Stable Isotopes in Peat Profiles Reveal Long-term Carbon and Nitrogen Dynamics at SPRUCE

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Introduction

Peat is a large reservoir of stored carbon and peat cores preserve a long-term record of system carbon and nitrogen dynamics. Stable isotopes are one marker of carbon and nitrogen dynamics in peat cores. Here, we investigated controls over $\delta^{15}N$ and $\delta^{13}C$ patterns in peat cores from the Marcell S1 forested bog in northern Minnesota.

Methods

· Peat cores were collected in mid-August 2012 in 17 plots along 3 boardwalks extending out into bog S1 (Figure 1) using a modified hole saw (0-30 cm) or a Russian peat corer (30-250 cm depth).
· Hollows were sampled to -250 cm and hummocks to -10 cm. Cores were sampled every 10 cm to 1 m; every 25 cm from 1-2 m, every 50 cm thereafter. Cores were taken in treed or non-treed locations. Mean depth of core sections is reported.
· Foliage, roots, and fungi were also sampled.
· $\delta^{15}N$ and $\delta^{13}C$ in samples were measured at the University of new Hampshire; radiocarbon was measured at Lawrence Livermore National Laboratory.
· $\delta^{13}C$ patterns were analyzed using multiple regression in JMP with $\delta^{15}N$, %N, and %C as continuous variables and depth, plot location, topography (hummock or hollow), or vegetation (treed or non-treed) as nominal variables. $\delta^{15}N$ was analyzed using the same variables and $\delta^{13}C$.
· $\delta^{13}C$ and $\delta^{15}N$ were also correlated against radiocarbon ($\Delta^{14}C$).

Results

· $\delta^{13}C$ was lowest in hummocks (above 0 cm) and then increased by 3‰ to -85 cm (Figure 2a).
· $\delta^{15}N$ was lowest in hummocks and increased by up to 6‰ to -35 cm before declining (Figure 2b).
· The log C/N steadily declined to around 3 at -85 cm (C/N = 20) (Figure 2c).
· In multiple regression analyses, $\delta^{15}N$ and $\delta^{13}C$ correlated strongly with depth, plot location, %C, %N, and each other, with $\delta^{13}C$ also correlating with topography (Table 1). The models explained 85% and 74% of variance for $\delta^{13}C$ and $\delta^{15}N$.
· Depth accounted for <50% of variance and the depth coefficients for $\delta^{13}C$ and $\delta^{15}N$ correlated strongly (Figure 3).
· Plot location accounted for <15% of variance and the plot coefficients for $\delta^{13}C$ and $\delta^{15}N$ correlated negatively (Figure 4a), with high $\delta^{15}N$ and low $\delta^{13}C$ coefficients in the western lagg zone closer to uplands (Figure 4b).
· Patterns in $\delta^{15}N$ and $\delta^{13}C$ against radiocarbon (Figure 5a and 5b) were used to link stable isotopes to specific time periods.

Discussion/Conclusions

· The negative correlation of $\delta^{15}N$ with %N (Table 1) presumably reflected removal of ^{15}N-depleted N via denitrification, diffusion, or plant N transfer via mycorrhizal fungi. The step increase in the depth coefficient for $\delta^{15}N$ of ~3‰ from -25 cm to -35 cm (Figure 3) suggested that the N removal process primarily operates at a discrete depth, presumably corresponding to the juncture between aerobic and anaerobic layers defined by the water table.
· Higher $\delta^{15}N$ and lower $\delta^{13}C$ in plots closer to uplands (Figure 4b) may reflect distinct hydrology and accompanying shifts in C and N dynamics in the lagg area.
· The Suess effect and aerobic decomposition lowered $\delta^{13}C$ in recent surficial samples.
· Small increases in $\delta^{13}C$ at -112 cm (4290 calibrated years BP) and -85 cm (3820 calibrated years BP) may reflect C dynamics during a suspected transitional fen stage (based on paleoecology at a nearby bog, Verry and Janssens 2011), with reduced methanotrophy during this period retaining less ^{13}C-depleted carbon derived from methane than in later periods.
· This may reflect a phase during which sedges transported methane directly to the atmosphere, thereby minimizing the refixation in *Sphagnum* cells of ^{13}C-depleted, methanotrophic-derived carbon dioxide.
· A peak in $\delta^{13}C$ and trough in $\delta^{15}N$ at -400‰ $\Delta^{14}C$ (4220 calibrated years BP, Figure 5) suggests that processes increasing $\delta^{13}C$ such as high sedge abundance may decrease sequestration of ^{15}N-enriched organic matter.

Referencess:

Verry ES, Janssens J. 2011. Geology,vegetation, and hydrology of the S2 bog at the MEF: 12,000 years in northern Minnesota. *RK Kolka, Peatland Biogeochemisty and Watershed Hydrology at the Marcell experimental Forest*: 93-135.

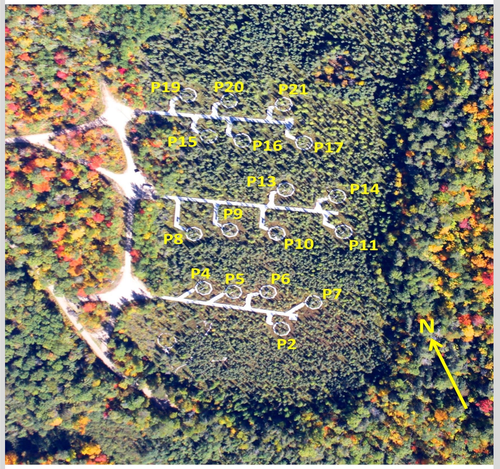

Figure 1. Aerial photograph of the S1 bog (23 September 2014) showing the 17 experimental plots (each 10.4 m in diameter to the outer edge of the visible perimeter boardwalk). Plot numbers on the image represent the plot areas within which peat was sampled.

Figure 2a

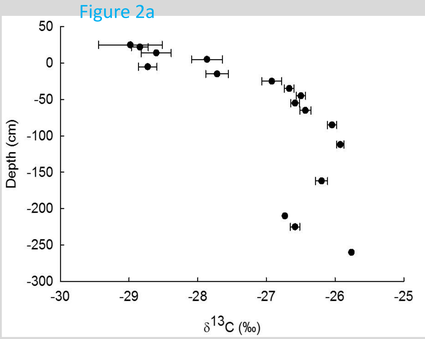

Figure 2b

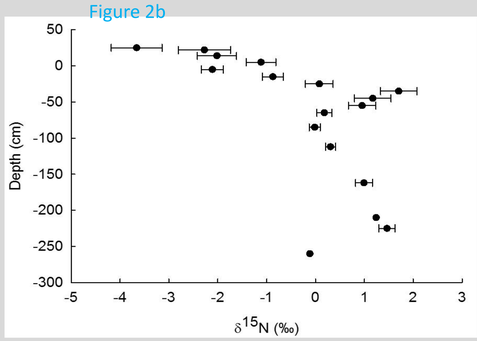

Figure 2. $\delta^{15}N$, $\delta^{13}C$, and log C/N versus depth (Figure 2a, 2b, and 2c). Values (±SE) are averaged across hummock versus hollow cores and across treed versus non-treed cores. Averages (±SE) are given for each depth, with n given in parentheses following the depth: 25 cm (3), 22 cm (7), 14 cm (14), 5 cm (14), -5 cm (19), -15 cm (17), -25 cm (17), -35 cm (15), -45 cm (17), -55 cm (17), -65 cm (17), -85 cm (18), -112 cm (17), -162 cm (17), -210 cm (1), -225 cm (8), -260 cm (1).

Figure 2c

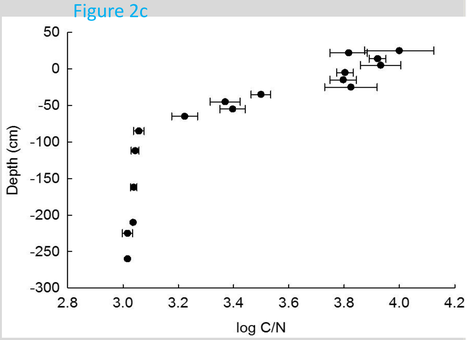

Table 1. Regression model for explaining $\delta^{13}C$ and $\delta^{15}N$ in peat profiles at SPRUCE. *Vegetated* vs non-vegetated, *hummock* vs. hollow topography. Plot and depth treated as nominal variables. Value = Coefficient ± standard error; Var. = % variance explained. n = 219.
$\delta^{13}C$ model, adjusted r^2 = 0.853, p <0.001 $\delta^{15}N$ model, adjusted r^2 = 0.738, p <0.001

Source	Value±SE	%Var.	P	Source	Value±SE	%Var.	P
Intercept	-30.68±1.14	--	--	Interc	33.41±4.47	--	--
$\delta^{15}N$	0.18±0.03	14.4	**<0.001**	$\delta^{13}C$	0.74±0.14	9.7	**<0.001**
%N	0.366±0.141	3.4	**0.010**	%N	-1.061±0.277	5.0	**<0.001**
%C	0.066±0.024	3.9	**0.006**	%C	-0.235±0.045	9.1	**<0.001**
Vegetated	-0.07±0.07	0.6	0.287	Veg	0.12±0.14	0.3	0.367
Hummock	0.29±0.12	1.9	0.056	Humm	1.11±0.29	4.8	**<0.001**
Plot	--	16.7	**0.008**	Plot	--	17.8	**<0.001**
Depth	--	59.2	**<0.001**	Depth	--	53.3	**<0.001**

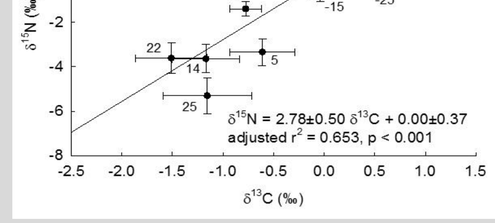

Figure 3. Depth coefficients of $\delta^{15}N$ and $\delta^{13}C$ from regression models correlate in peat profiles. The depth in cm is indicated next to coefficients (±SE).

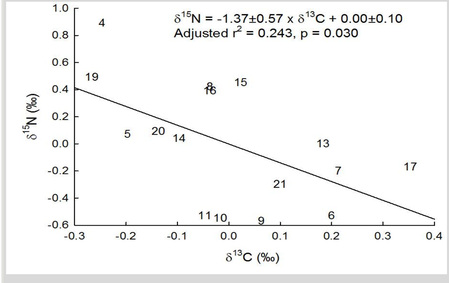

Figure 4a. Plot coefficients of $\delta^{15}N$ and $\delta^{13}C$ from regression models correlate in peat profiles. Standard error bars omitted for clarity, and averaged 0.24‰ for $\delta^{15}N$ and 0.12‰ for $\delta^{13}C$. The plot number is the symbol for the paired coefficient values. Data plotted below, equation, $\delta^{15}N$ = -1.37±0.57 × $\delta^{13}C$ + 0.00±0.10, adjusted r^2 = 0.243, p = 0.030.

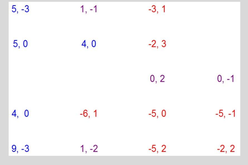

Figure 4b. Plot coefficients of $\delta^{15}N$ and $\delta^{13}C$ showing the spatial relationship among coefficient values. Plot locations as given as in Figure 1**, with plot 4 at lower** left. Values are given × 10 for the $\delta^{15}N$ and $\delta^{13}C$ coefficients, as ($\delta^{15}N$, $\delta^{13}C$). Coefficients are color-coded, with blue = high $\delta^{15}N$, red = low $\delta^{15}N$, and purple intermediate $\delta^{15}N$.

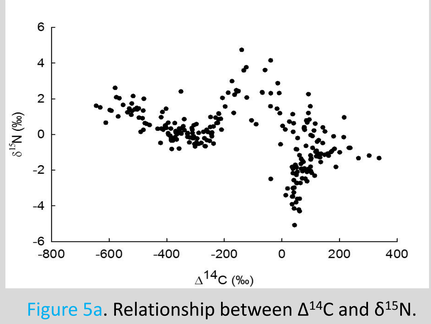

Figure 5a. Relationship between $\Delta^{14}C$ and $\delta^{15}N$.

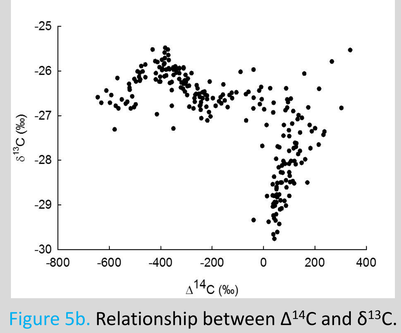

Figure 5b. Relationship between $\Delta^{14}C$ and $\delta^{13}C$.

Acknowledgements

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