Silvicultural Impacts on Outflow From Tate's Hell State Forest Into East Bay Estuary in Northwest Florida

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Abstract

Internal cycling of nutrients from sediment and water column in a forest can be important contribution to the nutrient load of aquatic ecosystems. During 1988 to 1998, silvicultural activities impacted 3,639 miles of rivers and streams in the southern United States. Therefore, understanding nutrient transport in forests can aid efforts to protect aquatic resources. Two watersheds in Tate's Hell State Forest were selected to conduct a study on silvicultural impacts on surface water quality. Of the two sites one had been impacted with ditching and fertilization while the other was not. During June 2003 to May 2005 a field study determined nutrient [nitrate (NO_3^-); ammonium (NH_4^+) and ortho-phosphate] concentrations in run-off water and sediments and potential impacts on the East Bay estuary. Results showed NO_3^-; NH_4^+ and ortho-phosphate in water and sediment, were higher in concentration at the impacted verses the non-impacted site. At the impacted site NO_3^-; NH_4^+ and ortho-phosphate in the water column were 16 to 33%; 39 to 47% and 66% to 84% higher, respectively. Sediment sample concentrations from the impacted site were significantly ($p< 0.05$) higher and ranged (mg kg^{-1}) from 0.25 ±.01 to 0.44 ± 0.03 for NO_3^-; 9.34 ± 0.02 to 12.77 ± 0.45 NH_4^+ and 1.01± 0.02 to 1.50 ± 0.02 ortho-phosphate. In this ecosystem the sediment acted as a source of NH_4^+ and ortho-phosphate and as a sink for NO_3^- in this ecosystem. If proper management practices of forests are not carried out they can be potential sources of aquatic systems degradation.

Introduction

Impacts from silvicultural activities can be considerable if best management practices (BMPs) are not applied. From 1988 to 1998 an average of 3,639 miles of rivers and streams in the southern U.S. were impacted by silvicultural activities. Non-point source impacts on water quality include increases in nutrient concentrations, primarily nitrogen and phosphorus. High levels of nutrients may also result from leaching of soils that might have been disturbed or exposed.

Site and Background History

Tate's Hell Forest is located in Franklin County, Florida and borders the Apalachicola National Forest near the Apalachicola National Estuarine Research Reserve (NERR) site (Fig. 1). Silvicultural ditching, diking and rapid drainage transported fresh water from the once swamped area to allow for pine forest production. These activities resulted in alteration of the natural drainage and led to channelized rainfall runoff into receiving water bodies such as East Bay which flows directly into the Apalachicola Bay. A six-year study conducted in the Apalachicola estuary indicated that the alterations along with extensive clear cutting, resulted in flash flooding during heavy rainfalls. Runoff from Tate's Hell is assumed to be primarily responsible for periodic increases in higher nutrient levels, tanned water color and decreases in dissolved oxygen and pH in the upper portions of the Apalachicola Bay.

Goals and Objectives

The overall goal of this project is to determine the source and extent of nutrient runoff from silvicultural sites in Tate's Hell State Forest into East Bay. Specific objectives includes:

1. Compare the concentration of nutrient in run-off water from an Non-impacted "pristine" (Hogs Branch) vs an impacted site.
2. Compare nutrient concentrations in sediment cores collected seasonally at each site .

Figure 1: Study Sites Showing Sampling Locations

Materials and Method

Site Selection:

Two sites were selected for the study. Hogs Branch Creek (non-impacted) and High Bluff Creek (impacted) (Fig.1). These sites were chosen because of the variation in physical disturbance level which would make for useful comparison.

Hogs Branch drains runoff from government owned lands that have been unaltered (natural vegetation and non-fertilized) and will be used as the control site. High Bluff Creek drains run-off from privately owned lands which had a high level of disturbance. This area has been clear cut, fertilized and planted with pine trees for commercial pine production.

Water Quality Monitoring:

Grab samples were collected from 3 points at each monitoring station on a monthly basis for 24 months. The parameters measured were nitrate, ammonium, and ortho-phosphate.

YSI 6920 Sonde continuous-stage water quality loggers (Fig. 2a, b & c)) were installed at strategic points at both sites, to measure; temperature, dissolved oxygen and pH. The measurements were recorded at 30 minute intervals. Data download and calibration were done every 3-4 weeks.

Orphimedes bubbler level loggers and CSI tipping bucket rain gauges (Fig. 2d) with data loggers were installed to collect and record water levels and rainfall at 30 minute intervals, respectively.

Sediment Sampling:

Soil core samples were taken during the summer and winter seasons from the same 3 locations as the water samples. Samples were taken up to a depth of 30.5 cm (12 inches) by use of a gravimetric corer. Sediment samples were analyzed for the same nutrient parameters as the water samples.

Nutrient Analysis

Water and sediment samples were colorimetrically analyzed by use of a Bran & Luebbe Auto-analyzer III.

Moisture content of sediment samples were determined. Sediment samples to be analyzed for nitrate & ammonium were extracted using 2M KCl solution and for the analysis of ortho-phosphate, sediment samples were extracted with 0.01 M $CaCl_2$.

Figure 2. Water Quality Logger Deployment (a & b), Data Retrieval (c) and Rain Gauge (d)

Results And Discussion

Nutrient Concentration in Water Column

During the study period, the nitrate concentration in the water column was significantly ($p< 0.05$) higher at the impacted site during most of the study period (Figs. 3, 4 & 5). Nitrate concentrations increased at both sites with an increase in rainfall.

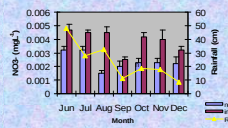

Fig. 3. Nitrate Concentration 2003

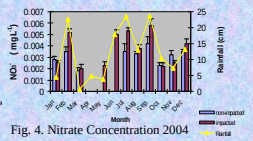

Fig. 4. Nitrate Concentration 2004

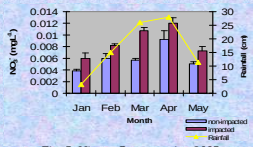

Fig. 5. Nitrate Concentration 2005

Ammonium (Figs. 6, 7 & 8) and ortho-phosphate (Figs 9, 10 & 11) concentrations were higher at the impacted site during the entire period of the study. Ammonium concentrations were significantly ($p< 0.05$) higher most of the times while ortho-phosphate was significantly higher for each month during the study.

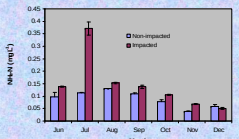

Fig. 6. Ammonium Concentration 2003

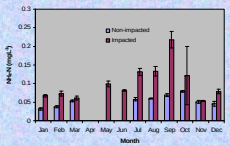

Fig. 7. Ammonium Concentration 2004

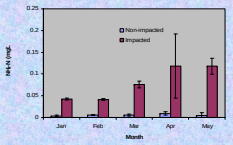

Fig. 8. Ammonium Concentration 2005

The data showed that when the DO concentrations (Table 1) were lower during the warmer months the concentration of NH_4 and orthophosphate increased. This showed that DO and temperature impacted the concentration of these two nutrient species in the water column.

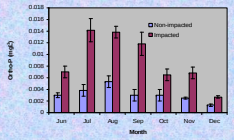

Fig. 9. Ortho-phosphate Concentration 2003

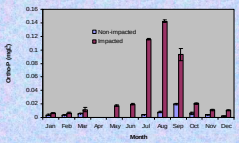

Fig. 10. Ortho-phosphate Concentration 2004

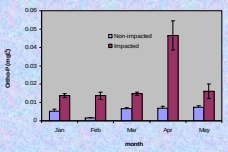

Fig. 11. Ortho-phosphate Concentration 2005

The water column at the non impacted site was less impaired. The DO content and pH were higher than the impacted site and the temperature readings were lower at the said site (Table 1).

DO (mg/L)			Temp (°C)		pH	
2003	Non-impacted	Impacted	Non-impacted	Impacted	Non Impacted	Impacted
Jun	2.99	1.88	24.88	26.21	4.08	5.05
Jul	1.94	0.80	24.93	26.31	4.10	4.36
Aug	1.84	1.36	25.07	26.52	4.07	4.33
Sep	1.98	1.56	24.23	25.03	5.01	5.31
Oct	2.89	2.65	20.87	21.70	5.99	6.11
Nov	3.67	3.46	19.76	19.85	6.05	6.12
Dec	4.25	3.74	17.83	17.91	6.24	6.43
2004						
Jan	5.03	4.02	13.38	14.23	6.08	6.01
Feb	4.76	3.98	13.55	14.57	5.46	5.37
Mar	4.02	3.53	16.75	17.96	5.21	5.68
Apr	4.79	4.59	16.23	17.08	6.34	6.39
May	3.45	3.19	19.05	19.39	5.87	5.85
Jun	3.22	3.01	22.17	23.74	4.78	5.45
Jul	3.26	1.60	26.02	28.08	3.95	5.00
Aug	2.54	1.39	26.00	27.39	3.98	4.22
Sep	1.81	1.54	23.46	24.41	3.79	4.05
Oct	2.47	2.22	21.84	23.03	3.91	4.50
Nov	4.05	3.67	17.11	19.55	5.52	5.47
Dec	5.00	3.89	14.86	15.75	7.33	7.21
2005						
Jan	6.42	6.70	11.08	12.42	6.41	5.33
Feb	6.84	7.05	12.95	14.75	5.98	6.03
Mar	5.52	5.03	17.60	18.21	7.93	5.97
Apr	3.97	2.67	19.13	19.77	6.77	4.87
May	3.80	2.86	21.71	23.31	6.61	4.91

Table1. Physical Parameters (Water Column)

Nutrient Concentration in Sediment Cores

All three species of nutrients (NO_3^-, NH_4^+ and ortho-phosphate) were higher at the impacted site when compared to the non-impacted site. Nitrate concentrations were higher at both sites during the rainy seasons.

The NH_4^+ and ortho-phosphate concentrations were higher in the winter season when the sediment was more oxygenated. Under anoxic conditions nitrate is reduced to NH_4^+ and ferric iron which binds P is reduced to soluble ferrous iron. The action of these two mechanism during anoxic conditions leads to higher NH_4^+ concentrations and liberation of P from the sediment to surface water.

Therefore, during the summer period (anoxic) more NH_4^+ and ortho-phosphate are liberated to surface water hence less is found in the sediment.

Nitrate	Non-impacted	Impacted
Summer 2003	0.2158 ± 0.003	0.4414 ± 0.029
Winter 2004	0.1946 ± 0.005	0.2472 ± 0.005
Summer 2004	0.2448 ± 0.023	0.3971 ± 0.023
Winter 2005	0.1588 ± 0.005	0.2495 ± 0.005
Ammonium		
Summer 2003	5.504 ± 0.742	9.341 ± 0.017
Winter 2004	6.976 ± 0.022	9.509 ± 0.017
Summer 2004	6.414 ± 0.191	9.424 ± 0.029
Winter 2005	9.588 ± 0.013	12.775 ± 0.451
ORP		
Summer 2003	0.537 ± 0.005	1.13 ± 0.038
Winter 2004	0.653 ± 0.018	1.294 ± 0.037
Summer 2004	0.588 ± 0.015	1.009 ± 0.015
Winter 2005	0.777 ± 0.005	1.501 ± 0.024

Table 2. Nutrient Concentration ($mgkg^{-1}$) in Sediment

Conclusion

Nitrate, ammonium and ortho-phosphate concentrations were higher in the water column at the impacted when compared to the non-impacted site. At the impacted site NO_3-N, NH_4^+-N and ortho-phosphate in the water column were 25 to 33%, 39 to 47% and 50% to 64% higher, respectively.

The physio-chemical parameters (DO, Temp. and pH) of the water column were shown to be more impaired at the impacted site.

Nutrient concentrations in the sediment samples were also significantly ($p<0.05$) higher at the impacted site nitrate, ammonium and ortho-phosphate concentrations were 30, 40 and 48% higher respectively at the impacted site.

It has been shown definitely in the Tate's Hell area that sites heavily impacted by silvicultural operations, if not managed appropriately, can cause decline in water quality which can then have adverse impacts on aquatic biota in the receiving water bodies.