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Forest vegetation in relation to surface water chemistry in the North Branch of the Moose River, Adirondack Park, N.Y.

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Abstract. The Regional Integrated Lake-Watershed Acidification Study (RILWAS) was conducted to identify and to quantify the environmental factors controlling surface water chemistry in forested watersheds of the Adirondack region of New York. The RILWAS vegetation research was designed to: (1) compare the quantitative patterns of forest cover and tree community structure in the study catchments of the Moose River drainage system; and (2) identify important vegetation differences among study watersheds that might help to explain inter-watershed differences in water chemistry and aquatic responses to acidic deposition. Field transect data indicated that the overall drainage system includes 50% mixed forest cover, 38% hardwood forest, 10% coniferous forest, and 2% wetland cover. Major tree species include yellow birch, red spruce, American beech, sugar maple, eastern hemlock, and red maple. Analysis of forest structure indicated that mean weighted basal area estimates ranged two-fold from 24–48 $m^2 ha^{-1}$ among watersheds. Likewise, mean weighted estimates for aboveground biomass and aboveground annual productivity ranged among watersheds from 160 to 320 MT ha^{-1} and from 8 to 18 MT ha^{-1} yr^{-1}, respectively. Results showed that differences in surface water chemistry were independent of vegetation differences among watersheds.

The Regional Integrated Lake-Watershed Acidification Study (RILWAS) was conducted to identify and to quantify the environmental factors controlling surface water chemistry in forested watersheds of the Adirondack region of New York. Although the overall investigation included a range of contrasting forested watersheds throught the Adirondacks, much of RILWAS focused on the complex chain-lake system in the North Branch of the Moose River (Goldstein et al. 1987). The RILWAS vegetation research effort was designed to complement parallel studies of geology (Newton et al., 1986), hydrology (Peters and Driscoll, 1987), water chemistry (Driscoll et al., 1987), and fish ecology (Schofield and Driscoll 1987) in the Moose River system. Specific objectives of the descriptive vegetation studies were as follows: (1) to compare the quantitative patterns of forest cover and tree community structure in the study catchments of the Moose River drainage system; and (2) to identify important vegetation differences among watersheds that might help to explain inter-watershed differences in water chemistry and aquatic responses to acidic deposition.

The study was conducted within the North Branch of the Moose River in the central Adirondack Park region of New York State (43°45' to 43°51' N, 74°50' to 74°55' W). This heavily forested region of the Northeast is dominated by the maple-beech-birch and spruce-fir cover types (Eyre 1980). Climate for the region is characterized by a mean annual temperature of 5 °C and total annual precipitation averaging 100–120 cm. The geology of the upper Moose River basin is characterized by grantic gneiss and interlayered meta-sedimentary bedrock, overlain with a mantle of glacial till that the averages < 3m in thickness (Newton et al., 1987). Soils in the basin are predominantly Spodosols, Histosols, and Inceptisols. Additional details on the geology, soils, hydrology and water chemistry within the study area are available in the companion papers by Newton et al., (1987), Peters and Driscoll (1987) and Driscoll et al., (1987).

Forest cover types in the study area were sampled and were mapped during the summer of 1982 and 1983 using a combination of techniques, including air photo interpretation, ground reconnaissance, and quantitative transect sampling. At the initiation of the sampling, air photos (1978, scale 1:24,000) were used to classify each watershed into major forest cover types based upon tone and textural differences. Tree species in each watershed were sampled using 2 m wide belt transects oriented along specific compass bearings within each cover type. Individual belt transects were usually 210 m in length, although some transects were extended beyond that distance to allow more complete sampling of large heterogeneous stands. Within each transect, all trees > 2.5 cm dbh (diameter breast height) were recorded for diameter, species, condition (live or dead), and transect position. Upon completion, the position of each transect was carefully noted on a U.S.G.S. topographic map and on an air photo acetate overlay. Total transect sampling areas within each watershed varied from 0.08 to 0.46 ha.

The field transect data from each cover type and watershed were used to compute estimates by species for each of the following quantitative stand parameters: live tree density, live tree frequency, live tree basal area, mean diameter, and importance value (Whittaker 1970). During data reduction, the cover type transect data from each watershed were pooled and were averaged with areal weighting into three major cover types: hardwood, conifer, and mixed. These cover types were delineated using the following guidelines: (1) in hardwood forest, at least two-thirds or the total community importance value (I.V. = relative density + relative frequency + relative basal area) was represented by hardwood species; (2) in conifer forest, at least two-thirds of the community importance value was contributed by conifers; and (3) mixed communities fell between the bounds for the hardwood and coniferous types. A vegetation map was prepared for the study area as described by Cronan and DesMeules (1985).

During the second field season, tree cores were collected on a limited basis from each RILWAS catchment (Cronan et al., 1985). The objective

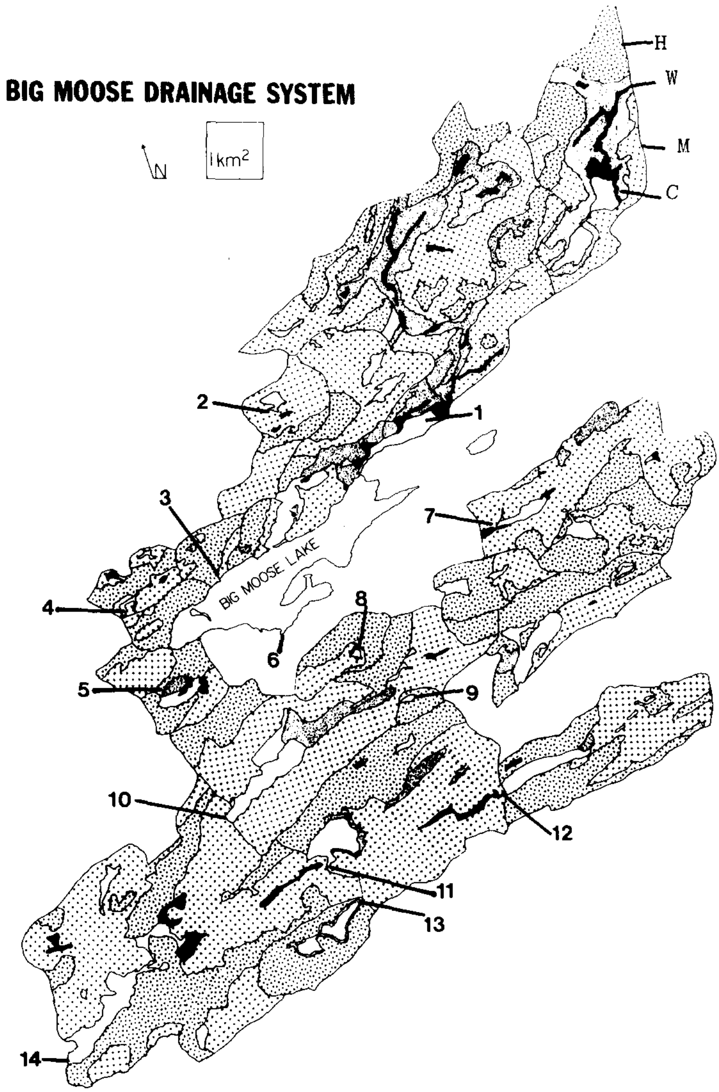

Figure 1. Distribution of forest cover types in the North Branch of the Moose River drainage system. Cover types include mixed forest (M), hardwood forest (H), coniferous forest (C), and wetland (W). Numbers correspond to watershed names in Table 3.

of this survey was to develope age versus dbh relationships for the major species in each watershed and to collect growth increment data that could be used to estimate recent forest productivity. These data were used to develop species-specific regressions relating tree age and average growth increment to the field dbh data.

Using the field data base and selected forest inventory values from the

Table 1. Distribution of forest cover types within the immediate drainage area for each catchment in the North Branch of the Moose River, New York. Forest age ranges are also indicated

Catchment	Percent Cover Type				Age range for Dominant Trees (YR)
	Hardwood (%)	Mixed (%)	Conifer (%)	Wetland (%)	
Andy's	32	29	33	6	55–125
Cascade	51	46	3	0	60–120
Chub	71	29	0	0	65–300
Constable	21	72	6	1	60–180
Dart's	24	66	7	1	55–115
Mays	64	34	0	2	55–165
Merriam	13	87	0	0	60–145
Moss	30	62	6	2	15–125
North Bay	71	29	0	0	60–215
Pancake	78	20	0	2	60–70
Queer	57	38	4	1	55–150
Rondaxe	33	64	0	3	55–150
Sis/Bubb	93	7	0	0	50–135
Squash	43	57	0	0	60–110
Sub-Squash	81	19	0	0	60–110
West	46	48	4	2	60–150
Townsend	64	35	1	0	55–125
Windfall	92	0	8	0	60–155
Entire Drainage System	38%	50%	10%	2%	

literature, an effort was made to compute estimates of tree canopy leaf area, forest aboveground biomass, and forest net aerial productivity for each cover type and watershed. For the calculations of leaf area, biomass, and productivity, species-specific diameter measurements from each cover type were combined with species-specific regression on diameter equations developed by Whittaker et al., (1974), Tritton and Hornbeck (1982), Smith and Brand (1983), Young et al., (1964), and Young and Carpenter (1967). The resulting species-specific estimates were extrapolated to a stand level using stem density data and were weighted by cover type area to produce overall watershed level estimates. Productivity estimates were also developed using the field data on tree growth increments. Here, rather than relying solely on the published productivity regressions listed above, the growth increment data were used with the published biomass regressions listed above to produce two successive estimates of standing biomass for a given species and cover type. Then, productivity was calculated as the difference between the biomass estimates.

The field data were used to develop quantitative descriptions of tree community composition and structure for the forest cover types in each watershed (Cronan et al., 1985). Results indicated that coniferous stands were dominated by red spruce, red maple, eastern hemlock, balsam fir, and

Table 2. Comparison of mean weighted stand structure in the RILWAS catchments

Catchment	Basal Area $m^2 ha^{-1}$	Density stems ha^{-1}	Leaf Area Index	Biomass MT ha^{-1}	Annual Production* 1 MT $ha^{-1} yr^{-1}$	2
Andy's Creek	32.0	1810	7.1	166	8.2	12.3
Cascade	37.3	1810	8.4	228	12.4	18.0
Chub	41.4	1260	9.0	326	15.3	17.6
Constable	41.5	1430	9.0	280	13.5	17.4
Dart's	41.8	1780	9.2	239	13.0	16.4
Mays	36.2	1200	7.8	246	11.7	17.3
Merriam	39.5	1920	8.8	258	14.0	19.7
Moss	44.5	1340	8.3	255	12.1	14.1
Pancake	32.3	2030	7.5	220	10.4	22.2
Rondaxe	48.1	1690	10.4	286	15.9	20.0
Sis/Bubb	41.4	1780	8.8	277	13.4	20.2
Squash	37.9	1670	8.3	231	12.8	19.6
West	48.3	1290	10.0	322	16.2	16.7
Townsend	37.7	1430	8.3	246	12.6	17.7
Windfall	24.9	910	5.6	171	8.9	10.9

* Estimate 1 used the productivity regression equations cited in the text.
* Estimate 2 used the biomass difference approach and the tree increment data from the RILWAS catchments.

yellow birch. Mixed forest stands were generally dominated by yellow birch, red spruce, eastern hemlock, red maple, sugar maple, and American beech. Finally, the predominant tree species in the hardwood cover type were yellow birch, American beech, sugar maple, and red spruce. Throughout most of the drainage system, the forest cover exhibited a two-tiered age structure. Many of the dominant trees were 50 to 70 yr. old; yet, there were also significant numbers of older yellow birch, hemlock, and various other species in the age range of 120 to 180 yr. old. As a whole, the northern Moose River drainage area was dominated by intermediate aged aggrading forest composed of 50% mixed cover, 38% hardwood cover, 10% coniferous cover, and 2% wetland cover (Table 1).

The general differences in forest structure among the study catchments of the Moose River drainage area are presented in Table 2. Mean weighted basal area values for the watersheds ranged from approximately 25 m^2 ha^{-1} at Windfall Pond to 48 m^2 ha^{-1} at West Pond. Estimates for mean weighted leaf area index ranged from 5.6 at Windfall Pond to 10.4 at Rondaxe Lake. Weighted mean estimates for aboveground tree biomass varied two-fold from approximately 160 MT ha^{-1} in the Andy's Creek area to approximately 320 MT ha^{-1} in the West Pond and Chub Pond catchments. Similarly, productivity estimates varied two-fold from 8 to 9 MT ha^{-1} yr^{-1} in the Windfall and Andy's Creek catchments to 18 MT ha^{-1} yr^{-1} in the Rondaxe Lake catchment.

The general inter-watershed differences in solution chemistry have been

Table 3. Summary of mean annual water chemistry parameters for the RILWAS catchments. Data from Driscoll et al., (1986)

Catchment	pH	SBC* $\mu eq\ l^{-1}$	SO_4^{2-} $\mu eq\ l^{-1}$	DOC $\mu mol\ l^{-1}$
1. Andy's Creek	5.0	162	136	566
2. Merriam Pond	4.5	107	136	450
3. Pancake Creek	5.3	163	132	525
4. Squash Pond	4.6	118	132	580
5. West Pond	5.2	167	112	679
6. Big Moose	5.1	161	140	339
7. Constable Creek	5.2	160	148	417
8. Townsend Pond	5.2	179	154	255
9. Windfall Pond	5.9	220	140	387
10. Dart's Lake	5.2	163	140	321
11. Moss Lake	6.4	246	140	310
12. Cascade Lake	6.5	266	138	326
13. Bubb Lake	6.1	194	132	279
14. Lake Rondaxe	5.9	195	134	303

* SBC = Sum of Base Cations

described for the RILWAS system by Driscoll et al., (1987) and are summarized in Table 3. Using the combined water chemistry and vegetation data sets, an effort was made to examine possible biogeochemical interactions between forest cover and surface water chemistry in the Moose River drainage system. At the outset, it was hypothesized that surface sulfate concentrations would be highest in coniferous watersheds because of increased leaf surface area and dry deposition capture (Matzner 1983). However, results indicated that sulfate concentrations were relatively constant across the study area (except at West Pond where sulfate reduction lowered sulfate levels). Thus, mean sulfate concentrations in hardwood watersheds (> 75% hardwood cover) averaged 135 $\pm$ 4 μeq $SO_4^{2-}\ l^{-1}$, while drainage from coniferous watersheds (< 25% hardwood cover) averaged 141 $\pm$ 6 μeq $SO_4^{2-}\ l^{-1}$.

Results also indicated that variations in surface water chemistry between watersheds could not be clearly accounted for by differences in the successional status of forest vegetation. Virtually all of the study catchments were found to contain intermediate aged aggrading forests. As such, these aggrading forest stands acted as strong sinks for inorganic nitrogen, so that nearly all of the watersheds exhibited marked seasonal fluctuations in stream water nitrate concentrations (Driscoll et al., 1987), with minimum values during summer (Table 4). Another critical factor affecting nitrate fluxes in some catchments was the presence of wetlands where denitrification could occur (e.g. Andy's Creek and West Pond).

Table 5 presents another way of examining the relationships between forest vegetation and surface water chemistry. Using data from Driscoll (unpub. data), five catchments were identified which exhibited nearly identical mean annual surface water chemistries. The question was then

Table 4. Comparison of mean nitrogen concentrations in runoff during summer (June–October) versus winter (November–April) in the RILWAS catchments. Data from Driscoll (unpub. data)

Catchment	Summer NO_3^--N $mg\,l^{-1}$	Winter NO_3^--N $mg\,l^{-1}$
Andy's Creek	0.08	0.44
Merriam Pond	0.16	0.40
Pancake Creek	0.17	0.51
Squash Pond	0.17	0.42
West Pond	0.14	0.19
Big Moose	0.32	0.38
Constable Creek	0.09	0.40
Townsend Pond	0.26	0.46
Windfall Pond	0.21	0.49
Dart's Lake	0.31	0.38
Moss Lake	0.28	0.41
Cascade Lake	0.29	0.47
Bubb Lake	0.17	0.24
Lake Rondaxe	0.23	0.39

Table 5. A comparison of forest cover in five RILWAS catchments which exhibit nearly identical mean annual surface water chemistries. Water chemistry from C. Driscoll (Unpub. data)

Catchment	pH	Ca	SBC	SO_4^{2-}	NO_3^-	%HDW	%MXD	%CON
Pancake	5.3	86	163	132	32	80	20	0
Andy's	5.0	88	162	136	18	32	29	33
West	5.2	94	167	112	10	46	50	4
Dart's	5.2	96	163	140	24	24	66	7
Constable	5.2	98	160	148	17	21	72	6

* Concentrations in $\mu eq\,l^{-1}$
SBC = sum of base cations

asked whether these similar water chemistries coincided with consistent forest cover patterns. As shown in the table, there was no obvious relationship between forest cover and water chemistry. Percent cover values between catchments varied from 21–80% for hardwood forest, 20–72% for mixed forest, and 0–33% for coniferous forest. Similarly, biomass and productivity estimates varied two-fold between the five watersheds. Thus, surface water chemistry in these catchments was not clearly related to vetetation parameters. Likewise, the overall results from the Moose River system indicated that variations in surface water chemistry were independent of vegetation parameters among watersheds.

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