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Biogeochemistry of a Forested Ecosystem

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The publisher regrets that the online and print versions of this book were published with some errors on the below pages of this book. The correct datas are listed below:

On page xx, in the "Contents" a new entry "Trace Metals" has been added before "Throughfall and Stemflow". The revised contents is given below:

The online version of the original book can be found at
http://dx.doi.org/10.1007/978-1-4614-7810-2

On page 14, Photograph 3 has been replaced and the new photograph is given below:

Photograph 3 Hubbard Brook at an elevation of about 215 m. The characteristic boulder substrate and “stair-step” nature of this fifth-order stream are evident

On page 104, Photograph 8 has been replaced and the new photograph is given below:

Photograph 8 Collecting a streamwater sample from Watershed 4 at the Hubbard Brook Experimental Forest (Photo by D.C. Buso)

On page 111, the term "HBEF" in the caption of Table 25 has been expanded to "Hubbard Brook Experimental Forest".

Table 25 Seasonal average streamwater exports for Watershed 6 of the Hubbard Brook Experimental Forest for two decades (1964–1973 and 2000–2009)

Table 34 on page 165 has been modified and the new version is given below:

Table 34 **Nutrient budgets for various temperate zone terrestrial ecosystems in Eastern North America (kg/ha-year)**

Location[a]	Atmospheric deposition	Streamwater output	Net gain or loss	Annual precipitation (cm)	Dominant vegetation[b]	Geology[c]
Calcium						
Coweeta, NC (1)	4.4	5.3	–0.9	215	Q, C, Ac	M*g*, M*sh*
HBEF, NH (2)	1.0[d]	6.6	–5.6	165	Ac, F, B, Pic, Ab, Ts	I*g*, M*sh*
Cone Pond Inlet, NH (3)	1.2[d]	2.5	–1.3	145	Ts, Pic, Ab	I*g*
Long Island, NY (4)	3.3	9.6[e]	–6.3	124	Q, Pin	S*s*
E. Bear Brook, ME (5)	0.4[f]	10.1	–9.7	159	F, Ac, B, Pic, Ab, Ts	I*g*, M*sh*
S.E. U.S. (6)	6	19	–13	127	Q, Pin	S*s*, S*sh*, M*g*, M*sh*
Fernow, WV (7)	2.2[d]	8.6	–6.4	125	Q, L, Ac, B, F	S*s*, S*sh*, M*s*, M*sh*
Taughannock Creek, NY (8)	11.2[d] (0.8[g])	182	–171	96 (111[g])	Ac, Ti, Ts	S*sh*, S*c*
Sleepers River, VT (9)	1.3[d]	226	–225	149	Ac, B, Fr, F	M*c*
Walker Branch, TN (10)	1.3[f]	147	–146	118	Q, C	S*c*
Biscuit Brook, NY (11)	1.2[h]	16.5	–15.3	165[i]	Ab, Ac, B, F, Pic, Ts	S*s*
Turkey Lakes Watershed, ON (Canada) (12)	2.7[h]	20.8	–18.1	107	Ac, B, Pic, Ts	I*g*
Magnesium						
Coweeta, NC	1.0	3.1	–2.1	215	Q, C, Ac	M*g*, M*sh*
HBEF, NH	0.3[d]	2.2	–1.9	165	Ac, F, B, Pic, Ab, Ts	I*g*, M*sh*
Cone Pond Inlet, NH	0.3[d]	0.8	–0.5	145	Ts, Pic, Ab	I*g*
Long Island, NY	2.1	7.3[e]	–5.2	124	Q, Pin	S*s*
E. Bear Brook, ME	0.4[f]	2.5	–2.1	159	F, Ac, B, Pic, Ab, Ts	I*g*, M*sh*
S.E. U.S.	2	6	–4	127	Q, Pin	S*s*, S*sh*, M*g*, M*sh*
Fernow, WV	0.3[d]	3.3	–3.0	125	Q, L, Ac, B, F	S*s*, S*sh*, M*s*, M*sh*
Taughannock Creek, NY	1.6[d] (0.1[g])	34.8	–33.2	96 (111[g])	Ac, Ti, Ts	S*sh*, S*c*
Sleepers River, VT	0.2[d]	9.5	–9.3	149	Ac, B, Fr, F	M*c*
Walker Branch, TN	0.2[f]	77	–77	118	Q, C	S*c*
Biscuit Brook, NY	0.3[h]	3.5	–3.2	165[i]	Ab, Ac, B, F, Pic, Ts	S*s*
Turkey Lakes Watershed, ON (Canada)	0.5[h]	1.5	–1.0	107	Ac, B, Pic, Ts	Ig

Sodium						
Coweeta, NC	3.6	8.2	–4.6	215	Q, C, Ac	M*g*, M*sh*
HBEF, NH	1.1[d]	7.2	–6.0	165	Ac, F, B, Pic, Ab, Ts	I*g*, M*sh*
Cone Pond Inlet, NH	1.0[d]	4.6	–3.6	145	Ts, Pic, Ab	I*g*
Long Island, NY	17	23[e]	–6	124	Q, Pin	S*s*
E. Bear Brook, ME	5.2[f]	15.6	–10.4	159	F, Ac, B, Pic, Ab, Ts	I*g*, M*sh*
S.E. U.S.	5	26	–21	127	Q, Pin	S*s*, S*sh*, M*g*, M*sh*
Taughannock Creek, NY	1.4[d] (0.3[g])	18.9	–17.5	96 (111[g])	Ac, Ti, Ts	S*sh*, S*c*
Sleepers River, VT	0.8[d]	6.5	–5.7	149	Ac, B, Fr, F	M*c*
Walker Branch, TN	1.0[f]	2.7	–1.7	118	Q, C	S*c*
Biscuit Brook, NY	1.2	2.2	–1.0	165[i]	Ab, Ac, B, F, Pic, Ts	S*s*
Turkey Lakes Watershed, ON (Canada)	0.7[h]	2.1	–1.4	107	Ac, B, Pic, Ts	I*g*
Potassium						
Coweeta, NC	4.1	5.0	–0.9	215	Q, C, Ac	M*g*, M*sh*
HBEF, NH	0.6[d]	1.4	–0.8	165	Ac, F, B, Pic, Ab, Ts	I*g*, M*sh*
Cone Pond Inlet, NH	0.4	0.3	+0.1	145	Ts, Pic, Ab	I*g*
Long Island, NY	2.4	3.9[e]	–1.5	124	Q, Pin	S*s*
E. Bear Brook, ME	0.5[f]	1.8	–1.3	159	F, Ac, B, Pic, Ab, Ts	I*g*, M*sh*
S.E. U.S.	1	6	–5	127	Q, Pin	S*s*, S*sh*, M*g*, M*sh*
Fernow, WV	1.1[d]	3.6	–2.5	125	Q, L, Ac, B, F	S*s*, S*sh*, M*s*, M*sh*
Taughannock Creek, NY	1.1[d] (0.2[g])	5.6	–4.5	96 (111[g])	Ac, Ti, Ts	S*sh*, S*c*
Sleepers River, VT	0.7[d]	11.2	–10.5	149	Ac, B, Fr, F	M*c*
Biscuit Brook, NY	0.2[h]	2.7	–2.5	165[i]	Ab, Ac, B, F, Pic, Ts	S*s*
Turkey Lakes Watershed, ON (Canada)	0.3[h]	0.6	–0.3	107	Ac, B, Pic, Ts	I*g*
Dissolved inorganic nitrogen (NH_4–N + NO_3–N)						
Coweeta, NC	6.2	0.66	+5.5	215	Q, C, Ac	M*g*, M*sh*
HBEF, NH	5.3[j]	0.23	+5.1	165	Ac, F, B, Pic, Ab, Ts	I*g*, M*sh*
Cone Pond Inlet, NH	3.5[d, k]	<0.1	+3.5	145	Ts, Pic, Ab	I*g*
E. Bear Brook, ME	1.7[f]	0.3	+1.4	159	F, Ac, B, Pic, Ab, Ts	I*g*, M*sh*

(continued)

Table 34 (continued)

Location[a]	Atmospheric deposition	Streamwater output	Net gain or loss	Annual precipitation (cm)	Dominant vegetation[b]	Geology[c]
S.E. U.S.	2[k]	1[k]	+1[k]	127	Q, Pin	S*s*, S*sh*, M*g*, M*sh*
Fernow, WV	7.4[h]	4.4	+3.0	125	Q, L, Ac, B, F	S*s*, S*sh*, M*s*, M*sh*
Taughannock Creek, NY	10.3[d] (5.4[g])	5.6	+4.7	96 (111[g])	Ac, Ti, Ts	S*sh*, S*c*
Sleepers River, VT	4.7[d]	1.9	+2.8	149	Ac, B, Fr, F	M*c*
Walker Branch, TN	1.7[f]	0.03	+1.7	118	Q, C	S*c*
Biscuit Brook, NY	8.2[h]	3.3	+4.9	165[i]	Ab, Ac, B, F, Pic, Ts	Ss
Turkey Lakes Watershed, ON (Canada)	25.6[h]	2.1	+23.5	107	Ac, B, Pic, Ts	I*g*
Phosphorus						
Coweeta, NC	0.04	<0.01	+0.04	215	Q, C, Ac	M*g*, M*sh*
HBEF, NH	0.02[d]	0.01	+0.01	165	Ac, F, B, Pic, Ab, Ts	I*g*, M*sh*
Taughannock Creek, NY	0.186[d] (0.03[g])	0.197	–0.011	96 (111[g])	Ac, Ti, Ts	S*sh*, S*c*
Sleepers River, VT	0.15[d]	0.13	+0.02	149	Ac, B, Fr, F	M*c*
Walker Branch, TN	–	0.03	–	118	Q, C	S*c*
Biscuit Brook, NY	–	<0.001	–	165[i]	Ab, Ac, B, F, Pic, Ts	S*s*
Turkey Lakes Watershed, ON (Canada)	–	0.01	–	107	Ac, B, Pic, Ts	I*g*
Sulfate–Sulfur						
Coweeta, NC	7.5	6.4	+1.1	215	Q, C, Ac	M*g*, M*sh*
HBEF, NH	6.7[j]	12.6	–5.9	165	Ac, F, B, Pic, Ab, Ts	I*g*, M*sh*
Cone Pond Inlet, NH	6.7[d]	9.7	–3.0	145	Ts, Pic, Ab	I*g*
E. Bear Brook, ME	3.7[f]	13.2	–9.5	159	F, Ac, B, Pic, Ab, Ts	I*g*, M*sh*
S.E. U.S.	8	7	+1	127	Q, Pin	S*s*, S*sh*, M*g*, M*sh*
Fernow, WV	11.6[h]	8.1	+3.5	125	Q, L, Ac, B, F	S*s*, S*sh*, M*s*, M*sh*
Taughannock Creek, NY	18.1[d] (4.4[g])	38	–19.9	96 (111[g])	Ac, Ti, Ts	S*sh*, S*c*
Sleepers River, VT	3.8[d]	17.6	+	149	Ac, B, Fr, F	M*c*
Walker Branch, TN	5.5[f]	5.4	+0.1	118	Q, C	S*c*
Biscuit Brook, NY	8.2[h]	9.9	–1.7	165[i]	Ab, Ac, B, F, Pic, Ts	S*s*
Turkey Lakes Watershed, ON (Canada)	6.1[h]	5.5	+0.6	107	Ac, B, Pic, Ts	I*g*

Chloride						
Coweeta, NC	6.2	9.1	–2.9	215	Q, C, Ac	M*g*, M*sh*
HBEF, NH	2.6[j]	3.3	–0.7	165	Ac, F, B, Pic, Ab, Ts	I*g*, M*sh*
Cone Pond Inlet, NH	1.9[d]	3.4	–1.5	145	Ts, Pic, Ab	I*g*
E. Bear Brook, ME	8.3[f]	18.0	–9.7	159	F, Ac, B, Pic, Ab, Ts	I*g*, M*sh*
Taughannock Creek, NY	11.5[d] (0.7[g])	41.7	–30.2	96 (111[g])	Ac, Ti, Ts	S*sh*, S*c*
Sleepers River, VT	1.7[d]	2.4	–0.7	149	Ac, B, Fr, F	M*c*
Walker Branch, TN	2.2[f]	6.5	–4.3	118	Q, C	S*c*
Biscuit Brook, NY	2.5[h]	3.7	–1.2	165[i]	Ab, Ac, B, F, Pic, Ts	S*s*
Turkey Lakes Watershed, ON (Canada)	0.9[h]	0.6	+0.3	107	Ac, B, Pic, Ts	I*g*

[a](1) S. Laester, personal communication for precipitation and streamwater chemistry in Watershed 27 (2008). (2) Present study; average for 2008 water-year. (3) S. Bailey, unpublished averages for water-year 2007–2008 (4) Woodwell and Whittaker (1967). (5) L. Rustad, I. Fernandez for 2008 water-year. (6) Gambell and Fisher (1966). (7) M.B. Adams for 2005 calendar year for Watershed 4 (Adams et al. 2006). (8) Likens (1974a, b) for 1970–1971. (9) S. Bailey and J. Shanley, unpublished averages for water-year 2008 and 2009, Watershed 9, personal communication. (10) Lutz et al. (2012); 2008 water-year. (11) D. Burns, personal communication, calendar-year, volume-weighted average for 2008. (12) I. Creed, personal communication, average for 2006 water-year catchment #32

[b] Vegetation footnotes: Ab, Abies; Ac, Acer; B, Betula, C, Carya; F, Fagus; Fr, Fraxinus, L, Liriodendron; Pin, Pinus; Pic, Picea; Pr, Prunus; Ps, Pseudotsuga; Q, Quercus; Ti, Tilia; Ts, Tsuga

[c]Geology footnotes: I*g*, igneous, granitic; S*c*, sedimentary, carbonate; S*sh*, sedimentary, shale; S*s*, sedimentary, sandstone; M*x*, Metamorphic (*x* refers to subscripts used above

[d]Bulk precipitation

[e]To water table

[f]Wet only

[g]Wet plus dry data for 2010 from nearby Connecticut Hill CASTNET site (T.J. Butler)

[h]Wet plus dry deposition

[i]Mean 2007–2009

[j]Bulk precipitation plus dry deposition (see Table 17 for bulk precipitation)

[k]NO_3–N only

On page 170, in the paragraph beginning "Adjustments for net gaseous input...." the sentence "Nevertheless, considerable effort..." has been moved to the end of the paragraph. The revised page is listed below:

Adjustments for net gaseous input and dry deposition of aerosols were not incorporated systematically in Table 34, but much more information is available than 35 years ago. Recently, Mitchell and colleagues (2011) used a new approach to predict SO_2 concentrations as a function of SO_2 emissions, latitude and longitude, and then estimated dry deposition from relations between concentrations and deposition flux from the U.S. CASTNET and Canadian CAPMoN networks at 15 sites in northeastern USA and southeastern Canada. Although dry deposition estimates are still relatively uncertain within the mass balance for these systems, this approach seems promising and allowed the prediction of dry deposition values for the HBEF of 0.5 to 2.5 kg S/ha-year. Nevertheless, considerable effort should be devoted to the problem of measuring dry deposition and gaseous exchange in forested ecosystems in the future in order to reflect quantitatively these important fluxes in biogeochemical cycling and fluxes.

On page 173, in the list entry 3, the sentence beginning "Flux is greatly influenced..." has been revised and the corrected sentence is given below:

Flux is greatly influenced by hydrology and, during 49 years, precipitation has ranged from 95 to 186 cm/year in W6 at the HBEF.

On page 174, a reference citation "van Doorn et al. 2011" has been added after "Likens 2010" at the end of list entry 6, in the paragraph beginning "Enigmatically, rapid forest...".

Enigmatically, rapid forest biomass accumulation has ceased since ~1982 at HBEF due to increased tree mortality, related in part to the effects of acid rain (Likens et al. 1998, 2002a; Siccama et al. 2007). This important finding is the subject of intense, ongoing investigation (Likens and Franklin 2009; Likens 2010; van Doorn et al. 2011).

On page 178, in list entry 23, the comma after "reduction" has been removed and the corrected entry is given below:

23. Many of the important biogeochemical relationships and transformations within the forest ecosystem are regulated by microorganisms, such as nitrogen fixation, nitrification, and denitrification or sulfur oxidation and reduction at HBEF (e.g., Zhang et al. 1999; Findlay 2013; Groffman and Rosi-Marshall 2013).

On page 178, in list entry 24, the word "Stream water" has been closed up to read "Streamwater" in the sentence "Streamwater chemistry varied....".

24. Streamwater chemistry collected and measured at high density in all tributaries throughout the Hubbard Brook Valley during spring (May–July) and fall (October–December) of 2001 gave a remarkable new landscape view of streamwater chemistry in the valley (Likens and Buso 2006). Streamwater chemistry varied throughout the valley in relation to changes in elevation, distance from origin of streamflow, drainage area, and type of drainage. Concentrations of hydrogen ion, aluminum, and dissolved organic carbon varied by two to tenfold in relation to these factors, but other elements, e.g., chloride and dissolved silica, changed relatively little throughout the valley. The main Hubbard Brook, a fifth-order river, changed concentration very little throughout its 13-km length despite inputs from some 20 major tributaries.

In References, on page 193, the references "Likens GE, Bormann FH (1970); Likens GE, Bormann FH (1985); Likens GE, Bormann FH (1995)" have been rearranged and the revised order is given below:

Likens GE, Bormann FH (1970) Chemical analyses of plant tissues from the Hubbard Brook Ecosystem in New Hampshire. Bulletin 79, Yale University School of Forestry, New Haven, CT, 25 pp

Likens GE, Bormann FH (1972) Nutrient cycling in ecosystems. In: Wiens J (ed) Ecosystem structure and function. Oregon State University Press, Corvallis, OR, pp 25–67

Likens GE, Bormann FH (1974a) Acid rain: a serious regional environmental problem. Science 184(4143):1176–1179

Likens GE, Bormann FH (1974b) Linkages between terrestrial and aquatic ecosystems. Bioscience 24(8):447–456

Likens GE, Bormann FH (1985) An ecosystem approach. In: Likens GE (ed) An ecosystem approach to aquatic ecology: Mirror Lake and its environment. Springer-Verlag, New York, pp 1–8

Likens GE, Bormann FH (1995) Biogeochemistry of a forested ecosystem, 2nd edn. Springer-Verlag, New York, 159 pp

Likens GE, Buso DC (2006) Variation in streamwater chemistry throughout the Hubbard Brook Valley. Biogeochemistry 78:1–30

Likens GE, Buso DC (2010a) Long-term changes in streamwater chemistry following disturbance in the Hubbard Brook Experimental Forest, USA. Verh Int Verein Limnol 30(10):1577–1581

Likens GE, Buso DC (2010b) Salinization of Mirror Lake by road salt. Water Air Soil Pollut 205:205–214

Likens GE, Buso DC (2012) Dilution and the elusive baseline. Environ Sci Technol 46(8): 4382–4387. doi:10.1021/es3000189

Likens GE, Davis MB (1975) Post-glacial history of Mirror Lake and its watershed in New Hampshire, U.S.A.: an initial report. Verh Int Verein Limnol 19:982–993

Likens GE, Fallon Lambert K (1998) The importance of long-term data in addressing regional environmental issues. Northeast Nat 5(2):127–136

Likens GE, Franklin JF (2009) Ecosystem thinking in the Northern Forest – and beyond. Bioscience 59(6):511–513

Likens GE, Moeller RE (1985) Chemistry. In: Likens GE (ed) An ecosystem approach to aquatic ecology: Mirror Lake and its environment. Springer-Verlag, New York, pp 392–410

Likens GE, Bormann FH, Johnson NM, Pierce RS (1967) The calcium, magnesium, potassium and sodium budgets for a small forested ecosystem. Ecology 48(5):772–785

Likens GE, Bormann FH, Johnson NM, Fisher DW, Pierce RS (1970) The effect of forest cutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed-ecosystem. Ecol Monogr 40(1):23–47