Stable Isotopes in Ecosystems, Examination 1 Name _____**KEY**_____
February 22, 2005 Student ID _____

Please restrict your response to the space available; do not extend your answers to the back of the paper. Answer directly and fully - don't beat around the bush. The point values for each question are given in parentheses. Any notes you added to printouts of Winston Weatherly's notebook are allowed in answering the exam. All page references refer to Winston's notebook.

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I have always been fascinated by the hydrological cycle ever since I was a child growing up in Wanship, Utah. The Weber River runs right in front of our old farm and before the Rockport Dam was built we used to get some very large fluctuations in the flow rates from the river as the snowmelt occurred each spring. Much of the water in the Weber River is now used for irrigation. Now having learned about the utility of stable isotope analyses in understanding various aspects of the hydrological cycle, I was keen to go back to the places where I roamed as a child to examine the magnitude of stable isotope ratio variations that I would find in the different components of the hydrological cycle along the Weber River drainage. Last August in the middle of the summer, I collected my water samples for stable isotope ratio analyses. Among the various components of the hydrological cycle that I was able to examine, the following were what I was able to get precise measurements of:

- 1 sample of surface water from the Great Salt Lake
- 1 sample of surface water from Echo Reservoir
- 1 sample of surface water from Rockport Reservoir
- 1 sample of the Weber River near my favorite fishing spot (secret location #1)
- 1 sample of the Weber River near my brother Wilford's secret fishing spot (secret spot #2)
- 1 sample of water from another secret spot
- 6 samples of Weber River water from various locations between the Uinta Mountains and the Great Salt Lake
- 1 sample of well water from our Dad's farm in Wanship

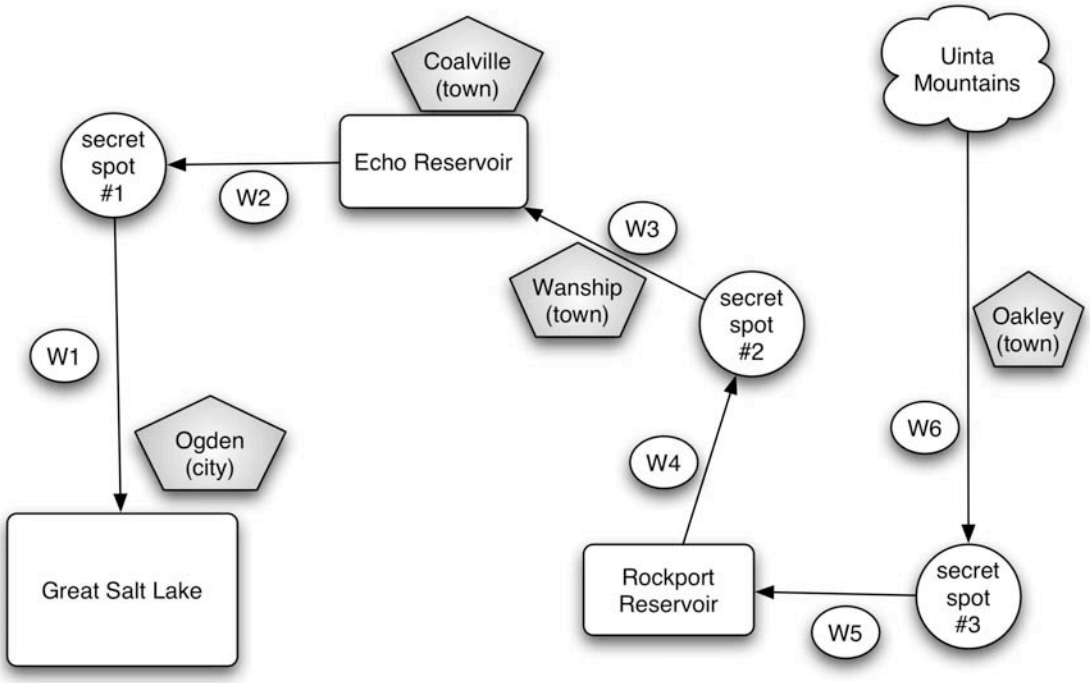
1 (10 points). Do the isotope ratios of the water data presented indicate that there is a reservoir of evaporatively enriched water upstream of the first sample observation? Answer first with a "**yes**" or "**no**" and then provide a justification for your answer below.

(5 points) Yes.

(5 points) If standing water is allowed to exchange with the atmosphere for an extended period of time (as in a reservoir), it will become evaporatively enriched in ^{2}H and ^{18}O relative to the incoming precipitation. The precipitation data provide the information needed to plot the meteoric water line. When the river water samples from above Rockport Reservoir are added to this plot, each of the values plot to the right of the meteoric water line, even the river water sample closest to the Uinta Mountains. This could only occur if there was standing water (i.e. a reservoir) upstream of river sample W6.

2 (2 points each). The following water samples are associated with the locations from the lake, reservoir, river, and well sites shown on the map below. There are 12 different river or lake locations and 1 well location. Please match the location letter (i.e., A through N) with a specific geographic region below. Please indicate whether the value of the sample is on the local meteoric water line (yes or no). All data are in "delta" notation relative to the SMOW standard and are expressed in per mil (‰) units.

Location	δ^2H of water, ‰	$\delta^{18}O$ of water, ‰	location on map below	Is the isotope ratio of this sample on the local meteoric water line
A	-141	-17.6	**Weber River W5**	**no**
B	-115	-12.6	**Rockport Rervoir**	**no**
C	-82	-8.9	**Echo Reservoir**	**no**
D	-79	-8.2	**Weber River W1**	**no**
E	-145	-17.8	**Weber River W6**	**no**
F	-110	-12.2	**Weber River W3**	**no**
G	-110	-12.2	**Wanship well**	**no**
H	-80	-8.7	secret spot #1	**no**
J	-143	-17.7	**secret spot #3**	**no**
K	-81	-8.8	**Weber River W2**	**no**
L	-111	-12.3	**secret spot #2**	**no**
M	-48	-1.3	**Great Salt Lake**	**no**
N	-113	-12.4	**Weber River W4**	**no**



3 (5 points). The "well water from our Dad's farm" appears to be right **next to which site** based on similarity of hydrogen and oxygen isotope ratio values? **W3**

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Two years ago I spent the Labor Day holidays exploring some of the remote regions up and down the central Arizona Mountains north of Tucson. The people were very friendly, the food was exceptionally good, and the vegetation was most interesting. I had the good fortune to be able to come back to the exact same sites again during the Easter Holidays last spring. Having just finished my lecture on carbon isotope ratios at the time of the first field trip, I was fascinated to see that there were both C_3 and C_4 grasses in this part of the world. For the most part, these sites were grassland ecosystems. I collected all of the grasses growing in a 5 m by 5 m plot at five different sites and took them back to the lab. Once at home in the lab, I ground up the leaves and measured the average carbon isotope ratio ($\delta^{13}C$) for the vegetation on different plots. Remembering that I could get the climate data off the internet, I downloaded the long-term winter and summer climate data. Below is a summary of the data I now have - what a fascinating story this will be when I publish it next year.

Site	$\delta^{13}C$ of plants in winter (‰)	$\delta^{13}C$ of plants in summer (‰)	Total winter rainfall (mm)	Total summer rainfall (mm)	Average temperature in winter (°C)	Average temperature in summer (°C)
1	-27.8	-25	344	420	15	25
2	-23.7	-13	80	460	17	33
3	-28.0	-20	335	400	16	29
4	-27.1	-24	276	386	15	24
5	-26.9	-16	281	460	15	30

4 (10 points). Why would you expect to see the observed negative relationship between the carbon isotope ratio of plants in winter and total amount of winter precipitation?

(5 points) The carbon isotope ratio of C3 plants in winter increases with decreasing precipitation. This pattern is expected because stomata limit photosynthesis more under water-limited conditions.

(5 points) As stomata partially close, the ci/ca ratio decreases. As the ci/ca ratio decreases, there is less carbon isotope discrimination, resulting in higher carbon isotope ratios.

5 (10 points). Identify all sites having summertime vegetation that is greater than 90 % C_4 plants.

(5 points each) sites 2 and 5

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The cryptobiotic crusts of southern Utah are very fascinating to me. I have always been impressed by the sensitivity of these biological communities to damage. Much is now known about the ecology of the organisms that comprise the crusts. We owe much appreciation to Dr. Jayne Belnap for her pioneering studies on the ecology and physiology of crusts in southern Utah. What I have found very interesting is that the nitrogen isotope ratios of plant communities in southern Utah exhibit some very interesting variations depending on the extent to which the biological crusts have developed. One data set I collected showed the following:

Trail site sampled	$\delta^{13}C$ of surface soil, ‰	$\delta^{15}N$ of surface soil, ‰
soils with well-developed biological crusts; little if any human traffic	-15.9 ‰	+3.9 ‰
soils recovering after extensive human trampling	-16.1 ‰	+8.8 ‰

6 (12 points). Why should the presence or absence of the cryptobiotic crusts influence the nitrogen isotope ratios of surface soils?

(6 points) Cryptiobiotic crusts contain lichens, which are the primary source of nitrogen input through nitrogen fixation in southern Utah ecosystems. Nitrogen fixation results in the production of soil organic nitrogen that approaches 0 ‰.

(6 points) Thus, when cryptobiotic crusts are present on the landscape, they will tend to lower ^{15}N soil values. On the other hand, denitrifying bacteria in the soil convert ammonia from mineralization processes into gaseous nitrogen preferentially using ^{15}N organic nitrogen, resulting in residual organic matter that is ^{15}N enriched.

7 (12 points). If we were to examine the nitrogen isotope ratios of soil organically bound nitrogen in the soil at some depth below the soil surface in the soils with well-developed biological crusts, would the nitrogen isotope ratios be ^{15}N enriched or ^{15}N depleted relative to the surface?
Answer "**^{15}N enriched**" or "**^{15}N depleted** "and then provide a justification for your answer.

(5 points) ^{15}N enriched

(7 points) Denitrifying bacteria in the soil convert ammonia from mineralization processes into gaseous nitrogen preferentially using ^{15}N organic nitrogen, resulting in residual organic matter that is ^{15}N enriched. Since nitrogen input into the soil occurs primarily at the surface, then as denitrifying bacteria continue to process organic nitrogen with depth, the remaining organic nitrogen should become progressively ^{15}N enriched.

I then sampled a number of different locations near the Abajos Mountains of southern Utah where there were signs of biological crusts and juniper trees as well. The data I obtained are shown below and are extremely provocative. I hope to get time this summer to write these results up for publication as they certainly have some range management implications.

Site	$\delta^{15}N$ of surface soils at the site, ‰	$\delta^{15}N$ of juniper needles at the site, ‰	Soil nitrogen content at the site, mg N per g soil
1	+2.6	-0.2	0.53
2	+6.8	+3.6	0.21
3	+5.1	+2.2	0.28
4	+3.3	+0.3	0.44
5	+8.3	+5.2	0.10

8 (15 points). Based on the data set above, do roots of the juniper tree harbor nitrogen-fixing bacteria that provide all or a substantial proportion of the nitrogen used by the tree? Answer "**yes**" or "**no**" and provide an acceptable justification for your answer that explains the observations collected from across **all** sites and that takes into consideration changes in soil nitrogen content.

(5 points) No.

(10 points) Although there may be an initial suggestion from the data that juniper trees harbor nitrogen-fixing bacteria (based on observations at sites 1 and 4), the juniper needles have ^{15}N values that become progressively higher as soil nitrogen levels decrease. Were the trees to have had nitrogen-fixing bacteria, the opposite pattern would have been expected.