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RELATIONSHIP OF STAND AGE TO STREAMWATER NITRATE IN NEW HAMPSHIRE

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Abstract. Streamwater nitrate content of six watersheds during spring and summer was apparently related to stand age or age since disturbance. Nitrate concentration averaged 10.3 ppm right after cutting, dropped to a trace in medium-aged stands, and then rose again to a maximum of 4.8 ppm as stands became overmature.

Clearcutting results in accelerated discharge of NO_3– (in addition to other nutrients) into mountain streams in New England (*Pierce et al. 1972*). However, investigations in the White Mountains of New Hampshire (*Pierce et al. 1972*) and investigations in the Bowl Research Natural Area (*Leak 1972*), indicate that NO_3– discharge during the spring-summer period varies considerably among streams draining forest stands that apparently have not been disturbed recently.

The cause of this variation is not known. However, at least two hypotheses exist. Some believe that NO_3– discharge may increase during years when the soil freezes; and there is some evidence from New England watersheds as basis for this point of view. However, soil frost occurs only sporadically in New England watersheds below elevations of 2,500 to 3,000 feet, and the preliminary evidence to date indicates that its effects on nutrient discharge occur during the winter and do not carry over into the spring-summer period (*Hornbeck 1973*). Thus, soil frost does not seem to explain the consistent year-to-year high or low nutrient discharges that characterize a given stream during the spring-summer period.

The other hypothesis is that consistent spring-summer nutrient discharge rates (NO_3– in particular) may be related to stand age. Marks and Bormann (*1972*) suggested that very young fast-growing pioneer stands are effective in reducing nutrient loss from ecosystems. It is not unreasonable to suggest that old overmature stands that are not increasing rapidly in vegetative mass or humus depth become less effective in utilizing available nutrients, resulting in an increased nutrient discharge into the streamwater.

To gain some additional information about the relationship of stand conditions to NO_3^- discharge, we cruised six of the control watersheds reported by Pierce *et al.* (*1972*) and related certain stand features to the reported streamwater concentrations of NO_3^-.

Methods

The six control areas examined were the Dartmouth Outing Club (D.O.C.) tract, Davis Brook, Conner Brook, Underhill Brook (the control area for the Stony Brook cutting area), Greeley Brook, and Church Pond (*Pierce 1972*). However, the Church Pond control was very small and apparently influenced by recent logging, so it was dropped from the study. Available information from a portion of the Bowl was incorporated into the investigation.

Each control area was cruised, using a metric prism (factor of 4 m^2/hectare). Points were systematically located at a square spacing of approximately 120 meters (6 chains). On one small watershed (Davis Brook) the sampling intensity was doubled. Numbers of points per watershed were:

D.O.C.	40
Davis	7
Conner	28
Underhill	41
Greeley	15

These numbers generally reflect the relative sizes of the watersheds. However, the Greeley, Underhill, and Conner tracts have a sizable acreage of steep and rocky spruce-fir land that could not be cruised readily. The Bowl tract also contains some acreage of steep ledge that was not cruised.

There is some evidence that size of drainage should be considered in evaluating nutrient discharge. However, no clear relations between drainage size and nutrient discharge were noted in this study. (Stuart, G. Effects of timber harvest on water chemistry, White Mountain National Forest. Unpublished report, 10 p., 1973.)

At each point, the immediate stand was classified visually into one of three structural classes recognized by silviculturists: (1) even-aged (a single recognizable age class); (2) holdover (a young even-aged stand with a few old trees); and (3) uneven-aged (more than two age classes or age classes unrecognizable). The first two classes commonly denote fairly recent cutting.

Basal area was measured at each point, by species. Holdovers were tallied separately. On even-aged plots, one of the dominant stems was bored for age. Borings also were taken regularly in the even-aged stands underlying holdovers. An occasional holdover or larger stem on uneven-aged plots was bored to determine age.

Results

Four areas — D.O.C., Davis, Conner, and Underhill — support mixtures of hardwoods, with a smaller proportion of softwoods. Greeley is a spruce-fir area, with mountain paper birch. The Bowl stand is primarily hardwoods, with some inaccessible high-altitude spruce-fir, as mentioned earlier (table 1).

Stand composition may indicate the history of these areas. Intolerant hardwoods (paper birch and pin cherry) denote recent disturbance in hardwood types. A high percentage of even-aged or holdover stands indi-

Table 1.—Species composition, in percent of basal area[1]

Area	Tolerant-intermediate hardwoods	Intolerant hardwoods	Softwoods
D.O.C.	47	24	29
Davis	53	5	42
Conner	72	6	22
Underhill	76	3	21
Greeley	—	18	82
Bowl	93	—	7

[1] Percentages for the Bowl are based on number of stems 200 mm diameter (at root swell) or larger (*Leak 1975*).

cates heavy cutting within the past 100 years or so. The D.O.C. tract contains the highest percentage of intolerants (24 percent) and has a very high percentage of even-aged and holdover stands (95 percent). Davis and Conner have only 5 to 6 percent intolerants, but 86 percent or more of even-aged and holdover stands. Greeley has a high percentage of mountain paper birch, but this is a natural associate of spruce-fir and does not reflect recent cutting. Also, the even-aged condition of Greeley reflects the tendency of spruce-fir to grow in small even-aged stands. Both Underhill and the Bowl have very few intolerants and are primarily uneven-aged (table 2).

The age summaries indicate that the even-aged stands and young stands under holdovers on the D.O.C. tract range up from 30 years of age (table 3). About one-fourth of these stand types fell within the 30- to 50-year class. Logging roads, stumps, and collapsed shelters were present. Apparently, the D.O.C. tract was cut heavily 30 to 35 years ago. Much of this cutting was concentrated along the stream that was water-sampled. The stand-age data indicate that another heavy cutting was made 60 to 85 years ago.

Table 2.—Percentage distribution of plots among stand-structure classes

Area	Even-aged stands	Holdover stands	Uneven-aged stands
D.O.C.	44	51	5
Davis	100	—	—
Conner	50	36	14
Underhill	13	23	64
Greeley	80	7	13
Bowl	—	—	(100)[1]

[1] The Bowl stand is predominantly uneven-aged.

The presence of stone walls in the Davis tract indicates that it was pasture land that was abandoned 55 to 95 years ago. The range in age reflects the fact that old pastures often were abandoned gradually and did not regenerate completely within a short time.

The Conner tract contained slightly older second-growth stands than the Davis tract. Although the range in plot ages begins at 40 years (table 3), the majority of the even-aged and holdover stands fall within the 60- to 140-year range. We suspect that two heavy cuttings took place, one 60 to 85 years ago, the other 100 to 140 years ago.

The uneven-aged stands that predominate in the Underhill area contain trees up to about 185 years of age (table 3) or a little more. Most of the timber is old and mature. However, the ages are not as great as those in an overmature stand such as the Bowl, which contains trees up to 240 years or older (*Leak 1972*). Furthermore, the largest trees in the uneven-aged plots at Underhill were about 790 mm (at root-swell), both yellow birch and sugar maple. In contrast, birch and sugar maple in the Bowl commonly run over 800 mm (sugar maple) or 900 mm (yellow birch). One holdover yellow birch at Underhill was 995 mm, but holdover trees commonly run large for their age.

The stands at Greeley Brook run from 65 to 350 years of age (table 3). The Greeley stands are old overmature spruce that are

Table 3.—Range in approximate stand age, by stand-structure classes, in years

Area	Even-aged stands		Young Stands under holdovers		Uneven-aged stands		Approximate weighted average age
	Range	*Aver.*	*Range*	*Aver.*	*Range*	*Aver.*	
D.O.C.	30 - 85	60	30 - 80	60	80 - 230	155	65
Davis	55 - 95	75	—	—	—	—	75
Conner	85 - 160	125	40 - 110	75	—	(155)	110
Underhill	65 - 80	70	60 - 105	70	110 - 185	155	125
Greeley	100 - 350	200	65	65	175 - 350	260	200
Bowl	—	—	—	—	—	200	200

near the maximum age for the species (nearly 400 years). There is no evidence of any logging. Many trees are dead and dying.

The Bowl stand is recognized as one of the best examples of virgin overmature hardwoods in New Hampshire.

If an average age is determined for each tract by weighting the average age per stand-structure class by the percentage of plots per structure class, the tracts rank in order of increasing age as follows: D.O.C., Davis, Conner, and Underhill, with Greeley and the Bowl about tied for the oldest (table 3).

Streamwater concentrations of NO_3- for the spring-summer period are given in table 4 for the several stand conditions covered by this study. The nutrient data for the Bowl are taken from Leak (*1974*), covering the summer period primarily. The watershed for Tributary 3 is most representative of the Bowl hardwood stand; Tributary 2 also drains part of the stand as well as some mixedwood stands and high-elevation spruce-fir.

The other nutrient data are directly from Pierce *et al.* (*1972*). For comparison, table 4 includes comparable nutrient data from the recent clearcuttings examined by Pierce. Notice that NO_3- discharge is high in recent clearcuttings. It is much lower in the area cutover 30 to 35 years ago. Minimum NO_3- content occurs in even-aged second-growth hardwoods. NO_3- content picks up a little in mature hardwoods. And it becomes noticeably higher in overmature stands, both spruce and hardwoods. This trend is in line with the hypothesis described earlier on the relationship of nutrient release to stand age or age since disturbance.

Table 4.—Comparison of NO_3- streamwater contents (spring-summer period) by stand conditions listed in order of increasing time since disturbance

Stand Conditions	NO_3- ppm Range	NO_3- ppm Average
Recent clearcuttings (*Pierce et al. 1972*)	0.2-28.3	10.3
Cut 30 to 35 years ago—D.O.C.	.4- 5.4	2.3
Second-growth even-aged hardwoods—Davis, Conner	<.1- .9	.15
Old-growth mature hardwoods—Underhill	<.1- 3.6	.8
Overmature spruce—Greeley	.8- 3.5	2.4
Overmature hardwoods—Tributary 2	1.7- 2.6	2.2
Overmature hardwoods—Tributary 3	3.6- 5.3	4.8

Discussion

The results of this study seem to show a good relationship between streamwater NO_3- during the spring-summer period and stand age or age since disturbance. Beginning with high concentrations of NO_3- right after heavy cutting, the concentrations drop off to a minimum in medium-aged stands and then rise again as the stand goes through maturity into overmaturity.

The study dealt with spring-summer concentrations because of the availability of nutrient data for this period. However, recent evidence indicates that differences among stands in spring-summer concentrations hold up during the winter period when nutrient concentrations and streamwater discharge are highest.

Since completion of this manuscript, we found through personal communication that P. M. Vitousek and W. A. Reiners, of the Department of Biological Sciences at Dartmouth College, Hanover, N.H., have independently uncovered the same relationships. They found that nitrate concentrations throughout the year in streams draining old-aged forest ecosystems on Mt. Moosilauke were consistently higher than those draining successional (intermediate-aged) ecosystems. A manuscript about this, entitled "Ecosystem Succession and Nutrient Retention: A Hypothesis", was submitted in November 1974 to Bioscience.

It is difficult to make an extremely positive statement about the relationship of stand age to nutrient discharge. The subject is complex; many factors other than stand age must influence the nutrient-discharge pattern. Additional research is needed to show how these results relate to the inhibition of nitrification that has been observed in certain climax ecosystems (*Rice and Pancholy 1972*). However, the study certainly has strengthened the hypothesis of a stand-age/nutrient-discharge relationship.

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