as well as freshwater fish, were found to have $\delta^{34}S$ values lower than $+10^0/_{00}$ with a mean value near $0^0/_{00}$. As expected, the continental sulphur isotope composition is very dependent upon locality because of lithospheric weathering and possibly atmospheric pollution. In all likelihood as more data are obtained, the $\delta^{34}S$ ranges for many species will be as large or larger than the $20^0/_{00}$ found for moose. Silver Tip variety grizzly bears in the Peace River area of northwest Alberta had $\delta^{34}S$ values near $0^0/_{00}$ consistent with the lack of consumption of significant amounts of salmon.

Whereas the $\delta^{34}S$ values for salmon are closer to the marine range, the $\delta^{13}C$ values are closer to continental values. This probably reflects the higher concentrations of sulphur in marine as compared to freshwater food webs. For example, at a river mouth, mixtures of equal volumes of fresh and ocean water would contain mainly oceanic SO_4^{2-} with $\delta^{34}S$ values approaching $+20^0/_{00}$.

The $\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$, and $\delta^{18}O$ values for baleen sampled at 2cm intervals from an 8.4m Bowhead whale all exhibited similar temporal variations. Coincident minima were interpreted as representing periods with higher continental dietary components as would be realized feeding in the vicinity of the Mackenzie River discharge area.

C, N, and S isotope data were obtained from hair from the mammoth "graveyard" collection on the Berelekh River, a tributary of the Indigirka River, Russia. The geological age determined for a tusk was 12, 240± 160y and for ligaments and skin, 13,700 ± 400y. The average $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ values of -23, + 4.6, and $5.5^0/_{00}$ respectively attest to their continental environment. The $\delta^{13}C$ and $\delta^{15}N$ values are almost identical to those found for muskox hair in the high Canadian Arctic. $\delta^{34}S$ values differed by $10^0/_{00}$ presumably relating to geological weathering. This study also suggests that the isotope composition of hair in some environments can remain unchanged for thousands of years.

Oral Presentation

SPATIAL AND TEMPORAL VARIATION IN MeHg TRANSFER IN LAKES: EFFECTS OF DIEL VERTICAL MIGRATION BY INVERTEBRATE PREDATORS

P.R. Leavitt[2]*, Kidd*[1]*, K.A., M.D. Graham*[2]*, and R.H. Hesslein*[1]

[1]Department of Fisheries and Oceans, Freshwater Institute, Winnipeg, MB, R3T 2N6;
[2]Limnology Laboratory, Department of Biology, University of Regina, Regina, SK, S4S 0A2.

The cladoceran Leptodora kindtii is a large (18 mm), transparent predator common in unstratified eutrophic lakes. We hypothesized that transparency is insufficient protection from predation by zooplanktivorous fishes and that large Leptodora should undergo diel vertical migration (DVM) to reduce mortality. Methylmercury (MeHg) bioaccumulates through the food chain and tends to be higher in predatory than non-predatory organisms. We hypothesized that adult Leptodora occupied a higher trophic position and had higher MeHg concentrations than juveniles, and that fish exposure to MeHg is therefore dependant upon the magnitude of DVM and relative availability of large Leptodora. To investigate these hypotheses, the vertical distribution, size-structure, and sex ratios of Leptodora populations were quantified using discrete samples on three dates in Katepwa and Buffalo Pound lakes (Qu'Appelle Valley, Saskatchewan, Canada). Additional animals from each site were collected by net-tow, sorted by sex and age, and analyzed for stable N isotope ratios ($\delta^{15}N$), body pigments and MeHg contents.

In 22 m-deep Katepwa Lake, both adult and juvenile Leptodora remained two trophic levels ($\delta^{15}N$ 12-16‰) above particulate organic matter (POM; $\delta^{15}N$ 5-8‰) and densities increased throughout the summer. On all dates, juvenile Leptodora were evenly distributed throughout the water column. In contrast, most adults underwent direct DVM; these animals were located near lake-bottom during the day, and exhibited migration intensity proportional to body size. In contrast, in 4 m-deep Buffalo Pound the densities of Leptodora declined through the summer, while their trophic positions increased from herbivores ($\delta^{15}N_{Lept}$-$\delta^{15}N_{POM}$ = ~4‰) to carnivores (~8‰). Neither lifestage exhibited DVM. Results from MeHg analyses will be discussed in context with observed differences in DVM and Leptodora densities between lakes. Survey data suggest that fish exposure to bioaccumulating pollutants may vary substantially due to diel and seasonal changes in prey density and food-web structure.

Poster Presentation

APPLICATIONS OF DUAL-ISOTOPES TO STUDIES OF CARBON FLUXES IN FOREST ECOSYSTEMS

Guanghui Lin

Lamont-Doherty Earth Observatory and Biosphere 2 Center of Columbia University,
PO Box 689, Oracle, Arizona 85623, USA

Applications of stable isotopes at their natural or enriched abundance are providing new insights into ecophysiological processes, community interactions, and ecosystem functions. During last two decades, dual-isotope technique (i.e. using two stable isotopes simultaneously) was frequently applied to study complex ecological processes in terrestrial and marine ecosystems, especially the responses of ecophysiological, community and ecosystem processes to global environmental changes. In this study, we applied the dual stable isotope approach to investigate the impact of elevated atmospheric CO_2 (200ppmv above ambient) and elevated air temperature (4^oC above ambient) on major components of soil respiration in the sun-lit and environmentally-controlled terracosms with 4-year-old Douglas fir seedlings and reconstructed forest soils. In a two-year period, we measured seasonably the soil CO_2 efflux rates, the carbon isotope ratios of possible carbon sources, the oxygen isotope ratios of possible water sources and the carbon and oxygen isotopic compositions of soil-respired CO_2 in these experimental microcosms. Since there were significant differences in isotopic compositions among three possible carbon sources for soil respiration, we had to use oxygen isotopes at the same time to estimate quantitatively the relative contribution of rhizosphere respiration, litter decomposition and soil organic matter (SOM) oxidation to the overall soil respiration. Our results indicated that rhizosphere respiration and litter decomposition increased under both elevated CO_2 and elevated temperature, while SOM oxidation was affected only by increasing temperature. Release of newly-fixed carbon as rhizosphere respiration is the most responsive component to elevated CO_2, but SOM oxidation is the most responsive one to increasing temperature. The results from this case study and others clearly demonstrate that applications of the dual-isotope technique can yield new insights into ecological processes than using only a single isotope.

Poster Presentation

BIOGEOCHEMICAL CHARACTERISTICS OF PEAT SWAMP FORESTS IN THAILAND INFERRED FROM CARBON AND NITROGEN STABLE ISOTOPE ANALYSES

Takeshi Matsubara[1], *Eitaro Wada*[2], *Narin Boontanon*[2], *Shigo Ueda*[3]

[1]The College of Cross-Cultural Communications and Business, Shukutoku University, Japan
[2] Center for Ecological Research, Kyoto University, Japan
[3] National Institute for Resources and Environment, Japan

There are wide areas of peat swamp forest in Narathiwat, the southern part of Thailand. Specific fauna and flora matter cycle pattern are kept in the areas. However, recent land development at the areas caused destruction of the forests. We applied carbon and nitrogen stable isotope analyses to provide basic understandings of carbon and nitrogen cycles at the forest and surrounding areas. The results suggested that inorganic nitrogen in precipitation is a major source for organisms at the peat swamp forests. The effect of nitrogen fixation and NH_3 volatilization is low in the area due to low pH (4-5) of the swamp water. Whereas denitrification activity increased gradually along hill site (low) to river mouth (high). Higher nitrogen isotope ratios at natural forests ($\delta^{15}N$; ca. 2 ‰) suggested that denitrification activity is higher at the NF than at the secondary forests (SF) (ca. –5 – 0 ‰). Carbon isotope values suggested that photosynthetic activity is higher at SF ($\delta^{13}C$; ca. –28 ‰) than at NF (ca. –32 ‰). Fluctuation of carbon isotope ratios is affected primarily by vertical depression of light intensity at NF, and differences in photosynthetic activity depending on leaf longevity at SF.

Poster Presentation

ISOTOPE EFFECTS DURING MICROBIAL CONVERSIONS OF ORGANIC SULFUR COMPOUNDS IN SOILS

B. Mayer[1*]*, C. Heinzer*[1]*, and K. Knief*[2]

[1]Ruhr-Universität Bochum, Institut für Geologie, Bochum, Germany
[2]UFZ Umweltforschungszentrum Halle Leipzig GmbH, Leipzig, Germany
*present address: University of Calgary, Department of Physics and Astronomy, 2500 University Drive NW, Calgary, AB, Canada T2N 1N4, bernhard@earth.geo.ucalgary.ca

Biological processes play an important role in the sulfur cycle of terrestrial and aquatic ecosystems. All four major sulfur transformation reactions, (1) oxidation, (2) reduction, (3) immobilization, and (4) mineralization are usually microbially mediated. The isotope fractionation patterns during inorganic sulfur transformations such as sulfide oxidation or dissimilatory bacterial sulfate reduction are reasonably well understood. In contrast, there is little information available in the literature on isotope effects during processes, which involve organic sulfur compounds. The objective of this study was to determine the extent of sulfur isotope fractionation during the conversion of organic sulfur compounds into inorganic sulfate (mineralization) in forest soils.

In two laboratory experiments, forest floor horizons with sulfur contents between 0.1 and 0.2 %, nearly exclusively in organic binding form, were irrigated repeatedly with deionized water of different oxygen isotopic composition. Significant amounts of inorganic sulfate, which were observed in the regularly collected soil seepage water, were obviously generated by mineralization reactions, since the forest soils contained hardly any inorganic sulfur compounds. The seepage water sulfate was precipitated as $BaSO_4$ and analyzed mass spectrometrically for sulfur and oxygen isotope abundance ratios. Also, the $\delta^{34}S$ values of various soils sulfur compounds were determined before and after the experiment.

Differences in the oxygen isotope compositions of the newly formed sulfate were used to evaluate whether (1) hydrolysis of organic sulfates or (2) mineralization of carbon-bonded sulfur predominantly occurred. The extent of sulfur isotope fractionation accompanied with these two processes was determined by comparing the $\delta^{34}S$ values of the seepage water sulfate with those of the various organic soil sulfur compounds. The obtained results indicate that the microbial oxidation of carbon-bonded sulfur to inorganic sulfate (mineralization) proceeds with no significant isotope fractionation. In contrast, hydrolysis of organic sulfates seems to be accompanied by noticeable isotope selectivity favoring the lighter ^{32}S in the newly formed sulfate. These results might proof useful in forthcoming isotopic studies of the sulfur cycle, since the mineralization and hydrolysis of organic sulfur compounds is an important source of aqueous sulfate in most terrestrial and aquatic ecosystems.

Poster Presentation

δ^2H AND $\delta^{18}O$ OF PLANT AND SOIL WATER IN A SUBTROPICAL SAVANNA PARKLAND: VERTICAL STRATIFICATION OF SOIL WATER ACQUISITION AND PLANT RESPONSE TO RAINFALL.

A.J. Midwood*, *T.W. Boutton, and S.R. Archer.*

Dept. Rangeland Ecology and Management, Texas A&M University, College Station TX, 77843-2126, USA, and *Macaulay Land Use Research Institute, Craigiebuckler, Aberdeen, AB15 8QH, Scotland, UK.

In subtropical savanna parklands of southern Texas, upland portions of the landscape are characterised by a two-phase vegetation pattern consisting of clusters of woody vegetation embedded in a matrix of grasses and herbaceous dicots. These uplands grade into low-lying, densely-wooded drainages and playas. The development of upland tree-shrub clusters within the grassland matrix is initiated by establishment of the tree-legume, *Prosopis glandulosa* var. *glandulosa* Torr., which subsequently facilitates the establishment of other understory shrub species. These woody plant clusters may expand laterally and fuse, forming larger groves. Similar successional processes appear to have yielded the woodlands in lower-lying landscape positions.

We hypothesized that coexistence of tree/shrub species in these highly diverse wooded landscape elements may be at least partially enabled by vertical stratification of root distribution and/or function, thereby reducing belowground competition for water and nutrients. The natural abundances of ^2H and ^{18}O in plant and soil water were used to test the hypothesis that tree/shrub coexistence is mediated by vertical partitioning of soil water uptake. In addition, the plasticity of these vertical patterns of soil water use by plants was examined following an isotopically unique rainfall event.

The dominant grass species in this landscape had the highest δ^2H and $\delta^{18}O$ stem water values, indicating that it utilized primarily near-surface (< 0.25 m) soil water. In contrast, *Prosopis* had the lowest δ^2H and $\delta^{18}O$ stem water values of all species in all landscape elements, indicating that it relied on deeper (0.5-3.0 m) soil water. Thus, the ability of this tree to colonize grasslands may be facilitated by its use of deeper soil water, thereby minimizing competition with herbaceous species. The co-dominant shrub in wooded landscape elements, *Zanthoxylum fagara*, generally had δ^2H and $\delta^{18}O$ stem water values significantly greater than those of *Prosopis*, indicating that this species relied primarily on surficial soil water (< 0.5 m). Thus, the two dominant woody plant species in this landscape, *Prosopis* and *Zanthoxylum*, acquire soil water from different portions of the soil profile.

δ^2H and $\delta^{18}O$ of stem water in all plants increased by +16 and +3‰, respectively, in response to 30 mm of rainfall (weighted δ^2H = -0.44‰ and $\delta^{18}O$ = -1.04‰). Prior to the rainfall, most species appeared to obtain water from below 0.5m in the profile. However, within 48 hrs after the rain, all plant species shifted their zones of water uptake to above 0.25 m in the profile, indicating that these species optimize soil water uptake strategies rapidly to acquire surficial soil water present following rainfall.

Ongoing work seeks to further elucidate patterns of soil water acquisition and partitioning between species in order to better understand plant-soil-climate relationships and successional processes in this region.

Oral Presentation

A STABLE ISOTOPE ($\delta^{13}C$, $\delta^{15}N$) BASED QUANTITATIVE ASSESSMENT OF THE IMPACT OF LAND BASED DISCHARGES OF ORGANIC MATTER AND TRACE METALS ON THE SEDIMENT CHARACTERISTICS IN TABLE BAY, CAPE TOWN.

Monteiro, Pedro M.S. *and Woodborne, S.*

Council for Scientific and Industrial Research, PO Box 320, Stellenbosch 7599, South Africa.
(Email: pmonteir@csir.co.za)

The study set out to verify whether, four years after the commissioning of the lengthened Green Point outfall, that the hypothesis:

"Sewage discharged into Table Bay through the Green Point and Camps Bay outfalls has had an insignificant medium to long term environmental impact as reflected by the biogeochemical composition of the sediments."

still held.

The approach was to use stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) as tracers for the source of the organic matter in the sediments. This was complemented with a suite of 4 trace metals (Copper, Cadmium, Lead and Mercury) as tracers of the impact of the industrial component of the land based effluents. The aim of this combined approach was to link the measured trace metals in the sediments to specific inputs.

The results confirmed earlier predictions that land derived organic matter in general and sewage in particular play a minimal role in the total organic load of the sediments in Table Bay. The bulk of the organic matter in the sediments is of natural marine origin linked to the Benguela upwelling system. The bulk of the terrestrial organic matter in the sediments of Table Bay originated from the outflows of both the Diep and the Salt rivers along the eastern margin. The importance of this finding is that the management of water quality in those systems will play a key role in maintaining the environmental and ecological quality of the far field in Table Bay.

Trace metal distributions in the sediments were mainly and predictably correlated to the changes in the percentage of very fine sand and organic content. The exceptions were the elevated concentrations along the nearshore between Granger Bay and Camps Bay which appear to be linked to storm water outflows. The results also point specifically to the refinery outfall as being a source of Cadmium contamination in the near field sediments. This highlighted storm water quality as a source of concern due to its clear near field (< 500m) impact along the terrestrial margins of the Bay. This impact is important due to its relevance to the safety of marine resources such as filter feeders for human consumption. Monitoring and control of the quality of these effluents should be a priority.

Oral Presentation

APPLICATION OF EA PYROLYSIS-IRMS $\delta^{18}O$ ANALYSES AS A NEW TOOL TO EVALUATE ANIMAL MIGRATION PATTERNS

John Morrison[1], *Francois Fourel*[1], *Len Wassenaar*[2], *and Keith Hobson*[2]

[1]Micromass UK Ltd , Floats Road, Wythenshawe , Manchester M23 9LZ UK, Tel 44 161 7184 611, Fax 44 161 998 89 15, e-mail john.morrison@micromass.co.uk
[2]Environment Canada, 11 Innovation Blvd., Saskatoon, SK

A Carlo Erba NA-1500 elemental analyser was interfaced to an Micormass Optima stable isotope ratio mass spectrometer configured in continuous flow oxygen pyrolysis mode.

The $\delta^{18}O$ isotope values of wings from monarch butterflies and feathers from several migrant songbird species from different sites across North America were measured using the on line $\delta\ ^{18}O$ pyrolysis technique. The results of the measurements and how they correlate both to the previously measured hydrogen isotope signature of the samples and the localised oxygen and hydrogen isotope signature of the rainwater at the collection sites will be discussed.

The new $\delta^{18}O$ pyrolysis method will be described in terms of the experimental set-up and the results of a number of evaluation studies. The evaluations studies were aimed at resolving basic questions such as yield characteristics from different sample types, linearity of measurement with respect to sample size, and accuracy of measurement associated with the technique.

Poster Presentation*

THE EFFECTS OF ACID WASHING AND LIPID EXTRACTION ON THE SIMULTANEOUS ANALYSIS OF CARBON AND NITROGEN ISOTOPES IN BENTHIC MACROINVERTEBRATES

***J.P. Neary*[1]*, J.M. Culp*[2]*, K.A. Hobson*[3]*, and L.I. Wassenaar*[2].**

[1]Department of Biology, University of Saskatchewan, Saskatoon, SK, Canada S7N 0W0; [2]National Hydrology Research Institute, Environment Canada, 11 Innovation Blvd. Saskatoon, SK, Canada S7N 3H5; [3]Prairie and Northern Wildlife Research Center, Canadian Wildlife Service, Saskatoon, Saskatchewan, Canada S7N 0X4

Measurements of stable carbon and nitrogen isotope values of food web components has recently emerged as an important analytical tool. With the advent of on-line continuous-flow isotope-ratio mass spectrometry (CF-IRMS) both stable carbon and nitrogen isotopes can be measured on individual samples. However, off-line sample preparation techniques developed for dual inlet isotope analysis may be inappropriate for on-line simultaneous isotopic analysis. Acid washing and lipid extraction are commonly used in carbon isotopic studies to remove inorganic carbon and reduce sample variability, respectively. There is concern that these procedures might alter the stable-nitrogen isotope values which may influence the ecological interpretation of these data. Our objectives were to determine whether acid washing and lipid extraction would alter the stable-isotope values generated from the on-line analysis of carbon and nitrogen isotopes. Caddisfly larvae (*Hydropsychidae sp*.) were sampled from the Bow River near Calgary, Alberta, Canada in December 1996 and July 1997. They were exposed to one of four treatments which included, 1) lipid extraction, 2) acid washing, 3) lipid extraction & acid washing and 4) neither treatment (Control). The acid treatment involved exposing the caddisfly larvae to a 0.1 N solution of HCl for approximately 10 minutes. Lipids were extracted by repeatedly exposing ground larval tissue to a 2:1 Chloroform:Methanol solution. Preliminary results indicate that lipid extraction may be responsible for differences found between treatments for stable-nitrogen isotopes. Stable-nitrogen isotope analysis is used for trophic positioning and any methodological artifacts could confound food web interpretation. As a result, lipid extraction should be used only when lipid content is suspected or determined to be highly variable. Alternatively, lipid extraction techniques should be developed in which the stable-nitrogen isotope signatures are not altered.

Oral Presentation

VARIABILITY IN THE C ISOTOPE COMPOSITION OF SELECTED VOCS IN AN URBAN ENVIRONMENT.

***Norman, A.L.**, Hopper, J.F., J. Rudolph, D.E. Ernst, E. Czuba, and B. Keiser*

The stable isotope composition of compound-specific volatile organic compounds (VOCs) may prove valuable in distinguishing natural natural and anthropogenic VOC emissions in urban and rural ecosystems. VOCs are released to the atmosphere by a variety of geological, natural (principally vegetation), and anthropogenic sources. A study of $\delta^{13}C$ values of VOCs in urban and rural settings in New Zealand have shown that distinct carbon isotope compositions are associated with each location (Rudolph *et al*. 1997).

Concentrations, peak identification, and isotope compositions of selected non-polar C_5-C_8 gases from a rooftop sampling site in Toronto, Ontario were determined over a diurnal cycle. Measurements were made using an combination of an Ion Trap coupled to a CF-IRMS. Concentrations ranged from below detection limits to more than 10 ppb and $\delta^{13}C$ values varied between -23 and -48 ‰. Additional samples were collected in a parking garage, a roadway tunnel, and at a gasoline station for comparison.

The precision of $\delta^{13}C$ measurements was compound dependent, ranging from 0.5 to 2 ‰. Online $\delta^{13}C$ measurements of individual VOCs were within 0.8 ‰ of offline determinations. Temporal variations in $\delta^{13}C$ values for specific compounds in ambient air were greater than measurement uncertainties. For example the $\delta^{13}C$ determinations for pentane ranged from -26.1±0.8 to -30.7±0.8 ‰.

Rudolph, J., Lowe, D.C., Martin, R.J., Clarkson, T.S. (1997) A novel method for compound specific determination of $\delta^{13}C$ in volatile organic compounds at ppt levels in ambient air. Geophys. Res. Lett. **24**, 659-662.

Poster Presentation

STABLE NITROGEN AND CARBON ISOTOPIC COMPOSITION OF SESTON AND SEDIMENT IN TWO ADIRONDACK LAKES

***J.S.Owen**, M.J.Mitchell, and R.H.Michener*

SUNY College of Environmental Science & Forestry, Syracuse, NY
Boston University, Boston, MA

In two Adirondack lakes that differed in nitrate concentration, natural abundance seston $\delta^{15}N$ and $\delta^{13}C$ values were compared during 1992 and 1993. Sediment $\delta^{15}N$ profiles were also compared. In Arbutus Lake, seston $\delta^{15}N$ averaged 2.5 (SE=0.18) and 2.7 (SE=0.15) and 2 and 6 metres depth, respectively. In Dart's Lake, seston $\delta^{15}N$ averaged 1.3 (SE=0.12) and 1.1 (SE=0.07) at 6 and 14 metres depth, respectively.

In the epilimnion of Arbutus Lake, nitrate concentrations were generally low (range 0 to 13 ueq/L) with decreased nitrate concentration during the summer period; seston $\delta^{15}N$ and water column nitrate concentration were inversely correlated ($r = -0.82$, $p = .011$). In Dart's Lake, where nitrate concentrations were higher (range 12.9 to 22.4 ueq/L) and the magnitude of spring summer nitrate depletion lower, there was no significant correlation between seston $\delta^{15}N$ and nitrate concentration. Sediment $\delta^{15}N$ profiles in the two lakes also showed different patterns, with sediment in Dart's Lake having a much larger decrease with depth in $\delta^{15}N$ than Arbutus Lake. These results suggest a number of similarities between the processes controlling the distribution of stable nitrogen isotopes in freshwater and marine systems.

Poster Presentation*

STABLE-CARBON AND NITROGEN ISOTOPE DYNAMICS IN PLASMA AND MILK OF FEMALE POLAR BEARS AND THEIR CUBS

Susan C. Polischuk [1], *Keith A. Hobson*[1,2], *Malcolm A. Ramsay*[1]

[1] Department of Biology, University of Saskatchewan,
Saskatoon, Saskatchewan, Canada S7N 5E2
[2]Prairie and Northern Wildlife Research Centre, 115 Perimeter Road,
Saskatoon, Saskatchewan, Canada S7N 0X4

We measured stable-carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope ratios in plasma and milk proteins and lipids from female polar bears (*Ursus maritimus*) and plasma in cubs to 1) use isotopic shifts in cub plasma to trace their relative use of mother=s milk and seals prior to independence, and 2) determine the effect of seasonal fasting on $\delta^{13}C$ and $\delta^{15}N$ values in adult female bear plasma. Stable-nitrogen-isotope analysis of plasma showed that cubs-of-the-year (COYs) in spring were enriched over their mothers (mean cub $\delta^{15}N$ = 21.5 λ *vs*. 20.5 λ for mothers) when milk was their only food source. Once the cubs had access to seals, the plasma $\delta^{15}N$ values for mother and cub converged during the time of weaning, although $\delta^{15}N$ values for both adults and cubs shifted during the year. Stable-carbon-isotope-ratios in plasma also shifted by season and were correlated with the $\delta^{15}N$ shifts. The cub plasma $\delta^{13}C$ values were similar to $\delta^{13}C$ milk protein values but significantly enriched compared with $\delta^{13}C$ milk lipid values. The effect of seasonal fasting on $\delta^{15}N$ and $\delta^{13}C$ values in polar bear plasma was dependent on the time of year and length of fast. For bears that fasted between summer and fall, plasma values became depleted in $\delta^{13}C$ by 0.5 λ and less enriched in $\delta^{15}N$ by 1λ. Plasma from pregnant females, who fasted from summer to spring, became more enriched in $\delta^{13}C$ and $\delta^{15}N$ by 0.7λ and 2λ, respectively. Bears on the sea ice in spring had similar isotopic signatures to females that had undergone a 7-8 month fast, suggesting that bears on sea ice in spring are utilizing their muscle mass as an energy source. Longitudinal samples of bears during the fasting period showed variable $\delta^{13}C$ and $\delta^{15}N$ values and did not demonstrate any predictable patterns, although mothers and cubs tended to follow the same trend. This variability in stable-isotope values during the fasting period may be due to the differential ability of bears to minimize protein loss during extended fasts, a factor dependent on the magnitude of fat stores accumulated prior to fasting. Our study shows that stable isotope analysis can be used effectively to describe different feeding patterns within a species and to monitor the onset of weaning when isotopically discreet dietary alternatives are available to neonates. Stable-carbon and nitrogen isotope analyses also allowed us to determine how individual bears utilized their adipose and protein reserves during fasting.

Oral Presentation*

WHEN WHALES LEFT THE BEACH: ISOTOPIC INSIGHTS INTO A PHYSIOLOGICAL TRANSITION IN THE FOSSIL RECORD

***Lois J. Roe*[1], *J.G.M. Thewissen*[2], *Jay Quade*[3], *James R. O'Neil*[4], *Sunil Bajpai*[5], *Ashok Sahni*[6], *S. Taseer Hussain*[7]

[1]Department of Geosciences, University of Arizona, Tucson, AZ 85721 USA
[2]Department of Anatomy, Northeastern Ohio Universities College of Medicine, Rootstown, OH 44272 USA
[3]Desert Laboratory and Department of Geosciences, University of Arizona, Tucson, AZ 85721 USA
[4]Department of Geological Sciences, University of Michigan, Ann Arbor, MI 48109 USA
[5]Department of Earth Sciences, University of Roorkee, Roorkee 24667, INDIA
[6]Centre for Advanced Studies in Geology, Panjab University, Chandigarh 160-014, INDIA
[7]Department of Anatomy, Howard University College of Medicine, Washington, D.C. 20059 USA

The transition of the earliest cetaceans (archeocetes) from terrestrial to marine life involved not only the evolution of novel locomotory and acoustic systems, but required physiological innovations as well. The ability to dispose of excess ions associated with either incidental or deliberate ingestion or uptake of seawater was probably prerequisite to the transoceanic dispersal of whales in the middle Eocene. Locomotory and acoustic adaptations are studied through the morphology of fossils, but physiological transitions have no morphological correlates. Here we present an isotopic study of the physiological transition of the earliest whales, designed to determine when whales began to ingest seawater (either incidentally or deliberately) and eat marine prey. Our approach involves the determination of oxygen isotope compositions of the phosphate (PO_4^{3-}) and the carbon isotope compositions of the carbonate (CO_3^{2-}) of the teeth and bones of modern and Eocene cetaceans. This comparative approach provides otherwise unobtainable insights into a freshwater to marine physiological transition in the fossil record.

Changes in the carbon isotope compositions of the structural carbonate ($\delta^{13}C_{SC}$) and the oxygen isotope compositions of the phosphate ($\delta^{18}O_P$) of archeocete fossils from lower values in the early Eocene to higher values in the middle Eocene record the transition of early cetaceans to a fully marine life. Although this transition was geologically rapid, its fine structure was not simple but mosaic. The earliest cetaceans, *Ichthyolestes*, *Nalacetus*, and *Pakicetus*, from the early to middle Eocene lower Kuldana Formation of Pakistan, appear to have relied on terrestrial food and freshwater. The slightly younger cetaceans, *Ambulocetus* and *Gandakasia*, from the upper Kuldana Formation, also relied on terrestrial food, but appear to have been euryhaline with respect to water requirements. *Attockicetus*, from the overlying middle Eocene Kohat Formation, has much higher $\delta^{13}C_{SC}$ values than any of the cetaceans and almost certainly ate marine food, but continued to ingest primarily freshwater. All later cetaceans, with the possible exception of *Andrewsiphius* from the middle Eocene Harudi Formation of Kachchh, India, appear to have been fully marine. *Gaviacetus*, *Indocetus*, and *Remingtonocetus* from the Harudi Formation, and *Georgiacetus* from the middle Eocene McBean Formation of Georgia, all had $\delta^{13}C_{SC}$ and $\delta^{18}O_P$ values consistent with a marine diet and seawater ingestion.

A cetacean osmoregulatory system capable of handling the high concentrations of ions associated with life in the ocean had thus evolved by the middle Eocene. The evolution of this new osmoregulatory system was at least partially decoupled from the transition to a marine diet. This decoupling probably facilitated niche differentiation among early cetaceans, and may help to explain how the evolutionary diversification of cetaceans was able to occur so rapidly.

Oral Presentation

USING GIS AND STABLE ISOTOPES TO CHARACTERIZE FORAGING STRATEGIES FOR WOOD STORKS

Romanek C.S., *Gaines K.F., Bryan L.A. Jr., Brisbin I.L., Gariboldi J.C. and Jagoe C.H.*

Savannah River Ecology Lab, University of Georgia, Drawer E, Aiken, SC 29802

To evaluate the use of feathers in deciphering the foraging strategies if Wood Storks, carbon and nitrogen isotopes were analyzed from down feathers of nestling birds at coastal and inland colonies of the Georgia coastal plain.

Feathers from the inland colonies of Blackwater and Chew Mill have carbon isotope compositions that reflect a purely freshwater source of carbon in the diet while nitrogen isotopes suggest that the food chains are distinct. In contrast, feathers from the coastal colonies are generally enriched in ^{13}C as marine carbon sources contribute significantly to the food web. Variability in the magnitude of enrichment suggests that foraging strategies differ among individuals and between coastal and colonies, with storks from St. Simon Island utilizing a wider range of foraging habitats and food resources than storks from Harris Neck, or the inland colonies.

Predicted foraging strategies were validated by GIS tracking surveys for adult birds and regurgitant analysis of chicks. The foraging range for adult Wood Storks from St. Simon Island was broad and the stomach contents of chicks contained marine and freshwater prey. In comparison, storks form Harris Neck did not travel far for food and stomach contents contained mostly marine prey. From these data, it can be shown that the isotopic analysis provides a cost effective technique for determining foraging strategies when the timing of feather growth is known and distinct natural abundance patterns are expressed in foraging habitats.

Poster Presentation

ANALYSIS OF STABLE ISOTOPE DATA: A K NEAREST-NEIGHBORS RANDOMIZATION TEST

M. N. Rosing[1], M. Ben-David [2], and R. P. Barry [3]

[1]QERM, Center of Quantitative Sciences, University of Washington, Seattle, Washington 98195, USA
[2]Alaska Cooperative Fish and Wildlife Research Unit, University of Alaska Fairbanks, Fairbanks AK 99775, USA
[3]Department of Mathematical Sciences, University of Alaska Fairbanks, Fairbanks AK 99775 - 0660, USA

The use of stable isotope analysis in ecological and wildlife studies is rapidly increasing. Studies include evaluating flow of nutrients in ecosystems and studying dietary composition of individual animals. Several mixing models have been developed to evaluate the relative contribution of different foods to the diet of consumers. All these mixing models require that all prey types will be significantly different in bivariate space. This requirement usually poses a problem in analyzing data of stable isotope ratios because sample sizes in most studies are small and seldom normally distributed. We propose a randomization test that we based on the K nearest-neighbor approach. Results from our simulations of power revealed that the K nearest-neighbor test appears to have high power even with small sample sizes and comparatively low displacement. The K nearest-neighbor test described here provides the preliminary statistical analysis necessary for the use of the mixing models, and therefore is a new powerful tool for analyzing stable isotope data. In evaluating the test performance on data collected from martens and their prey on Chichagof Island, Southeast Alaska, we were able to reject our null hypothesis that all samples of prey were drawn from identical populations ($P = 0.05$). A program written in Pascal or S-Plus is available from the authors to evaluate the K nearest-neighbor statistic for several groups.

Oral Presentation

THE IMPORTANCE OF MARINE FOOD SOURCES TO A CYCLIC POPULATION OF ARCTIC FOXES

James D. Roth

Department of Ecology, Evolution & Behavior, University of Minnesota, St. Paul, MN 55108 USA

Arctic foxes are known to follow polar bears onto the sea ice in winter and scavenge seal carcasses from bear kills, and they also hunt seal pups in birth lairs. Yet the importance of these marine food sources to arctic fox populations has not been conclusively determined. I measured the stable carbon isotope ratios of tissues of arctic foxes harvested by local trappers near Churchill, Manitoba, from 1994 to 1997 to determine the relative importance of marine food sources in the arctic fox diet. I estimated the abundance of arctic foxes each year by den surveys and the density of collared lemmings, their primary terrestrial prey, using standard mark-recapture methods. Substantial variation in fox density was related to fluctuations in abundance of collared lemmings. The carbon isotope signature of fox tissues was significantly more marine in winter than in summer and in years of low lemming density. Contrary to most predator-prey systems, however, fox abundance began to increase before lemming abundance. During this increase marine sources constituted a greater component of arctic fox diet than in other years. Variation in marine productivity, therefore, appears to influence the abundance of this terrestrial predator, especially when their primary prey are scarce. This marine subsidy to arctic foxes could have a negative indirect effect on their terrestrial prey and could alter the predator-prey dynamics of this arctic food web.

Poster Presentation

WHAT DOES A MITE, BITE? INSIGHTS ON CARBON AND NITROGEN MOVEMENT THROUGH SOIL FOOD WEBS UNDER ALTERED CLIMATES

Rygiewicz, P.T.[1]*, E.A. Hobbie*[2]*, A.E. Moldenke*[3]*, and W.L. Griffis*[1]

[1]US Environmental Protection Agency, National Health and Environmental Effects Research Lab, Corvallis OR 97333 USA,
[2]National Research Council, National Health and Environmental Effect Research Lab, Corvallis OR 97333 USA, and
[3]Department of Entomology, Oregon State University, Corvallis OR 97331 USA

The TERA project is a study of the effects of elevated atmospheric temperature and CO_2 levels on tree seedling/soil ecosystem carbon and nitrogen cycles. One component of the study is to understand how below-ground soil food webs interact with changes in primary productivity. Twelve, sun-lit, controlled-environment terracosms were constructed consisting of 14, 2-year-old Douglas-fir seedlings planted in a native old-growth, Douglas-fir forest soil reconstructed by horizon. The 2X2 factorial experiment was begun in 1993 into the interaction of temperature (ambient, and ambient plus 4 C) and CO_2 (ambient, and ambient plus 200 ppm) Two additional terracosms were planted as open (above ground portion not enclosed) controls. To maintain or augment atmospheric CO_2 levels, tank CO_2 of $\delta^{13}C$ -38 was added as needed to the 12 enclosed terracosms. This served as a "natural" tracer, that was used to distinguish between recently-fixed carbon and old, detrital carbon. Soil fauna were surveyed every six months during the 5 above-ground growing seasons of the study. The entire seedling/soil ecosystem was destructively sampled at the conclusion of the experiment (i.e., 1997). We report here some preliminary isotopic analyses and comparisons between the presumed diet of the soil fauna and their isotopic measurements.

Root-feeding weevils (Curculiondae sp.) were very depleted in ^{13}C in terracosms that received tank CO_2. Weevil signatures reflected closely the amount of CO_2 added to each terracosm, indicating its presumably complete reliance on root carbon derived from recently-fixed CO_2. Several fungivorous mites (*Caenobelba*, *Odontodamaeus*, *Jacotella*, *Camisia*, *Eremaeus*, and *Kartoeremaeus*) displayed a significant, negative correlation between ^{13}C and ^{15}N signatures, which probably reflects varying proportions of mycorrhizal (recently-fixed photosynthate) versus saprotrophic (detrital-based) fungi in their diet. Gamasid mites, a predator of nematodes and springtails, were elevated in ^{13}C and ^{15}N. Centipedes (Lithobiomorpha sp.) also had elevated ^{13}C and ^{15}N signatures, reflecting their status as a top predator. These preliminary results suggest that isotopic analyses will be a powerful probe of trophic interactions among soil mesofauna. It appears feasible to separate C and N flows into food webs that originate from roots, mycorrhizal fungi or saprotrophic fungi. Such interactions are difficult to observe among individual species within a trophic level using conventional gut content analyses because of the minute nature of these organisms.

Oral Presentation

FROM ECOLOGICAL PATTERNS TO PROCESSES IN COASTAL WATERS: THE UTILITY OF LIGHT STABLE ISOTOPE TECHNIQUES IN AN ESTUARINE SETTING.

Thomas A. Schlacher[1] *& Tris H Wooldridge*[2]

[1] Department of Biology, University of the South Pacific, Suva, Fiji
[2] Department of Zoology, University of Port Elizabeth, Port Elizabeth, South Africa

Coastal habitats, and in particular estuarine ecosystems, are characterised by large environmental variability which to varying degree propagates to population-, community- and ecosystem fluctuations in time and space. Consequently, extracting patterns and processes by traditional techniques may often be masked by high variance (i.e. noise). Using chemical tracers which integrate process information over time may provide one a way to lower the ecological signal to noise ratio. In this study, the suitability of light stable isotope tracers was evaluated to extract patterns and process information at three different levels of ecological organisation: (1) seasonal shifts in the biochemical composition of emergent macrophytes tied to growth cycles (individual organism level). (2) utilisation of detritus by benthic macrofauna assemblages and gradients in trophic niche shifts (population to community level). (3) pathways of detritus flow in the ecosystem (ecosystem level). Macrovegetation fringing the estuary showed pronounced seasonal changes in their biochemical make-up which were coupled to annual growth dynamics. Senescence during autumn and winter halved the plants' nitrogen content and significantly lowered tissue $\delta^{15}N$ ratios; carbon ratios were not affected with $\delta^{13}C$ remaining constant irrespective of growth stage. Benthic macrofauna relied mostly on microalgal primary production, with detritus signals not detectable in presumed "detritivores". However, at any given site, ghost-shrimp populations in the high intertidal were more likely to switch to benthic feeding during emergence while their conspecifics of the lower shore are predominately suspension feeders. Such trophic niche shift along the intertidal gradient was indicated by corresponding shifts in $\delta^{13}C$ ratios. Our findings challenge the conventional wisdom of the prevalence of detritus pathways in estuarine ecosystems, which might instead revolve more tightly around microalgal primary production.

Oral Presentation*

INTEGRATING ECOLOGY AND ARCHAEOLOGY: RECONSTRUCTING PREHISTORIC HUMAN DIET IN AN ARID COASTAL ENVIRONMENT

Theresa M. Schober

Department of Anthropology, University of Florida, Gainesville

Stable isotope analysis in archaeology is a valuable tool for investigating the relative contribution of marine and terrestrial food resources to the diets of prehistoric peoples. In the cape region of Baja California Sur, explorers' chronicles and mission records provide evidence for diet during contact times. These records describe a population using a nomadic foraging and fishing lifestyle to survive in the harsh aridity of the peninsula. The task of palaeodietary reconstruction in this region presents interesting challenges. Preliminary data disclose some of the most enriched nitrogen isotope ratios in bone collagen reported for any prehistoric population in the world. The traditional explanation for such high nitrogen isotope ratios is marine dependence. However, this explanation, contradicts both the technological capabilities, as assessed from the archaeological record, and the high frequency of dental caries in pre-contact populations.

Many researchers have suggested mechanisms by which consumer tissues could physiologically inflate nitrogen isotope ratios under arid conditions. Prior to investigating potential physiological factors, isotopic variation due to environmental influences at the producer level must be established. The documentation of nitrogen isotope ratios at each trophic level in the terrestrial and marine foobwebs of the cape region is in process to identify alternative sources of isotopic enrichment. The results of an investigation of edible cactus species collected along coastal to highland transects from the Pacific and Gulf coasts of the peninsula indicate that carbon isotope ratios are relatively stable but intraspecific variation in nitrogen isotope values is great. This variation in nitrogen isotope ratios is discussed in terms of soil chemistry, altitude, and proximity of the plants to the coastline.

The inclusion of baseline foodweb isotope data in archaeological investigations is not yet standard practice. The present study demonstrates that it is an essential step in making accurate dietary interpretations from stable carbon and nitrogen isotope ratios of prehistoric human bone.

Poster Presentation

THE SEASONAL CHANGES OF CARBON AND NITROGEN STABLE ISOTOPIC SIGNATURES THE EASTERN BASIN OF LAKE ERIE.

M.R. Servos[1]*, M. Leggett*[1]*, M. Burley*[2]*, R. Hesslein*[3]*, O. Johannsson*[2]

[1]National Water Research Institute, Environment Canada,[2]Great Lakes Laboratory for Fisheries and Aquatic Sciences, [3]Freshwater Institute, Department of Fisheries and Oceans, Winnipeg, Manitoba.

The season variability of the isotopic signatures of carbon and nitrogen in plankton can be very large and influence the interpretation of results at higher levels in the food web if not taken into account. The stable isotopic signatures of carbon and nitrogen were followed in the plankton community June 18 and Nov 8 1994 in the eastern basin of Lake Erie. Individuals of the most abundant zooplankon species were hand picked as well as specific size classes separated for analysis. The carbon isotopic signature of individual zooplankton species varied by 2 to 4 λ and generally increased gradually in all species and fractions over the course of the summer by approximately 2λ. Signatures of nitrogen also increase gradually over the summer in most species of zooplankton. There was a clear separation between herbivorous *Bosmina* and *Daphn*ia and the predacious *Bythotrephes* and *Epischuria* which had signatures 3-4λ higher consistently through the season. The range in isotopic signatures of carbon seen in both phtyoplakton and zooplankton over the summer general encompasses the values measured in several species of fish and invertebrates (-20 to -26 λ) collected at the sites, but were outside those measured in aquatic plants (-16 to 18 λ). Both nitrogen and carbon stable isotopic signatures are effective tools to understand the food web interactions in this complex ecosystem.

Oral Presentation

USE OF STABLE ISOTOPES TO DETERMINE ORIGIN OF DRIFTING ORGANIC MATTER IN THE COLORADO RIVER DURING THE 1996 SPIKE FLOW FROM GLEN CANYON DAM THROUGH GRAND CANYON NATIONAL PARK

Joseph P. Shannon, *Dean W. Blinn, Peggy L. Benenati and Kevin P. Wilson*

Northern Arizona University, Department of Biological Sciences, PO Box 5640, Flagstaff, AZ, USA, 86011

In the spring of 1996 a Spike Flow of 1274 m^3/s was released from Glen Canyon Dam (GCD) for seven days. We collected drifting particulate organic matter with a 63 μm net at five sites over a 320 km reach and analyzed these samples for $\delta^{13}C$ and $\delta^{15}N$ ratios throughout the Spike Flow hyrdograph. Results were examined in an effort to determine if the origin of drifting organic matter changed over time or with distance from the GCD. Dual isotopic plots indicated that organic matter in the drift changed from the lentic signal of Lake Powell discharge to riparian/benthic within 25 km during the up-ramp and changed to an upland vegetation signal by 100 km down river. There was an overall depletion of ^{13}C and ^{15}N ratios during the seven days of the Spike Flow. Return to pre-Spike Flow ratios occurred with sites closer to the GCD than down river. We concluded that dual isotopic analysis indicated a shift from autochthonous to allochthonous organic sources during the Spike Flow which was supported by traditional drift analysis. Exact origins of the drift material was difficult to define and may improve with the addition of ^{34}S analysis. The construction of a food web for this river system using stable isotopes will be presented.

Poster Presentation

CONTINUOUS FLOW $\delta^{34}S$ MEASUREMENTS AND COMBUSTION DEVILTY

*Steven Silva and **Brian Fry****

U.S. Geological Survey-MS 434, 345 Middlefield Road, Menlo Park CA 94025
*currently on leave at the USGS from Florida International University

We are using a continuous flow elemental analyzer-mass spectrometer system to optimize conditions for stable isotopic analysis of sulfur in organic and inorganic materials. Our eventual goal is to run 100 samples or more in a batch, with sulfur peak yields and isotopic values of representative standard materials remaining consistent throughout. We are not there yet, but have made enough progress to share some experiences in poster-side discussions.

For the sulfur analysis, 2-10 mg samples are burned at high temperature (1020EC), with combustion gasses passing over tungstic oxide and elemental copper to convert sulfur to SO_2. Downstream of the single oxidation/reduction tube, water is removed in a combined magnesium perchlorate/phosphorous pentoxide trap, then SO_2 separated from CO_2 and N_2 using a Carlo-Erba 80 cm sulfur column. Isotopic determinations are made with a Micromass Optima mass spectrometer.

We have improved sulfur peak shapes in four ways: 1) we have increased the GC column temperature from 85 to 105EC, 2) we have keep the copper metal in the combustion tube out of the cool lower part of the tube, since it is known that copper sulfate can form below about 830EC, 3) we have dropped samples into the furnace about 5 seconds earlier than recommended for C+N work, and 4) we have added about 5 mg V_2O_5 to each sample in tin boats. With these modifications, we observe fairly consistent peaks of 40-70 second widths at 90mls/minute flow rates in runs of >175 samples. Without these steps, we often observe degrading combustion over the course of about 20 samples as indicated by 1) lower, broader peaks, 2) longer tails, 3) occasional double peaks, 4) variable and low elemental measurements, and 5) less consistent isotopic values.

In spite of these improvements, we can still occasionally observe 0.5-1λ variations in batches of 10 standards, with 1 or 2 outliers accounting for the broad range. We suspect the combustion step most determines the peak sharpness and isotopic consistency, and that the Carlo Erba system is not fully adequate for flash-combusting the relatively large samples typically needed for sulfur isotopic analysis. We are currently experimenting with combustion conditions such as higher temperatures and combustion aids to improve precision of the measurements, and invite your suggestions poster-side.

Poster Presentation*

ASSESSMENT OF MARINE RESOURCES IN THE DIET OF THE ALEXANDER ARCHIPELAGO WOLF USING STABLE ISOTOPE ANALYSIS.

Michele Szepanski

Department of Fish & Wildlife Resources, University of Idaho, Moscow, ID 83844.

The Alexander Archipelago wolf (*Canis lupus ligoni*) is unique to southeast Alaska, occurring on islands south of Frederick Sound and along the mainland between Dixon Entrance and Yakutat Bay. Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) are an important prey species for wolves across the southern part of the region. Spawning salmon are seasonally available, although their presence in wolf diets has not previously been quantified. We examined the range of bone collagen stable isotope (^{13}C, ^{15}N) values for wolves throughout southeast Alaska (n = 168), and used a dual-isotope mixing model to determine the relative contribution of marine prey items in the diet. Marine resources may augment the diet of southeast Alaska wolves during seasonal or annual fluctuations in the availability of deer, particularly in those areas on the mainland where densities of terrestrial ungulates are relatively low. We present results from the stable isotope analysis and discuss conclusions and potential implications for managing southeast Alaska wolves.

Poster Presentation

FEEDING HABITS OF DETRITIVOROUS TERMITES IN THE DECOMPOSITION PROCESS

Ichiro Tayasu

Laboratory of Forest Ecology, Division of Environmental Science and Technology, Graduate School of Agriculture, Kyoto University, Kyoto, 606-8502 Japan

I present a study of termites in special reference to feeding habits using carbon and nitrogen isotope ratios.

Termites are dominant soil animals and play a significant role in tropical terrestrial ecosystems, especially in the decomposition process. They show a remarkable adaptive radiation in feeding habits; soil-feeding, grass harvesting, lichen-feeding and fungus cultivating as well as wood-feeding. The soil-feeding habit is adopted in 51% of all genera of the Isoptera, constituting a major trend in higher termite diversification. In addition, a number of termites feed on highly decayed wood in an advanced stage of humification, which is currently known as wood/soil-interface feeders. Another trend is fungus-growers. They cultivate symbiotic fungi (Termitomyces) and consume the fungus comb.

Carbon and nitrogen isotope ratios of termites are determined among various kinds of feeding habits. I propose δ13C and δ15N to possible indicators of functional position in the decomposition process, although further research is required. δ13C and δ15N of wood-feeders are low and similar to those of woods. Calibrated by background values, fungus-growers are high in δ13C but similar in δ15N, due to the fungus-associated process. Soil-feeders are high in both δ13C and δ15N, suggesting the digestion of microbial-mediated substances. In fact, wood/soil-interface feeders have intermediate values between wood- and soil-feeders, representing a trophic gradient from wood- to soil-feeding.

I suggest that stable isotope ratios of termites represent a functional position in the decomposition process and probably reflect a role of termites in nutrient cycling. The values are possibly useful indicators in comparing with those of other detritivorous animals.

Oral Presentation*

PRESERVATION OF BIOSIGNATURES IN MUSEUM HERBARIUM COLLECTIONS

Mark A. Teece [1,2], *Marilyn L. Fogel*[1] *and Noreen Tuross*[2]

[1] Geophysical Laboratory, Carnegie Institution of Washington, Washington DC 20015 USA.
[2] Conservation Analytical Laboratory, Smithsonian Institution, Suitland MD 20746 USA.

Throughout the museums of the world there exist extensive collections of plant specimens. These herbarium specimens are a potential reservoir of information of changes in climate and environments throughout the world over the past two centuries. These samples are well documented, dated and geographically constrained. In order to fully realize the usefulness of the information contained within herbarium specimens we examined plant specimens from the National Museum of Natural History, Washington D.C. Although the macro-integrity of the plants survive storage and preservation under herbarium conditions, it is unknown whether the organic matter survives under these conditions.

The molecular and isotopic composition of organic matter present in herbarium specimens dating back to 1849 was determined. Isotopic composition of whole plant tissue, $\delta^{13}C$ and $\delta^{15}N$, and individual fatty acids were measured, as were C/N ratios and concentrations of amino acids. C/N ratios showed little consistent changes over time indicating preservation of organic matter. Indeed, a suite of amino acids similar to those of modern plants was detected in the oldest samples. The stable carbon isotopic composition of plant tissue faithfully recorded the signature of the pathway of CO_2 fixation used, thereby distinguishing plants using the C_4 pathway from those utilising CAM metabolism. Furthermore, whole tissue $\delta^{13}C$ was progressively more enriched in ^{13}C with increasing age, which closely followed observed changes in $\delta\ ^{13}C$ of atmospheric CO_2 over a similar time period. Individual fatty acids were isotopically lighter than the corresponding whole plant tissue, and closely paralled changes in bulk signatures over time. These studies indicate that storage under herbarium conditions results in the preservation of both molecular as well as isotopic biosignatures. Hence, herbarium collections will be a useful source of molecular information of changes in plant ecology and environmental changes in the recent past.

Oral Presentation

A STABLE ISOTOPE (δ^2H, $\delta^{13}C$) INVESTIGATION OF THE EASTERN NORTH AMERICAN MONARCH BUTTERFLY (*DANAUS PLEXIPPUS*) MIGRATION PHENOMENON

***Leonard I. Wassenaar*[1]**, *Keith A. Hobson*[2]

[1]Environment Canada, National Water Research Institute, 11 Innovation Blvd., Saskatoon, Saskatchewan, Canada, S7N 3H5, Canada
[2]Environment Canada, Prairie and Northern Wildlife Research Center, 115 Perimeter Rd., Saskatoon, Saskatchewan, S7N 0X4, Canada

Each year millions of Monarch butterflies (*Danaus plexippus)* from eastern North America migrate to over-winter in spectacular colonies located in Michoacan, Mexico, a phenomenon threatened by alteration of winter habitat. Despite decades of research there is no definitive information on links between Monarch natal origins and each of the discrete wintering colonies. Efforts to understand Monarch migration have previously focused on tag-and-recover methodology, with fewer than 90 recoveries reported over the past 30 years from several of the 13 wintering colonies. In short, tagging has not resolved how natal origins and wintering sites might be linked.

The goal of this study was to evaluate the applicability of using the stable hydrogen isotope technique of Hobson and Wassenaar (1997) to improve our understanding of Monarch migration. Here we present results of laboratory Monarch food web experiments, an extensive wild rearing program (89 sites) designed to "calibrate" the hydrogen isotope technique for the Monarch butterfly, as well as results of over 600 δ^2H and $\delta^{13}C$ analyses of Monarchs from the 13 wintering colonies. Isotopic results from wintering sites were consistent with our isotopic map for the breeding range of this species in eastern North America. We found no significant differences in stable-isotope profiles among sites, suggesting that all roost sites are well mixed and are comprised of butterflies from broad geographic areas.

[1]Hobson, K.A. and Wassenaar, L.I. (1997) Linking breeding and wintering grounds of neotropical migrant songbirds using stable hydrogen isotopic analysis of feathers. Oecologia 109:142-148

Poster Presentation

PATTERNS OF STABLE ISOTOPES OF S, C AND N IN A RIPARIAN FOOD CHAIN ON RIVERS RECEIVING PULP MILL EFFLUENTS.

M. Wayland *and K.A. Hobson,*

Canadian Wildlife Service, Saskatoon, SK.

There has been much concern about and research on the effects of pulp mill effluent (PME) on aquatic ecosystems. However, potential for dietary exposure of riparian wildlife to PME components has received scant attention. Stable isotopes can be an effective means of tracing sources of elements in food webs. Tree swallows are riparian birds that feed predominately on insects of aquatic origin. Therefore they may be exposed to chemicals in PME through the food chain. In this study, we examined stable S, C and N isotopes in tree swallows and some of their prey at sites upstream and downstream from two bleached kraft pulp mills in Canada. At one mill, caddisflies, a major food of tree swallows, were relatively enriched in ^{34}S and in ^{13}C immediately downstream from the pulp mill compared to the upstream site. Tree swallows were relatively enriched in ^{34}S, ^{13}C and ^{15}N at downstream sites compared to upstream sites. However, site-to-site changes in tree swallow stable isotope ratios did not parallel those in insects. Among-site differences in ^{34}S corresponded with an enrichment in ^{34}S in the PME signal. At the other mill, organic material in the effluent was relatively enriched in ^{34}S and depleted in ^{13}C. Consistent with this finding was the relative enrichment in ^{34}S in caddisflies and tree swallows downstream from the pulp mill compared to upstream sites. Among-site differences in ^{13}C and ^{15}N in tree swallows and their prey were not consistent with a PME effect. Information on stable isotopes at the base of the food chain is needed to interpret with confidence the results of this study.

Oral Presentation

COMPOUND SPECIFIC ISOTOPE CORRELATION (CSIS) OF FATTY ACIDS: A NOVEL APPROACH IN POPULATION DYNAMICS STUDIES

M.J. Whiticar[1]*, R.J. Veefkind*[1]*, J.N.C. Whyte*[2]*, and R.I. Perry*

[1]School of Earth and Ocean Sciences (SEOS), University of Victoria, Victoria, B.C., Canada
[2]Pacific Biological Station (PBS), Dept. of fisheries and Oceans, Nanaimo, B.C., Canada

CSIC offers an alternative approach for characterizing trophic provenance and tracking food web pathways. Current research focuses on short marine trophic trajectories. The techniques is based on CF-IRMS analysis of stable carbon isotope ratios in diagnostic individual organic molecules. In this study we examine the essential fatty acid signatures in different marine trophic levels. Spatial variation in carbon isotope composition of phytoplankton resulting from, e.g., differences in hydrographic properties, species composition, temperature, growth rate and pCO2, can therefore help to geographically link fish stocks to their former feeding grounds.

Initial results of CSIC using the essential poly-unsaturated fatty acids (PUFAs), docosahexaenoic acid (22:6n3 and eicosapentaenoic acid (20:5n3), in conjunction with the Canadian GLOBEC program will be presented.

Poster Presentation*

INTRA-TOOTH ISOTOPIC VARIATIONS (^{13}C, ^{18}O) IN HERBIVORES - IMPLICATIONS FOR PALEOECOLOGICAL RECONSTRUCTIONS

***Wiedemann, F.B.**, Bocherens, H., von den Driesch, A., Mariotti, A., Grupe, G.*

The stability of tooth enamel against post mortem alteration renders it one of the preferred study materials for isotopic analyses in the context of paleoecology. The range of intra-individual and intra-tooth isotopic variability should be considered in micro-sampling procedures. The awareness of intra-tooth isotopic variability is crucial for the study of paleoclimate as well as for the reconstruction of paleodiet and inferred use of ecological niches in the past.

Carbonate in Neolithic tooth enamel (Bovidae and Equidae from Ain Ghazal, Jordan) was analyzed for $\delta^{13}C$ and $\delta^{18}O$ in order to trace intra-tooth variation. Up to 13 enamel samples were taken per tooth from crown to root in horizontal layers with a drill.

Intra-individual variability of isotopic values is higher in equid than in bovid tooth enamel. Results for $\delta^{13}C$ in a given tooth vary within a range up to 2.9‰ (PDB) in equid enamel, but remain within the frame of C_3 or C_4 feeders respectively and do not indicate a clear shift from C_3 to C_4 consumption for a given individual. Results for $\delta^{18}O$ vary up to 6.9 ‰ (PDB) within one given tooth in equids.

Given the analysis of many individuals over a long time period at one given archeological site, this approach permits the comparison of stable isotope variations, both synchronically and diachronically, to better monitor seasonality or reconstruct climatic changes.

For the site of Ain Ghazal, information on short term climatic variation could provide important arguments for the discussion of cultural developments.

Poster Presentation

TRACING CHANGE IN LITTORAL FISH COMMUNITIES USING STABLE ISOTOPIC TECHNIQUES

***Yankovich, T.L.*[1]**, *R.J. Cornett*[1], & *S. Casselman*[2]

[1]Atomic Energy of Canada, Environmental Research Branch
[2]Department of Biology, Queen's University.

Often, major system perturbations, such as species introductions, can result in shifts in community structure, and in extreme cases, localized extinctions, as newly-introduced species out-compete and/or prey upon resident species. As a result, such changes often cause significant shifts in community composition including species abundance, condition, growth rate, body size, and/or diet.

The use of stable isotope fractionation studies may be particularly useful in perturbed foodwebs to quantify the impact of the perturbation on system structure, dynamics, and stability. For example, introduction of an efficient (or 'keystone') predator into a small, closed system can cause instability in the community structure and may lead to extinction of resident species.

This study has focused on the effect of the introduction of Northern pike into a littoral fish community on energy and contaminant flow in a small, closed lake which experienced a recent Northern pike introduction. Changes food chain length and predator-prey interactions of pre- and post-pike fish communities were quantified using $\delta^{15}N$ and $\delta^{13}C$.

Poster Presentation

CATEGORIZATION OF TROPHIC GROUPING FOR LITTORAL ORGANISMS USING A QUANTITATIVE STATISTICAL MODEL

Yankovich, T.L. & *R.J. Cornett*

Atomic Energy of Canada, Environmental Research Branch.

$\delta\ ^{15}N$ can be used to study community trophic structure and to quantify food chain length due to the tendency toward $\delta\ ^{15}N$ enrichment as predators consume prey. As a result, complexity in aquatic systems can be reduced to a series of boxes which group similar types of organisms based on their feeding patterns and/or dietary items. For example, strong empirical models have been developed which produce predictable relationships in $\delta\ ^{15}N$ signatures between organisms based on their trophic positions in pelagic foodwebs; however, relatively little is known about how these models apply to more complex, littoral systems inhabited by organisms with a relatively large degree of dietary overlap. To overcome this, a statistical method has been developed to quantitatively group littoral organisms into trophic levels based on their $\delta\ ^{15}N$ signatures and diets.

Poster Presentation*

TIDAL CURRENTS AND THE CONTROL OF ENERGY FLOW IN A MARINE FOOD WEB

Jeannette E. Zamon

Department of Ecology & Evolutionary Biology, University of California - Irvine

This study tests the hypothesis that tidal currents link an oceanic source of plankton to an inshore food web by creating predictable cycles of prey availability to planktivorous fishes. Preliminary analyses from the San Juan Islands, WA show that foraging by upper trophic level consumers (seabirds, harbor seals) peaks during the incoming tide. Foraging peaks are associated with changes in the distribution of planktivorous fish (Pacific herring and Pacific sandlance) and increases in plankton density in surface waters. Incoming tides cause the northward movement of the boundary
between oceanic, stratified water and vertically well-mixed, lower-salinity San Juan Channel water. Plankters eaten by surface-feeding fishes are more abundant in the deep layer of the oceanic water, and are mixed into surface water by nearshore tidal currents. However, the relative importance of local plankton production vs. tidally advected plankton production to the upper trophic levels is unknown.

Research is now underway which will use stable isotopes (13C, 15N) to determine trophic relationships and the relative importance of these distinct water masses in supporting the local food web. Because San Juan Channel water contains terrestrially-derived carbon, it is expected that consumers will show enriched 13C if plankton production entering the food web is of local origin. Alternatively, consumers should show depleted 13C if advected oceanic production is more important. This research will contribute to the understanding of why tidal channels often support enhanced
biological productivity, and will help in predicting the effects of changes in both the physical (e.g., river outflow, sea temperature) and biological (e.g. plankton/fish abundance and species composition) environment on the food web.

LIST OF PARTICIPANTS

(Sorted by surname)

Ray Alisauskas, Prairie and Northern Wildlife Res. Center, 11 Innovation Blvd. Saskatoon, SK, S7N 3H5, Canada.
email: ray.alisauskas@ec.gc.ca
Karrin Alstad, Northern Arizona University Forestry Dept, P.O. Box 15018 Flagstaff, Arizona, 86011-5018, USA
email: karrin@alpine.for.nau.edu
Lisa Atwell, Environment Canada, 11 Innovation Blvd. Saskatoon, SK, S7N 3H5, Canada
email: Lisa.Atwell2@ec.gc.ca
Candace Ayres, Archaeology Department, University of Calgary, 2500 University Dr. N.W., Calgary, Alberta, Canada
email: crdayres@acs.ucalgary.ca
Adriana Baggio Garlipp, Université Catholique de Louvain Rue des Bruyères, 24/301 1348, Belgium
email: a.baggio@usa.net
Nick Balster, University of Idaho, 869 Stefany Lane Moscow, Idaho, 83843, USA
email: bals9458@uidaho.edu
Stuart Bearhop, Institute of Biomedical and Life Sciences, Glasgow University, Graham Kerr Building, Glasgow, U.K. G12 8QQ
email: sbearhop@udcf.gla.ac.uk
Catherine Beaudoin, Department Biological Sciences, University of Alberta, CW-405 Biological Sciences, Edmonton, Alberta, T6G 2E9, Canada
email: cpb1@gpu.srv.ualberta.ca
Benjamin Becker, UC Berkeley, Division of Ecosystem Science, 151 Hilgard Hall #3110, Berkeley, CA, 94720-3119, USA
email: bbecker@nature.berkeley.edu
Nik Binder, Isomass Scientific, 319-5940 Macleod Trail SW Calgary, Alberta Canada
email: isomass@isomass.com
Ludek Blaha, Czech Academy of Sciences, Brno, Czech Republic
email: ludek.blaha@cciw.ca
Keith Bosley, Rutgers University, Institute of Marine and Coastal Science, 71 Dudley Rd., New Brunswick, NJ, 08901-8521, USA
email: klboz@ahab.rutgers.edu
Thure Cerling, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah, 84112, USA
email: tcerling@mines.utah.edu
Nancy Clum, DePaul University, Environmental Science Program, 1036 W. Belden Ave, Chicago, Illinois, 60614, USA
email: nclum@wppost.depaul.edu
Allison Cormie, Department of Sociology and Anthropology, Laurentian University, Ramsey Lake Rd., Sudbury, Ontario, P3E 2C6, Canada
email: abbco@mail.vianet.on.ca
Joseph Culp, Environment Canada, 11 Innovation Blvd. Saskatoon, SK, S7N 3H5, Canada
email: Joseph.Culp@ec.gc.ca
Stevie Davenport, CSIRO Marine Labs, GPO Box 1583, Castray Esplanade, Hobart, Tasmania, 7001, Australia
email: stephanie.davenport@marine.csiro.au
David Donald, Environment Canada, 2365 Albert Street, Room 300, Park Plaza, Regina, Saskatchewan, S4P 4K1, Canada
email: David.Donald@EC.GC.CA

Richard Doucett, Department of Biology, University of Waterloo, 200 University Ave. W., Waterloo, ONT, N2L 3G1, Canada
email: rrdoucet@sciborg.uwaterloo.ca
Chuck Douthitt, Finnigan-MAT, 9412 Rocky Branch Dr. Dallas, Texas, 75243, USA
email: 76241.2702@compuserve.com
Bob Drimmie, Environmental Isotope Lab, University of Waterloo, Waterloo, Ontario, Canada
email: rdrimmie@uwaterloo.ca
Elise Dufour, Laboratoire de Biogeochimie Isotopique UMR 162, CNRS-INRA-Universite Paris VI Paris, France
email: edufour@ccr.jussieu.fr
Jason Duxbury, University of Alberta, Department of Renewable Resources, Edmonton, Alberta, T6G 2H1
email: jduxbury@gpu.srv.ualberta.ca
Jim Ehleringer, Department of Biology, 247 S 1400 E, University of Utah, Salt Lake City, Utah, 84112-0840, USA
email: ehleringer@bioscience.utah.edu
Marlene Evans, Environment Canada, 11 Innovation Blvd. Saskatoon, SK, S7N 3H5, Canada
email: marlene.evans@ec.gc.ca
Matt Fantle, Carnegie Institute of Washington, 5251 Broad Branch Road N.W. Washington, DC, 20015, USA
email: fantle@ctpsun.ciw.edu
Sean Farley, Alaska Biological Science Center, 1011 E. Tudor Rd., Anchorage, Alaska, 99503-6199, USA
email: Sean_Farley@nbs.gov
Richard Farrell, Department of Soil Science, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK, S7N 5A8, Canada
email: farrell@sask.usask.ca
Andrea Farwell, University of Guelph, Department of Environmental Biology Guelph, Ontario, N1G 2W1, Canada
email: afarwell@evbhort.uoguelph.ca
Larry Flanagan, University of Lethbridge, 4401 University Drive, Department of Biological Sciences, Lethbridge, Alberta, T1K 3M4, Canada
email: larry.flanagan@uleth.ca
Marilyn Fogel, Carnegie Institute of Washington, 5251 Broad Branch Road N.W. Washington, DC, 20015, USA
email: fogel@ctpsun.ciw.edu
Francois Fourel, Micromass UK Ltd., Floats Rd, Wythenshawe, Manchester M23 9LZ, UK
email: francois.fourel@micromass.co.uk
Brian Fry, Visiting Scientist, U.S. Geological Survey, 345 Middlefield Rd., MS 434, Menlo Park, CA, 94025, USA
email: brianfry@usgs.gov
Sandra Garvie-Lok, Department of Archaeology, University of Calgary, 2500 University Dr. N.W., Calgary, Alberta, T2N 1N4, Canada
email: sjgarvie@acs.ucalgary.ca
Bjarni Gautason, University of Alberta, 1-26 Earth Sciences Building Edmonton, Alberta, T6G 2E3, Canada
email: bjarni.gautason@ualberta.ca
Matthias Gehre, UFZ Umweltforschungszentrum, Leipzig-Halle GmbH, Permoserstr. 15, Leipzig D-04318, Germany
email: gehre@ana.ufz.de
John Gibson, Environment Canada, 11 Innovation Blvd. Saskatoon, SK, S7N 3H5, Canada
email: gibsonj@nhrisv.nhrc.sk.ec.gc.ca
Bill Gummer, Canadian Wildlife Service, Regina , SK, Canada
email: Bill.Gummer@ec.gc.ca
Anette Giesemann, Institute of Ecotoxicology: FAL, Bundesallee 50 Braunschweig 38116, Germany
email: giesemann@poet.fal.de
Gerd Gleixner, TU-Muenchen, Voettingerstrasse 40, LS Allg. Chem. Biochem., Freising 85350, Germany
email: gerd@ibm1.chem.agrar.tu-muenchen.de

Elena Gorokhova, Stockholm University, Frescati Backe, Svante Arrheniusv. 21A, Stockholm 106 91, Sweden
email: elenag@system.ecology.su.se
Mark Graham, University of Regina, Department of Biology Regina, Saskatchewan, S4S 0A2, Canada
email: grahamma@meena.cc.uregina.ca
Linda Gregory, Department of Biology, University of Victoria, PO Box 3021, Stn CSC, Victoria, B.C., Canada
email: lgregory@uvic.ca
David Harris, University of California, Davis, 122 Hunt Hall, Dept Agronomy & Range Science, Davis, California, 95616, USA
email: dharris@ucdavis.edu
Roman Harrison, Department of Archaeology, University of Calgary, 2500 University Dr. N.W., Calgary, Alberta, T2N 1N4, Canada
email: rharriso@acs.ucalgary.ca
Jon Hartman, Europa Scientific, 1475 Worldwide Place Vandalia, Ohio, 45377, USA
email: sales@europa-us.com
Chris Harvey, Center for Limnology, University of Wisconsin, 680 N. Park St., Madison, Wisconsin, 53706-1492, USA
email: cjharvey@students.wisc.edu
Grant Hilderbrand, Washington State University, Department of Zoology Pullman, WA, 99164-4236, USA
email: ghilderbrand@wsu.edu
Amy Hirons, Institute of Marine Science, University of Alaska, PO Box 757000, Fairbanks, Alaska, 99775-7220, USA
email: ftach@aurora.alaska.edu
Erik Hobbie, National Research Council, National Health and Environmental Effects Research Lab, 200 SW 35th Street, Corvallis, OR, 97333, USA
email: hobbie@mail.cor.epa.gov
Keith Hobson, Prairie and Northern Wildlife Res. Centre, 11 Innovation Blvd. Saskatoon, SK, S7N 3H5, Canada
email: Keith.Hobson@ec.gc.ca
Peter Hodum, Department of Avian Sciences, University of California, Davis, California, 95616, USA
email: pjhodum@ucdavis.edu
Chris Holmden, Department of Geological Sciences, University of Saskatchewan, 114 Science Place, Saskatoon, SK, S7N 5E2, Canada
email: holmden@pangea.usask.ca
William Hoppes, Lawrence Livermore National Laboratory, PO Box 808, L-629, Livermore, California, 94551, USA
email: hoppes1@llnl.gov
Michael Horn, California State University, Department of Biological Sciences, Fullerton, California, 92834, USA
email: mhorn@fullerton.edu
Siri Ibarguen, Ohio State University, Zoology Department, 1735 Neil Avenue, Columbus, Ohio, 43210-1293, USA
email: ibarguen.2@osu.edu
Chad Jay, USGS Biological Resources Division, 1011 East Tudor Road, Anchorage, Alaska, 99503. USA
email: chad_jay@usgs.gov
Michael Jacoby, Washington State University, Department of Zoology, P.O. Box 644236, Pullman, Washington, 99164-4236, USA
email: gbear@mail.wsu.edu
Craig Johnson, USGS, Box 25046, MS 963, Denver Colorado, USA, 80225
email: cjohnso@usgs.gov
Klaus Jung, Dept. of Chemical Ecotoxicology, UFZ Center for Environmental Research, Permoserstr. 15, Leipzig, D-04318, Germany
email: kj@uoe.ufz.de
Kayoko Kameda, Lake Biwa Museum, Oroshimo 1091 Kusatsu, Shiga, 525-0001, Japan
email: kameda@lbm.go.jp

Jeffery Kelly, USDA-FS, Rocky Mountain Research Station, 2205 Columbia SE Albuquerque, New Mexico, 87106, USA
email: jeffrey.f.kelly/rmrs_albq@fs.fed.us
Carol Kendall, U.S. Geological Survey, 345 Middlefield Rd., MS 434, Menlo Park, CA, 94025, USA
email: ckendall@usgs.gov
Karen Kidd, Department of Fisheries and Oceans, Freshwater Institute, 501 University Cr., Winnipeg, Manitoba, R3T 2N6, Canada
email: kiddk@dfo-mpo.gc.ca
Diane Knight, Department of Soil Science, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK, S7N 5A8, Canada
email: knight@sask.usask.ca
Barbara E. Kornexl, UFZ Umweltforschungszentrum, Leipzig-Halle GmbH, Permoserstr. 15, Leipzig D-04318, Germany
email: kornexl@ana.ufz.de
H. Roy Krouse, University of Calgary, 2500 University Drive NW Calgary, Alberta, T2N 1N4, Canada
email: roy@earth.geo.ucalgary.ca
Carolyn Kurle, Department of Wildlife and Fisheries Science, Texas A&M University, College Station Texas, 77843, USA
email: kurlec@tamug.tamu.edu
Gary Landis, USGS, P.O.Box 25046, Mail Stop 963, Denver Federal Center, Denver, Colorado, 80225-0046, USA
email: g_landis@usgs.gov
Peter Leavitt, Department of Biology, University of Regina, Regina, SK, S4S 0A2, Canada
email: leavitt@leroy.cc.uregina.ca
Jeremy Leyden, University of Calgary, 2915 12th. Ave. N.W., Calgary, Alberta, Canada
email: jjleyden@acs.ucalgary.ca
Guanghui Lin, 32540 S. Biosphere Rd., PO Box 689, Oracle, Arizona, 85623, USA
email: glin@bio2.edu
Takeshi Matsubara, College of Cross-Cultural Communication and Business, Shukutoko University, Fujikubo, Miyoshi-machi, 354-0041, Japan
email: yumik@sfc.keio.ac.jp
Bernhard Mayer, Department of Physics & Astronomy, University of Calgary, 2500 University Drive NW, Calgary, Alberta, T2N 1N4, Canada
email: bernhard@earth.geo.ucalgary.ca
Rhonda McDougal, University of Manitoba, Department of Botany Winnipeg, Manitoba, R3T 2N2, Canada
email: ummcdo54@cc.umanitoba.ca
Andy Midwood, Macauley Land Use Research Institute Craigiebuckler, Aberdeen, Scotland, AB15 8QH, UK
email: mi432@mluri.sari.ac.uk
Reehan Mirza, Biology Department, University of Saskatchewan, 112 Science Place, Saskatoon, SK, S7N 5E2
Email: mirza@duke.usask.ca
Pedro Monteiro, Council for Scientific and Industrial Research, Jan Cillier Str Stellenbosch, W. Cape, 7599, South Africa
email: pmonteir@csir.co.za
John Morrison, Micromass UK Ltd., Floats Rd, Wythenshawe, Manchester M23 9LZ, UK
email: john.morrison@micromass.co.uk
Jim Neary, Environment Canada, 11 Innovation Blvd. Saskatoon, SK, S7N 3H5, Canada
email: Jim.Neary@ec.gc.ca
Ann-Lise Norman, Atmospheric Environment Service, 4905 Dufferin Street Downsview, ONT, M3H 5T4, Canada
email: annlise.norman@ec.gc.ca
Jeffery Owen, USDA Agricultural Research Service, 3450 SW Campus Way Corvallis, OR, 97331, USA
email: owenje@ucs.orst.edu
Garth Parry, Department of Soil Science, University of Saskatchewan, 5E85 Ag Building, 51 Campus Dr., Saskatoon, SK, S7N 5A8, Canada

email: parry@sask.usask.ca
Susan Polischuk, Department of Biology, University of Saskatchewan Saskatoon, SK, S7N 5E2, Canada
email: polischuks@sask.usask.ca
J.Bruce Pollard, Institute for Wetland and Waterfowl Research, PO Box 1160 Stonewall, Manitoba, ROC 2Z0, Canada
email: b_pollard@ducks.ca
Charles Robbins, Washington State University, Department of Zoology Pullman, WA, 99164, USA
email: ctrobbins@wsu.edu
Lois Roe, Department of Geosciences, University of Arizona, Gould-Simpson Bldg. Rm. 208, Tucson, ARIZONA, 85721, U.S.A.
email: lroe@geo.arizona.edu
Chris Romanek, Savannah River Ecology Lab, University of Georgia, Drawer E, Aiken, South Carolina, 29802, USA
email: romanek@srel.edu
Lisette Ross, Institute for Wetland and Waterfowl Research, PO Box 1160 Stonewall, Manitoba, ROC 2Z0, Canada
email: l_ross@ducks.ca
James Roth, University of Minnesota, Department of Ecology, Evolution and Behavior, 1987 Upper Buford Circle, St. Paul, Minnesota, 55108, USA
email: roth@biosci.cbs.umn.edu
Erik Rothacker, DePaul University, Department of Biological Sciences, 1036 W. Belden Ave Chicago, Illinois, 60614-3298, USA
email: species1@idt.net
Paul Rygiewicz, US Environmental Protection Agency, National Health and Environmental Effects Research Lab, 200 SW 35th Street, Corvallis, OR, 97333, USA
email: rags@mail.cor.epa.gov
Thomas Schlacher, University of the South Pacific, P.O. Box 1168 Suva , Fiji Islands
email: Schlacher_T@usp.ac.fj
Theresa Schober, University of Florida, 1350 Turlington Hall, Department of Anthropology, Gainesville, Florida, 32611, USA
email: tbone@nervm.nerdc.ufl.edu
Mark Servos, National Water Research Institute, Burlington, Ontario, Canada
email: mark.servos@cciw.ca
Joe Shannon, Northern Arizona University, Department of Biological Sciences, PO Box 5640, Flagstaff, AZ, 86011-5640, USA
email: Joseph.Shannon@nau.edu
Einav Shochat, Washington State University, Department of Zoology Pullman, WA, 99164, USA
email: shochat@wsu.edu
Ashish Sinha, University of Southern California, University Park Los Angeles, CA, 90089, USA
email: asinha@earth.usc.edu
Jan Smith, Biology Department, University of Saskatchewan, 112 Science Place, Saskatoon, SK, S7N 5E2
email: Smithr@sask.usask.ca
Rick Socki, NASA-LMES, Mail Code C-23, 2400 NASA Road, Houston, Texas, 77058, USA
email: rsocki@ems.jsc.nasa.gov
Maria Sotiropoulos, University of Alberta, Department of Biology, 15 Ashern Road, Winnipeg, Manitoba, Canada, R2Y 1H1
email: nscons@nscons.mb.ca
Shelley Szepanski, University of Idaho, Department of Wildlife Resources Moscow, Idaho, 83844, U.S.A.
email: szep9534@novell.uidaho.edu
Ichiro Tayasu, Laboratory of Forest Ecology - Kyoto University, Kitashirakawa, Sakyo-ku Kyoto, 606-8502, Japan
email: tayasu@kais.kyoto-u.ac.jp
Steve Taylor, Environment Canada, 11 Innovation Blvd. Saskatoon, SK, S7N 3H5, Canada
email: Steve.Taylor@ec.gc.ca

Mark Teece, Carnegie Institute of Washington, 5251 Broad Branch Road N.W. Washington, DC, 20015, USA
email: teece@ctspun.ciw.edu
Bill Tonn, Department Biological Sciences, University of Alberta, Edmonton, Alberta, T6G 2E9, Canada
Email: bill.tonn@ualberta.ca
Mary Veliz, Department Biological Sciences, University of Alberta, CW-405 Biological Sciences, Edmonton, Alberta, T6G 2E9, Canada
email: mveliz@gpu.srv.ualberta.ca
Moire Wadleigh, Memorial University, Department of Earth Sciences St. John's, Newfoundland, A1B 3X5, Canada
email: moire@sparky2.esd.mun.ca
Tom Waite, Department of Zoology, Ohio State University, 1735 Neil Avenue, Columbus, Ohio, USA, 43210
email: waite.1@osu.edu
Susan Waldron, Life Sciences Community Stable Isotope Facility, Scottish Universities Research and Reactor Centre East Kilbride G75 0QF, Scotland
email: s.waldron@surrc.gla.ac.uk
Len Wassenaar, Environment Canada, 11 Innovation Blvd. Saskatoon, SK, S7N 3H5, Canada
email: Len.Wassenaar@ec.gc.ca
Mark Wayland, Environment Canada, Wildlife Research Station, 115 Perimeter Road, Saskatoon, SK, S7N 0X4, Canada
email: mark.wayland@ec.gc.ca
Monica Webster, University of Calgary, 52 Woodmont Rise SW, Calgary, Alberta, T2W 4L5, Canada
email: mcwebste@acs.ucalgary.ca
William Whitehead, University of California at Davis, Department of Anthropology, 232 Kroeber Hall, Berkeley, California, 94720, USA
email: whitehea@qal.berkeley.edu
Michael Whiticar, SEOS - University of Victoria, SEOS PO Box 3055 Victoria, B.C., V8W 3P6, Canada
email: whiticar@uvic.ca
Felicitas Wiedeman, Anthropology Department, Rutgers University, P.O.Box 270, New Brunswick, NJ, 08903-0270, USA
email: wiedeman@eden.rutgers.edu
Renee Wiseman, Memorial University, Department of Earth Sciences, 293 Freshwater Rd., Bldg. 1 Apt. 110, St. John's, Newfoundland, A1B 1B7, Canada
email: rwiseman@morgan.ucs.mun.ca
Tamara Yankovich, Atomic Energy of Canada / Trent University, Environmental Research Branch, Stn 51A, Chalk River Laboratories, Chalk River, Ontario, KOJ 1J0, Canada
email: yankovit@aecl.ca
Jeannette Zamon, UC-Irvine/Friday Harbor Labs, c/o Friday Harbor Labs, 620 University Road, Friday Harbor, Washington, 98250, USA
email: jzamon@uci.edu

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