The Effects of Traditional and CAFO Agriculture on Summer Nitrate Levels in Stream Water

Elizabeth Diesel, Evan Teeters, David Lehmann, and Ryan Mathur

Abstract

Agricultural land use can add significant amounts of nutrients, including nitrates, to adjacent streams. Spruce Creek (central Pennsylvania) is a spring-fed stream with traditional livestock farms and the state's largest Concentrated Animal Feeding Operation (CAFO) along its banks. Warrior's Mark Run is a major tributary to Spruce Creek and also runs through traditional agricultural land. To evaluate geographic sources of nutrients and analyze the impact of different scales of farming upon nutrient loading, we monitored a variety of physical and chemical parameters in these streams during the summer of 2003.

CAFO agriculture contributes significant amounts of nitrates to Spruce Creek. The highest observed concentrations of nitrates on Spruce Creek were from immediately downstream of the CAFO on 21 of 48 days we sampled. Along Warrior's Mark Run, the location of highest nitrate concentration was variable, with highest values occurring evenly among three different locations at which there is significant streamside grazing. Although there is no CAFO along this stream, nitrate concentrations on Warrior's Mark Run was comparable with those on Spruce Creek.

Spruce Creek and Warrior's Mark Run have comparable average nitrate concentrations despite their great differences in average discharges. Therefore, a larger total volume of nitrates are being flushed through Spruce Creek, but the higher average discharge allows a lesser effect when compared to Warrior's Mark Run.

There were a number of watershed-wide increases in nitrate concentrations typically associated with watershed-wide "events". There were also increases in nitrate concentrations that occur only along Spruce Creek but not Warrior's Mark Run and vice versa. Each of these increases in nitrate concentration is associated with a stream-specific "event" which is likely tied to the agricultural use along that stream.

There is a difference in the effects of traditional and CAFO agriculture on water quality. CAFO agriculture adds more nitrates into Spruce Creek than the traditional agriculture, but the small size of Warrior's Mark Run makes it more susceptible to nutrient loading than Spruce Creek.

Introduction

Spruce Creek is one of the many spring-fed, limestone streams flowing through central Pennsylvania. The stream is about seven miles long, and its waters provide an exceptional habitat to the large rainbow and brown trout for which it is known. Over the years, those who live along its banks and those who frequent its waters have noticed a

dramatic decline in the quality of Spruce Creek's fishery. The suspected reason for this decline in quality is nutrient loading from the agriculture that is found on the banks of Spruce Creek and its tributaries. In particular, there is a CAFO found along the banks of Spruce Creek that is thought to influence water quality (see Figure 1). Downstream from this CAFO there is a tributary to Spruce Creek, called Warrior's Mark Run (see Figure 1). It is possible that the traditional agriculture along Warrior's Mark Run is contributing significant nitrate concentrations to Spruce Creek.

The purpose of this study was to ascertain and define the effects of traditional and CAFO agriculture on nutrient loading in Spruce Creek and Warrior's Mark Run. In order to do this, we measured nitrate and phosphate concentrations (in mg/L), turbidity (in FTU), TDS (in mg/L), water temperature (in °C), pH, and discharge (in cfs).

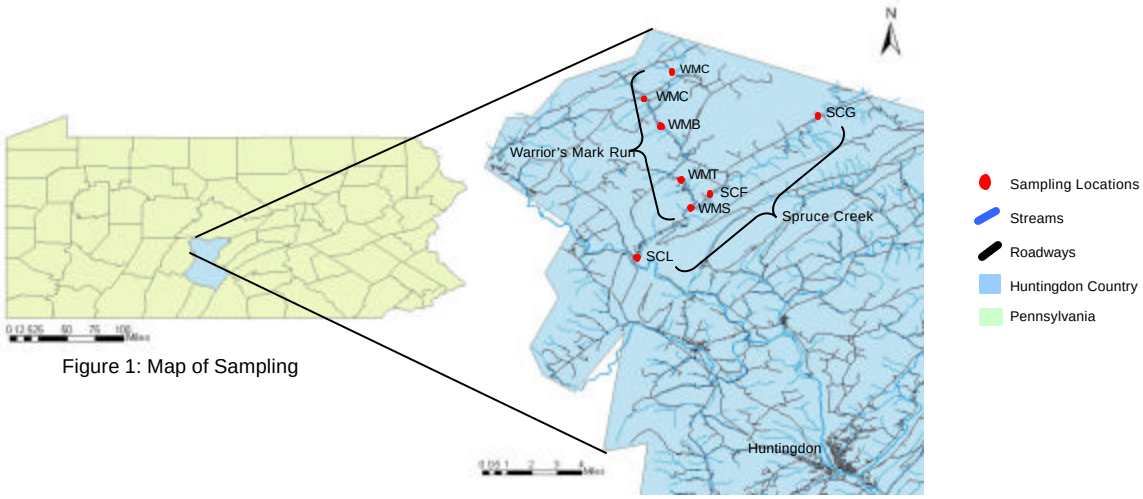


Figure 1: Map of Sampling

Methods & Materials

Sampling

There were ten sampling locations used for this study, as seen on Figure 1. We chose sampling sites both up and downstream from the agricultural areas on Spruce Creek and Warrior's Mark Run to observe variations in nutrient concentrations.

Samples were taken five days a week from June to August, and were taken two days a week during the fall and winter. Sampling includes water collection, Total Dissolved Solids and water temperature measurements using a HACH sension5, and discharge measurements using a water flow probe.

Laboratory Procedure

Nitrate concentrations are tested with a cadmium reduction method. Phosphate concentrations are tested with potassium persulfate followed by a sulfuric acid digestion. Turbidity is measured by simple spectrophotometric analysis. The procedures for these analyses are outlined in the HACH DR2000/Spectrophotometer Laboratory Procedures Manual. pH is tested using a sension1.

Results/Discussion

Seasonal Changes in Nitrate Concentrations

From June to the end of August nitrate concentrations average 10.44 mg/L for site SCGR, and from September to December concentrations average 4.91 mg/L, as is illustrated in Figure 2. There is a similar pattern for all sampling sites on Spruce Creek and Warrior's Mark Run.

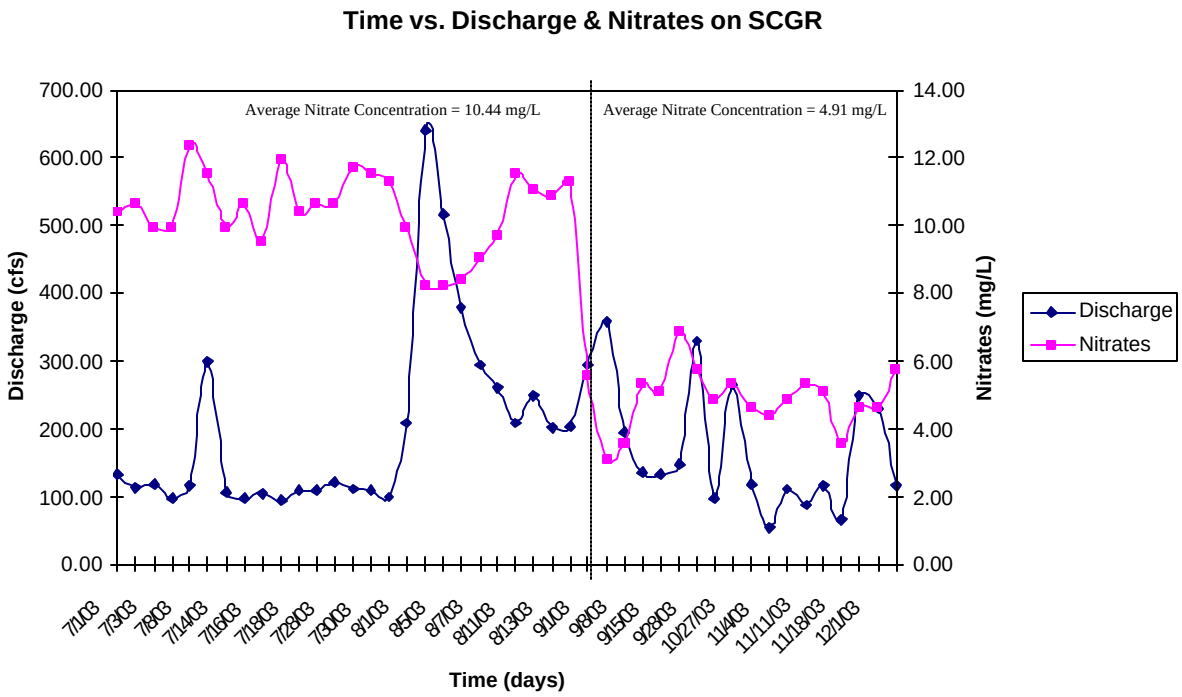


Figure 2: Seasonal Variation in Nitrate Concentrations
(Vertical line on graph indicates change in season)

This pattern shows the influence of season on the nitrate concentrations in Warrior's Mark Run and Spruce Creek. This seasonal fluctuation occurs due to decreased agricultural usage in the fall and winter months.

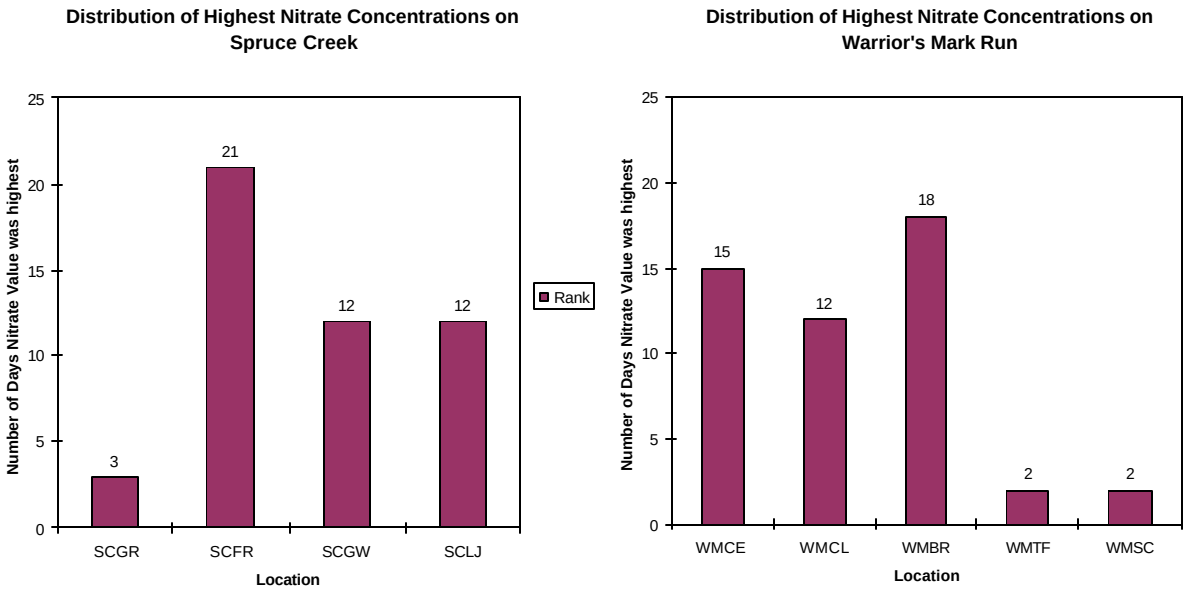


Figure 3: Distribution of Highest Nitrate Concentrations of Spruce Creek (a) and Warrior's Mark Run (b)

Effects of Traditional vs. CAFO Agriculture

As can be seen in Figure 3a, the sampling site directly downstream from the CAFO, SCFR, is consistently the site with the highest overall nitrate concentrations. This site has the highest nitrate concentration 21 of 48 days sampled. This shows that the CAFO is adding a significant amount of nitrates to Spruce Creek. Also, as the discharge increases downstream from this site, it would be expected that the nitrate concentrations decrease due to dilution. This is not the case. Therefore there must be another source of nitrates entering into the system downstream from SCFR, and this other source is Warrior's Mark Run.

On Warrior's Mark Run there are several sites where nitrates enter the stream system; and three of the five sampling sites (Figure 3b) frequently had the highest nitrate concentrations. On Warrior's Mark Run, nitrate loading is likely the result of episodic influx from traditional agriculture. As indicated in Table 1, nitrate concentrations in areas of traditional agriculture may exceed nitrate concentrations below the CAFO on Spruce Creek. Also, the nitrate concentrations are high along the entire length of the stream, which means there must be a large amount of nitrates entering into Spruce Creek from Warrior's Mark Run.

CAFO Agriculture	Average Nitrate Concentration (mg/L)	Average Discharge (cfs)
SCGR	10.4	200
SCFR	11.3	222
SCLJ	11.4	490
Traditional Agriculture		
WMCE	13.8	21
WMCL	13.9	9
WMBR	13.8	45
WMTF	9.0	71
WMSC	9.7	80

Table 1: Comparison of Average Nitrate Concentration and Discharge on Spruce Creek (CAFO) and Warrior's Mark Run (Traditional)

	Highest Nitrate Conc in mg/L	Lowest Nitrate Conc in mg/L	EPA Standard in mg/L
SCGR	12.40	3.10	0.31
SCFR	13.64	3.52	0.31
SCLJ	13.95	2.66	0.31
WMCE	16.83	3.77	0.31
WMCL	17.50	3.54	0.31
WMBR	17.94	4.21	0.31
WMTF	12.63	3.10	0.31
WMSC	13.42	3.52	0.31

Table 2: Comparison of Highest and Lowest Nitrate Concentration along Spruce Creek and Warrior's Mark Run to the EPA Standard

Stream Comparison

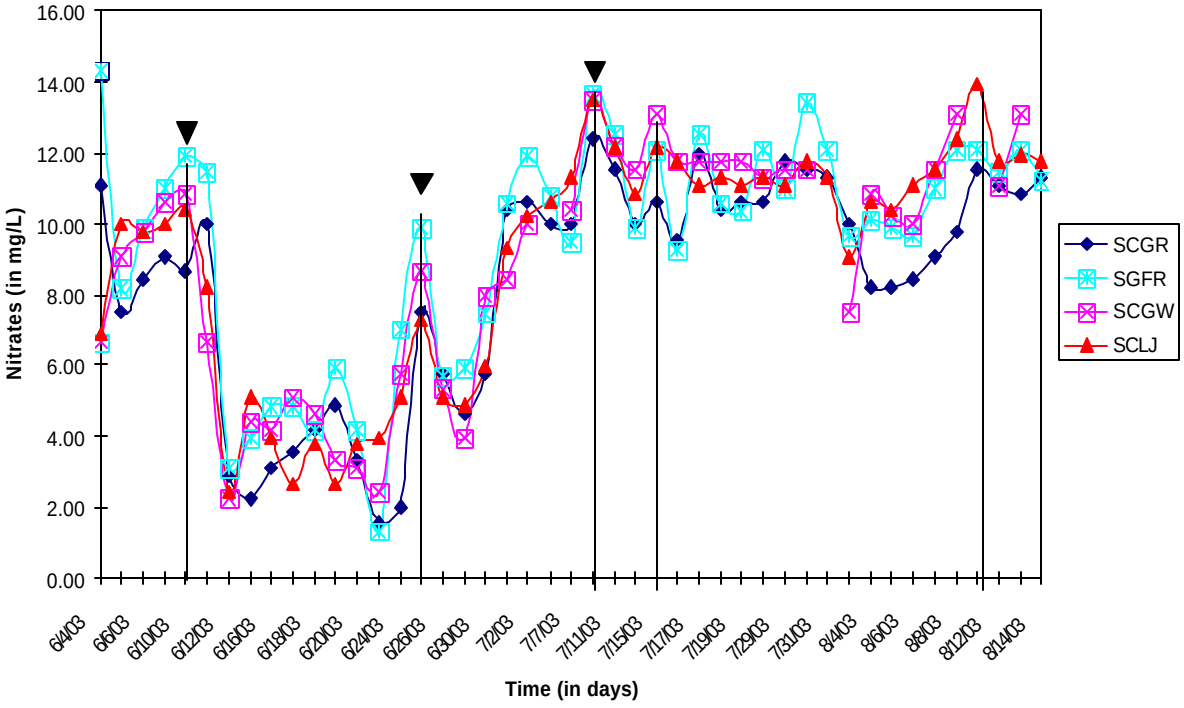
When comparing Spruce Creek and Warrior's Mark Run, one can see that the two streams have approximately equivalent nitrate concentrations (Table 1). Because of the differing discharges of the streams, Spruce Creek (higher discharge) contains a larger total amount of nitrate when compared to Warrior's Mark Run. This means that the CAFO on the banks of Spruce Creek is contributing far more nutrients into the stream than the traditional agriculture farms on the banks of Warrior's Mark Run. However, the large volume of water flowing through Spruce Creek dilutes the total amount of nitrates in the system until the concentrations are comparable. Also, the higher discharges of Spruce Creek indicate that there are more nitrates being flushed through the system over a given period than in Warrior's Mark Run.

Warrior's Mark Run is more affected by the agriculture along its banks due to its smaller size. Therefore, our data indicates that smaller streams are more susceptible to nutrient loading than are larger streams.

Spruce Creek and Warrior's Mark Run are both located within the EPA's Ecoregion XI, which defines recommended maximum nutrient concentrations for streams in this region. The nitrate concentration limit for Ecoregion XI is 0.31 mg/L (EPA). As can be seen in Table 2, the lowest concentrations seen at any sampling site along either Spruce Creek or Warrior's Mark Run are ten times the acceptable nitrate concentration and the highest nitrate concentrations are up to sixty times the acceptable limit.

These high nutrient concentrations in the streams are likely the result of lack of nutrient management plans for the vast majority of adjacent farms. Design and implementation of best management practices (BMP) seem warranted for these streams.

Nitrates on Spruce Creek



Nitrates on Warrior's Mark Run

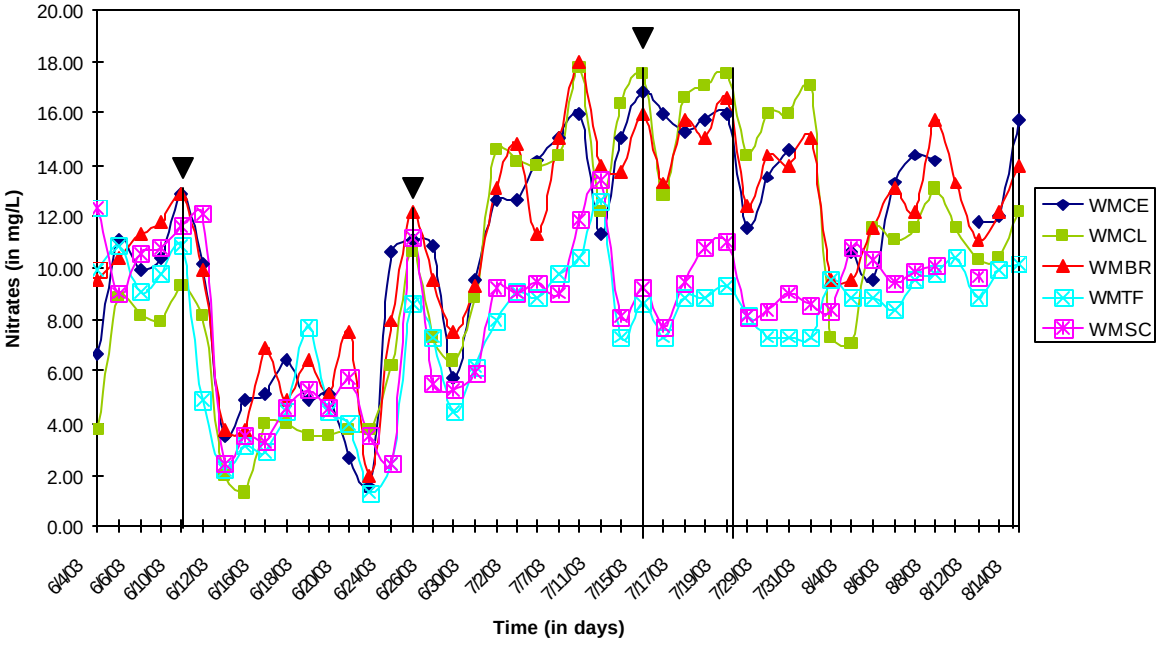


Figure 4: Watershed-Wide peaks (indicated by vertical lines with ?) and Stream-Wide peaks (indicated by vertical lines with no symbols) on Spruce Creek (a) and Warrior's Mark Run (b)

There is also evidence that timing of nitrate peaks do not always correspond in Spruce Creek and Warrior's Mark Run. In Figures 4a and b, three watershed-wide nitrate peaks can be seen over the course of the summer. But on Spruce Creek we see two stream-wide nitrate peaks that do not correspond with either of the stream-wide peaks on Warrior's Mark Run. This suggests that there are nitrate additions to the system that correspond directly with a particular event on a particular stream, and that these events can be detected.

These stream specific nitrate additions are likely tied to the agricultural use.

Dilution Effects

It is possible to see the dilution effects of high discharge events on the stream system, because significant drops in nitrate concentrations correspond to significant increases in the discharge of the streams, as seen in Figure 5.

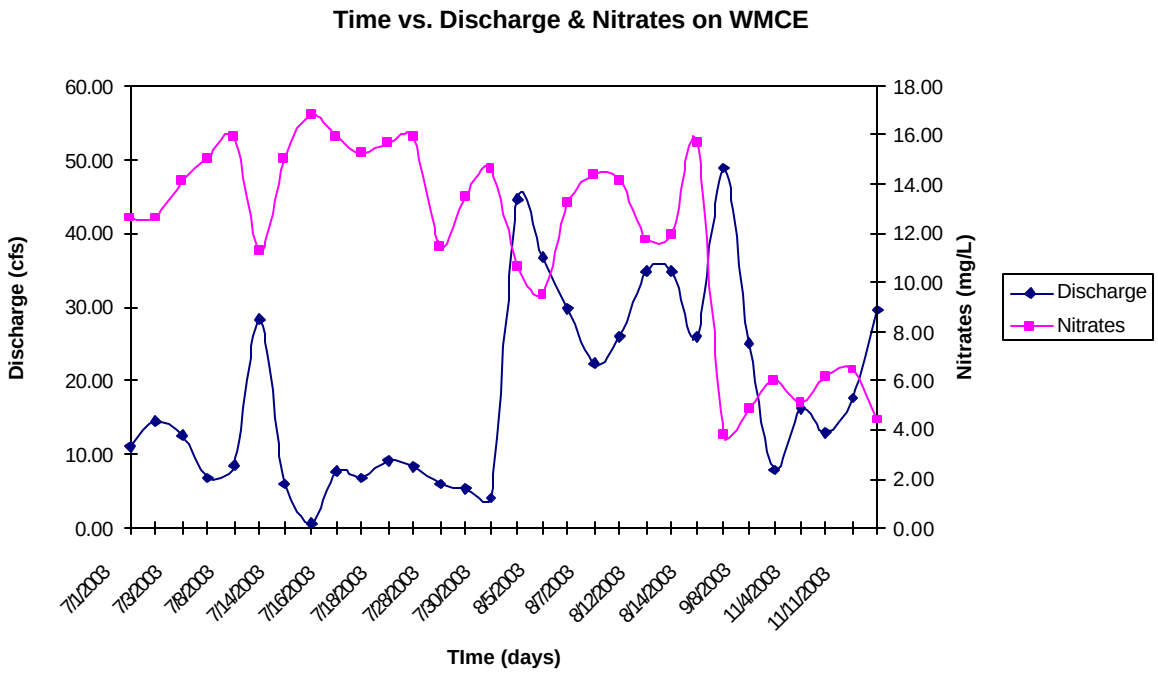


Figure 5: Dilution Effects on Nitrate Concentrations at Site WMCE

Conclusion

There is a difference in the effects of traditional and CAFO agriculture on water quality. CAFO agriculture adds more nitrates to the stream than the traditional agriculture, but the large discharge of Spruce Creek dilutes the nitrate concentrations. The small size of Warrior's Mark Run makes it more susceptible to nutrient loading than Spruce Creek, even though the traditional agriculture on its banks adds fewer nitrates than the CAFO.

References

[EPA] Environmental Protection Agency. 2000 Dec. Ambient water quality criteria recommendations: Information supporting the development of state and tribal nutrient criteria: Rivers and streams in nutrient ecoregion XI. <http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_11.pdf>. Accessed 2004 Mar 16.

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