NITROGEN AND CATION MOBILITY FOLLOWING AN OAK-HICKORY HARVEST IN THE MISSOURI OZARKS

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Abstract.--The influence of forest harvest and a stream channel buffer strip on nutrient concentrations in surface water was studied for an area in southeast Missouri vegetated with oak and hickory. Water samples for three types of collection sites (surface runoff plots, harvested subcatchments with and without a buffer strip, and control and treatment watershed outlets) were analyzed for NH_4^+-N, NO_3^--N, Ca, Mg, K and Na. Harvesting increased nutrient concentrations in surface runoff by 44, 67, 37, 52, 29 and 85% for NH_4^+-N, NO_3^--N, Ca, Mg, K and Na, respectively. Concentrations of nutrients decreased as the surface water moved into the intermittent drainage and were much reduced by the time the streamflow passed from the base of the treated watershed. Harvesting in headwater portions of larger watersheds appears to have little detrimental effect on quality of water leaving the larger watershed area. The buffer strip reduced concentrations of all nutrients except Na and NO_3^--N. Soil water and temperature conditions conducive to nitrification in areas near the intermittent drainage where a buffer strip was not present are probably responsible for these higher NO_3^--N levels. Significant amounts of nutrient redistribution are occurring within the harvested area but only a portion of these are leaving the watershed in streamflow.

Additional keywords: Nutrient cycling, buffer strips, water quality, streamflow, runoff, streamflow chemistry, forest harvest

INTRODUCTION

Forest harvesting and its influence on nutrient loss to streams has attracted considerable interest in recent years. Initially, concerns were voiced over detrimental effects of harvesting on water quality, primarily due to exceptionally high nitrate release from the denuded forest watershed at the Hubbard Brook Experimental Forest in New Hampshire (Likens, et al., 1970). These concerns continue but the added effect of nutrient loss decreasing subsequent forest productivity on harvested sites is often being discussed today. If substantial use of forest residue, including whole tree harvesting, to meet energy demands materializes, additional drains on nutrient reserves will occur and concerns of decreased forest growth are certainly warranted. In this context, forest harvesting methods which minimize nutrient loss should be identified for future management consideration.

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A few studies using experimental watersheds have been conducted in the region of oak-hickory vegetation to characterize the patterns of nutrient mobility and loss following harvest. Two studies have been conducted in the Appalachian Region utilizing experimental watersheds at the Fernow Experimental Forest and the Coweeta Hydrologic Laboratory (Aubertin and Patric, 1974; Henderson, et al., 1980). The study reported here was conducted in the Missouri Ozarks using the experimental watershed approach. It differs from previous studies, however, in that only the upper part of the catchment was harvested. This allowed us to investigate the effects of cutting in headwater subcatchments on downstream water quality. Small runoff plots were used to quantify the changes in nutrient concentrations in water as it progressed from headwater and side slope over to the main channel. This study also examined the influences of harvesting on changes in hydrology and sediment production. These aspects of the study are discussed by Settergren et al. elsewhere in this proceedings.

METHODS

Two small watersheds, 4.03 and 6.58 ha, located in Butler County in southeast Missouri were gauged in 1965 and calibrated for water yield. In 1978 the larger watershed was selected to receive a regeneration harvest in the upper one-third of the catchment. This portion of the watershed consists of two subcatchments, measuring 0.47 and 1.17 ha in area, which were instrumented with H flumes and Coshocton runoff samplers. Harvesting of the subcatchments began in December 1978 and was completed by March 1979. The smaller subcatchment was logged using "logger's choice" techniques by a local contractor. The entire area was cut without a buffer strip left along the intermittent drainage. Log skidding commonly crossed the drainage. Slash was distributed rather uniformly over the catchment including the drainageway. No erosion control or reseeding was done on this catchment.

More control was exercised over the logging of the larger subcatchment althoug it was performed by the same contractor. A 50-foot wide buffer strip was left along the intermittent drainage in which no cutting or skidding was done. Main skid trails were laid out on the contour. Upon completion of the harvest water bar were constructed across the trails which were also reseeded with fescue.

Small runoff plots were installed on both control and harvested watersheds, four plots on the control watershed and eight plots in both the uncut and cut portions of the harvested watershed. These plots were approximately 4.8 m^2 and were distributed among different combinations of aspect, slope position and slope gradient. They were designed to quantify surface runoff amounts and to collect samples for nutrient and sediment analysis. A more complete description of plot locations and construction is given by Settergren, et al. elsewhere in this proceedings.

In this paper we report concentrations of NH_4^+-N, NO_3^--N, Ca, Mg, K and Na found in samples of water flowing from the runoff plots, Coshocton samplers and main watershed flumes. Samples were collected from April 13, 1979, through April 4, 1980. The number of collections totaled 12 for both the runoff plots and the Coshocton samplers. Water samples at the main flumes were obtained by both stage and grab sampling. During the year 38 samples were obtained from the control watershed and 67 samples were collected from the harvested watershed. These samples represent the range of flow and seasonal variation. Ca and Mg concentrations were determined by atomic absorption, K and Na by flame emission, and NH_4^+-N and NO_3^--N by Technicon auto analyzer methodology.

RESULTS AND DISCUSSION

Nutrient Concentrations in Discharge Waters

Concentrations of NH_4^+-N, NO_3^--N, Ca, Mg, K and Na in surface water are presented in Tables 1 and 2 for the nitrogen and cation species, respectively. Nitrate-N concentrations did not exceed the U.S. Public Health drinking water standard (10 ppm NO_3^--N) at any time or place during the study. Over the year of study NO_3^--N concentrations in surface runoff from plots in the control watershed and uncut portion of the harvested watershed were nearly identical, averaging 0.41 and 0.44 mg/l, respectively (Table 1). Nitrate-N concentration in surface runoff was 0.71 mg/l in the cut areas of the harvested watershed. The presence of a buffer strip reduced the nitrate concentration from 0.83 mg/l to 0.40 mg/l in surface runoff from the harvested subcatchments. By the time streamflow reached the main flume, located less than 300 m below the clearcut, NO_3^--N concentration was only 0.12 mg/l, only slightly greater than that of the control watershed, 0.06 mg/l.

The highest NO_3^--N concentration, 6.0 mg/l, observed during the study occurred in surface flow from the runoff plots in the harvested area. The highest concentration in surface runoff from forested plots, 2.3 mg/l, was observed for plots in both the control and treated watersheds. Nitrate-N reached concentrations of 2.3 and 3.9 mg/l in Coshocton samples from the harvested subcatchments with and without buffer strips, respectively. A 1.0 mg/l NO_3^--N concentration was the highest recorded for the harvested watershed at main flume while the similar value for the control watershed was 0.5 mg/l.

Harvesting increased NH_4^+-N concentrations in surface runoff from 2.33 and 2.24 mg/l in control and uncut plots, respectively, to 3.29 mg/l (Table 1). Concentrations of NH_4^+-N in discharge from the harvested subcatchments were considerably lower than in surface flow from the runoff plots. Whereas NO_3^--N concentrations were greater with, compared to without, a buffer strip, the opposite was found for NH_4^+-N; 0.29 and 0.72 mg/l, respectively. However, by the time streamflow reached the main flume NH_4^+-N levels averaged only 0.03 mg/l and were virtually the same as those found for the control watershed, 0.05 mg/l. The highest NH_4^+-N concentration measured was 22.4 mg/l in surface flow from one of the runoff plots.

The reversal of the importance of ammonium and nitrate concentrations with or without a buffer strip is interesting. The total dissolved inorganic nitrogen concentration (NH_4^+-N, + NO_3^--N) is 1.12 mg/l for both situations (Table 1), but more nitrification apparently occurs in the absence of a buffer strip. It seems probable that the buffer strip results in more runoff infiltrating the soil surface before actually becoming streamflow in the intermittent draingae. The passage of this runoff through the soil permits removal of nitrate as well as am-

Table 1. Ammonium, nitrate and dissolved inorganic nitrogen concentrations in surface water from various collection points on control and harvested watersheds. Values are annual average concentration of collections made from April 13, 1979 through April 8, 1980.

Collection Location	NH_4^+-N		NO_3-N		Dissolved Inorganic N	
	Control Watershed	Harvested Watershed	Control Watershed	Harvested Watershed	Control Watershed	Harvested Watershed
	mg/1		mg/1		mg/1	
Runoff Plots						
Uncut	2.33	2.24	0.44	0.41	2.77	2.65
Cut		3.29		0.71		4.00
Subcatchments						
With Buffer		0.72		0.40		1.12
Without Buffer		0.29		0.83		1.12
Entire Watershed						
(Main Flumes)	0.05	0.03	0.06	0.12	0.11	0.15

monium and therefore the lower concentrations measured at the Coshocton. Without a buffer strip, more opportunity for nitrification and a greater proportion of surface flow resulted in the higher nitrate concentrations.

The concentrations of the cations Ca, Mg, K and Na generally behaved similarly in response to the various treatments (Table 2). Concentrations were similar in surface flow from the runoff plots located in both the control watershed and the uncut portion of the harvested catchment. Harvesting resulted in concentration increases amounting to 2.29, 0.61, 1.25 and 0.93 mg/l for Ca, Mg, K and Na, respectively. Concentrations of all cations decreased by the time the water flowed through the Coshocton and except in the case of Na the presence of a buffer strip resulted in lower concentrations than when it was not present. These differences support our previous suggestion that the buffer strip caused greater infiltration. A greater proportion of the water becoming streamflow did so by way of subsurface flow which had lower cation concentrations due to removal upon passage through the soil profile. More surface runoff with less cation removal became streamflow when a buffer strip was not present.

As with ammonium and nitrate, by the time streamflow reached the main flume cation concentrations were equal to or only slightly greater than those found for the control watershed. Based on these first year results it is clear that the impacts of harvesting in small headwater catchments on concentrations of dissolved nutrients are minimal after streamwater has passed through a relatively small run of forested area. In the upper segments of the basin, however, nutrients have been mobilized and redistribution has occurred.

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Table 2. Calcium, magnesium, potassium and sodium concentrations in surface water from various collection points on control and harvested watersheds. Values are annual average concentrations of collections made from April 13, 1979 through April 8, 1980.

Collection Location	Calcium		Magnesium		Potassium		Sodium	
	Control Watershed	Harvested Watershed	Control Watershed	Harvested Watershed	Control Watershed	Harvested Watershed	Control Watershed	Harvested Watershed
	mg/l		mg/l		mg/l		mg/l	
Runoff Plots								
Uncut	6.07	6.31	1.26	1.10	4.33	4.36	1.29	0.91
Cut		8.48		1.79		5.59		2.03
Subcatchments								
With Buffer		1.97		1.30		0.75		1.28
Without Buffer		3.43		1.68		1.59		0.84
Entire Watershed								
(Main Flumes)	2.41	2.83	1.12	1.38	0.51	0.46	1.07	1.07