Nutrient dynamics in montane wetlands, emphasizing the relationship between cellulose decomposition and water chemistry

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:: Abstract ::

Wetlands often function as a nutrient sink. It is well known that increased input of nutrient increases the primary productivity but it is not well understood what is the fate of produced biomass in wetland ecosystem. Water and sediment quality, decomposition rate of cellulose, and sediment accumulation rate in 11 montane marshes in northern Sierra Nevada, California were analyzed to trace the effect of nitrogen and phosphorus content in water on nutrient dynamics.

Concentrations of ammonium, nitrate, soluble reactive phosphorus (SRP) in water were in the range of 27 to 607, 8 to 73, and 6 to 109 ppb, respectively. Concentrations of ammonium, calcium, magnesium, sodium, and potassium in water were the highest in Markleeville, which has been impacted by animal farming. Nitrate and SRP concentrations in water were the highest in Snow Creek, which has been impacted by human residence and a golf course. Cellulose decomposition rates ranged from 4 to 75 % per 90 days and the highest values were measured in Snow Creek. Concentrations of total carbon, nitrogen, and phosphorus in sediment ranged from 8.0 to 42.8, 0.5 to 3.0, and 0.076 to 0.162 %, respectively. Accumulation rates of carbon, nitrogen, and phosphorus fluctuated between 32.7 to 97.1, 2.4 to 9.0, and 0.08 to 1.14 g m^{-2} yr^{-1}, respectively. Accumulation rates of carbon and nitrogen were highest in Markleeville and that of phosphorus was highest in Lake Van Norden. Correlation analysis showed that decay rate is correlated with ammonium, nitrate, and SRP in water. There was no correlation between element content in sediment and water quality. Nitrogen accumulation rate was correlated with ammonium in water. These results showed that element accumulation rates in montane wetland ecosystems are determined by decomposition rate rather than nutrient input.

This study stresses a need for eco-physiological researches on the response of microbial community to increased nutrient input and environmental change because the microbial community is responsible for the decomposition process.

Keywords: anthropogenic impacts, nutrient cycle, sedimentation, sediment characteristics

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1. Introduction

Wetlands function as nutrient sink or source and constructed wetlands have been used for wastewater treatment (Mitch and Gosselink, 2000). In wetland systems, material flow can be summarized as Fig. 1. Nutrients come from atmospheric de-position and with surface and ground water inflow. Plants uptake these nutrients and dead plant materials are decomposed by microbial community. Mineralized elements are reused by plants or leave wetlands in outflow. Remained matter accumulates on the bottom and forms peat. In general, sedimentation is responsible for the removal of phosphorus and nitrogen gas release through de-nitrification is responsible for the removal of nitrogen in wetlands (Schlesinger, 1997; Mitsch and Gosselink, 2000).

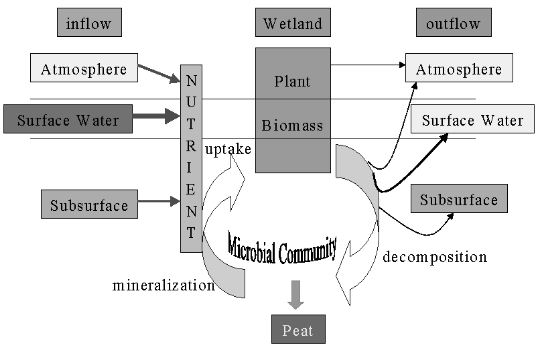

Fig. 1 Generalized diagram of components of a wetland mass balance

Increased nutrient input may favor certain features of organisms and changes in such characteristics would result in changes in the environment, which in turn would affect the fitness of these individuals (Lovelock, 1989). In natural wetland systems, increased nutrient input changes the plant and microbial communities, resulting in the change of ecosystem processes (Wilcox, 1995). One way to study this change is to monitor ecosystem characteristics in a long time. Another way is to compare ecosystem characteristics among many wetland systems, which are characterized by different environmental factors and anthropogenic impacts. In this study, the second way was chosen to examine the change of ecosystem charac-teristics due to human activities.

Water quality was analyzed and compared with human activities. Based on water quality data, I tried to interpret differences in decomposition rates, sedi-ment nutrient levels, and sedimentation rates. Even though this study did not deal with microbial community, results indicate the importance to study microbial response to increased nutrient input.

2. Materials and Methods

2.1 Sampling sites

Lake Tahoe is located at an elevation of 1,890 m at the northeast mountain ranges of California. The annual mean temperature is 6 ℃. Most precipitation occurs in winter as snowfall and very little direct water input to marshes in the Lake Tahoe basin occurs as rain during the growing season (less than 5% of annual total). Most water input is from run-off and ground water discharge derived from winter snow. Because the major source of water input to montane marshes is derived from water-shed run-off, changes in the watershed affect nutrient dynamics in marshes. Most residential development is located in the south and north regions of Lake Tahoe, due to geographical setting. Grazing by livestock is scattered throughout the areas.

Eleven montane marshes were selected in and around Lake Tahoe basin in the northern Sierra Nevada, California, based on anthropogenic impacts. Anthropogenic impacts were defined by distance to road, human residence, recreation area, and animal grazing area (see Kim et al., 2001 for details).

2.2 Water quality

Duplicate water samples were collected at July 28 and September 28, 1997 and returned to the laboratory in a cooler and filtered through Whatman #44 filter paper. The pH and conductivity of the water samples were measured with Fisher Scientific Accumet 1003 pH/mV meter and HANNA Hi 8633 Conductivity meter, respectively. Ammonium, nitrate and soluble reactive phosphorus were analyzed with Indophenol method, Hydrazine method and colorimetric method (molybdenum-antimony solution), respectively (Hunter et al., 1993). Calcium, magnesium, sodium, and potassium concentrations were analyzed using a Perkin-Elmer 2380 Atomic Absorption Spectroscopy following the methods described in Allen (1989).

2.3 Decomposition rate

Three filter papers (Whatman #1) were put in a 15 x 20 cm litterbag (1mm mesh size). Eight litterbags were put in the soil-water interface at each marsh at June 27, 1997. Four replicates of litterbags were recovered at July 28 and September 27, 1997. Recovered samples were washed with tap water twice. Recovered filter papers were dried at 105 °C for 24 hours. To subtract the inorganic content in filter papers, dry samples were ashed at 550 °C for 4 hours.

2.4 Sediment quality and sediment accumulation rate data

Data of Kim et al. (2001) and Kim and Rejmankova (2001) were used for analyses.

3. Results and Discussion

3.1 Water quality

The pH of 11 marshes was in the range of 6.74 and 7.96 (Fig. 2). The pH was relatively high in marshes impacted by human activities such as logging (7.48 at Bliss Creek), human residence and golf course maintenance (7.59 at Snow Creek), and animal farming (7.96 at Markleeville). Conductivity is correlated to ion concentration. Conductivity was the highest at Markleeville (2490 (μs/cm) and followed by 292 (μs/cm at Meyers Grade Marsh, 288 (μs/cm at Snow Creek, 181 (μs/cm at Pope Marsh, and 123 (μs/cm at Bliss Creek. Conductivity was related to the human activities such as road maintenance (Meyers Grade Marsh), logging (Bliss Creek), human residence and recreation site

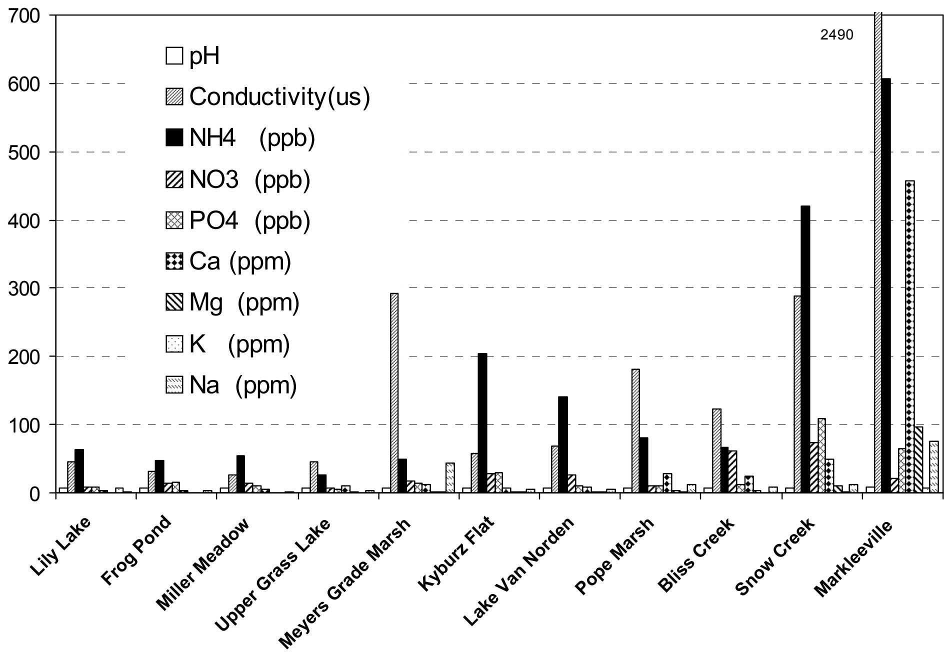

Fig. 2 Comparison of water characteristics among 11 montane marshes

(Pope Marsh and Snow Creek), and animal farming (Markleeville). Ammonium concentration was the highest at Markleeville (607 ppb) and followed by Snow Creek (420 ppb), Kyburz Flat (203 ppb), and Lake Van Norden (141 ppb). Ammonium is produced as the result of decomposition of material containing nitrogen and sediment represents a source of them (Hargreaves, 1998). Dominant plant species were *Chara* at Markleeville, *Ranunculus aquatilis* at Snow Creek, *Carex-Eleocharis* community at Kyburz Flat, *Eleocharis macrostachya* at Lake Van Norden, and *Nuphar* community at others. At September visit, *Chara* was already dead and almost decomposed. *Ranunculus* was also dead and started to decompose. Nitrate concentration was generally quite low and was the highest at Snow Creek (73 ppb), followed by Bliss Creek (61 ppb), Kyburz Flat (28 ppb), Lake Van Norden (26 ppb) and Markleeville (21 ppb). Nitrogen may enter a wetland in both the organic or inorganic forms. In a wetland system, nitrate is formed by the oxidation of ammonium and removed by plant or denitrification in anoxic condition (Schlesinger, 1997). Cation concentrations were higher at Markleeville, Snow Creek, Bliss Creek, and Pope Marsh. Sodium concentration was the highest at Meyers Grade Marsh as a result of road salt application in winter season (Burke, 1987).

3.2 Decomposition rate

It is not easy to compare decomposition rate among many different sites when in situ organic material is used for decomposition experiment. As standardized methods, cotton strip and filter paper have been used (Latter and Howson, 1977;

Maltby, 1988; Rejmankova et al., 1996). Filter paper is much easy to handle and measure decomposition rate well. Thus, we used filter paper to compare decomposition potential. Decomposition rate was the highest at Snow Creek (75 %) and the lowest at Kyburz Flat (3.4 %) per 90 days (Fig. 3). Decomposition rates at Markleeville, Bliss Creek, Lake Van Norden, and Meyers Grade Marsh were 34.6, 26.3, 13.4, and 11.6 % per 90 days, respectively. Decomposition rate is highly correlated to microbial activity. pH was high at the marshes where decomposition rates are high and Kok et al. (1990) and Kok and Van der Velde (1991) showed that pH is related to microbial activity. Cellulose decomposition rate explains this activity well (Kim and Chang, 1989). However, we cannot use this as absolute value of microbial activity because there were other substrates that contain different nutrient level and microorganism may favor high nutrient substrate rather than cellulose itself (Murphy et al., 1998). This is evident from the fact that Markleeville has the highest concentration of ammonium but decomposition rate was not the highest. Microbial community may prefer *Chara* as a substrate to cellulose because *Chara* contains high quality nutrients (low C/N ratio).

3.3 Sediment quality

Carbon concentration in sediment was the highest at Pope Marsh (42 %) and followed by Upper Grass Lake (40 %), Meyers Grade Marsh (30 %), and Lily Lake

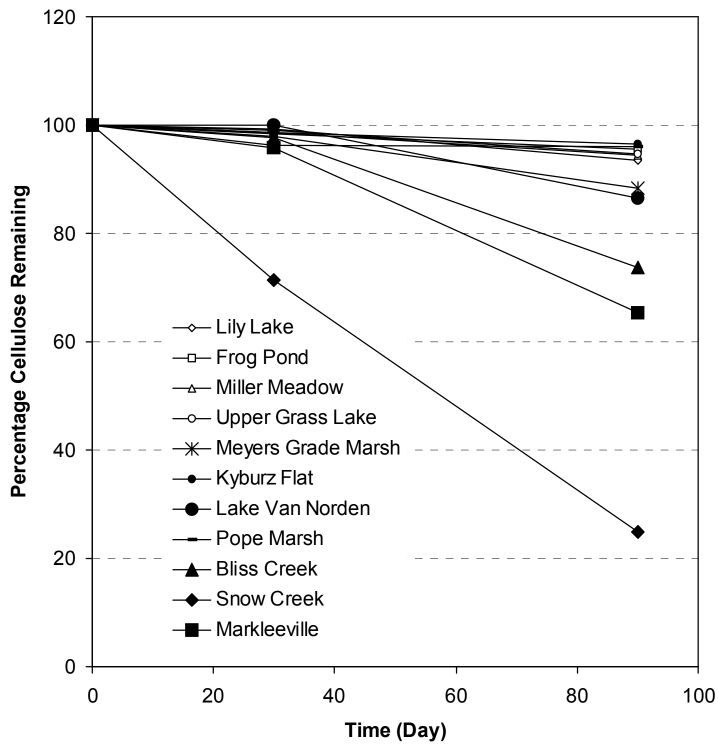

Fig. 3 Time versus cellulose decomposition diagram at 11 montane marshes

(29 %) (Fig. 4). Nitrogen concentration in sediment was 3.0, 2.8, 2.3, and 2.3 % at Upper Grass Lake, Pope Marsh, Markleeville, and Meyers Grade Marsh, respectively. Carbon and nitrogen concentrations were the lowest at Lake Van Norden (8 and 0.5 %, respectively) where the main component of sediment was allochthonous sand. Phosphorus concentration was 0.16, 0.13, 0.11, and 0.10 % at Miller Meadow, Markleeville, Meyers Grade Marsh, and Pope Marsh, respectively. Phosphorus concentration at other marshes was around 0.09 %. C/N and N/P ratios are important factors to characterize marshes because nitrogen or phosphorus limits production at many wetland systems (Gusewell et al., 1998). C/N ratio was the lowest at Markleeville as 11.13 and this value is in the range of algae sediment (Wetzel, 1983). C/N ratio at Kyburz Flat and Miller Meadow was less than 13. Even though decomposition rate was high at Snow Creek, C/N ratio was the highest as 15.6. This may come from the fact that Snow Creek sediment had high amount of live roots in upper 10 cm layer. N/P ratio was the lowest at Lake Van Norden (4.6) and followed by 10.6, 11.9, 17.1, and 18.6 at Miller Meadow, Snow Creek, Frog Pond, Markleeville, respectively. This implies that there was increased input of phosphorus bounding materials such as clay in these marshes. Possible anthropogenic sources are rough roads near Miller Meadow, fertilizer application at golf course near Snow Creek, increased erosion near Frog Pond, and input from animal at Markleeville.

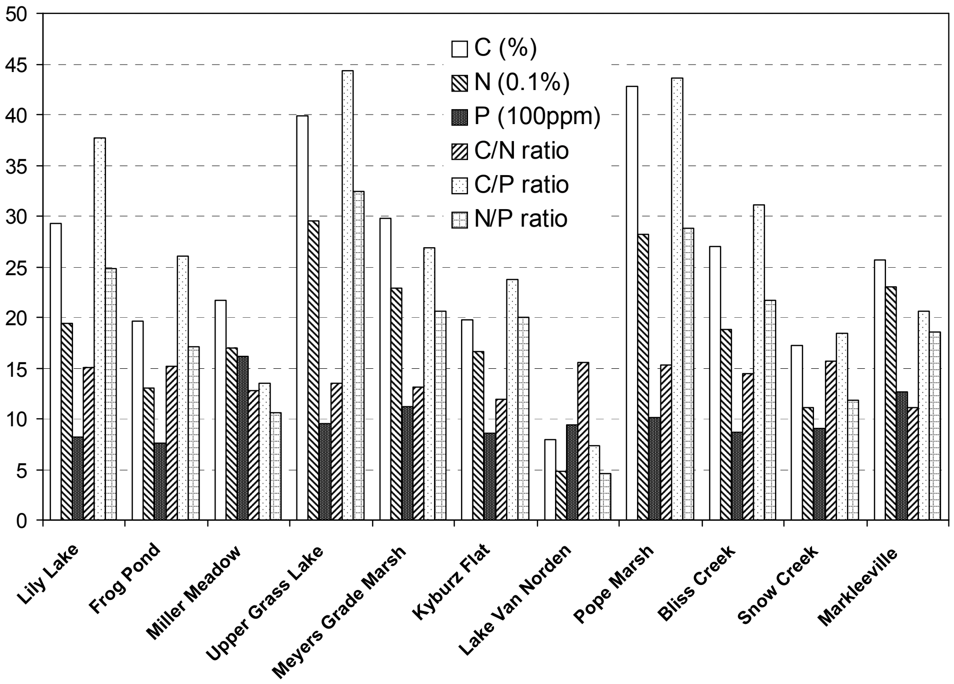

Fig. 4 Comparison of carbon, nitrogen, phosphorus content, and ratios in sediments among 11 montane marshes.Data from Kim et al. (2001) and Kim and Rejmankova (2001)

3.4 Sediment accumulation rate

Accumulation rates of organic carbon, nitrogen, phosphorus, dry mass, and sedimentation rates fluctuated between 32 (Upper Grass Lake) to 97 (Markleeville), 2.4 (Upper Grass Lake) to 9.0 (Markleeville), 0.076 (Upper Grass Lake) to1.138 (Markleeville), 81 (Upper Grass Lake) to 1346 g m^{-2} yr^{-1}(Lake Van Norden) and 0.9 (Upper Grass Lake) to 3.7 cm yr^{-1}(Miller Meadow), respectively (Fig. 5). Accumulation rates of carbon and nitrogen were highest at Markleeville, lowest at Upper Grass Lake, and high at Miller Meadow (97 and 7.4 g m^{-2} yr^{-1}), Pope Marsh (93 and 6.2 g m^{-2} yr^{-1}), and Snow Creek (88 and 5.6 g m^{-2} yr^{-1}). Those of phosphorus were highest at Lake Van Norden, high at Snow Creek (0.6 g m^{-2} yr^{-1}) and lowest at Upper Grass Lake. Markleeville and Bliss Creek have high carbon and nitrogen accumulation rates and might be related to high organic matter production rate according to increased nitrogen input as a result of animal farming and golf course maintenance, respectively. Phosphorus accumulation rate is decided by increased input from watershed and soil particle is main source of phosphorus input. Lake Van Norden was formed by damming a stream and soil particles has accumulated on the bed due to water velocity decrease. Phosphorus accumulation rate must be highest at this wetland. Also, high phosphorus accumulation rate was expected at Miller Meadow because a timber road passes main watershed of this wetland and soil particles have been washed out by rainfall.

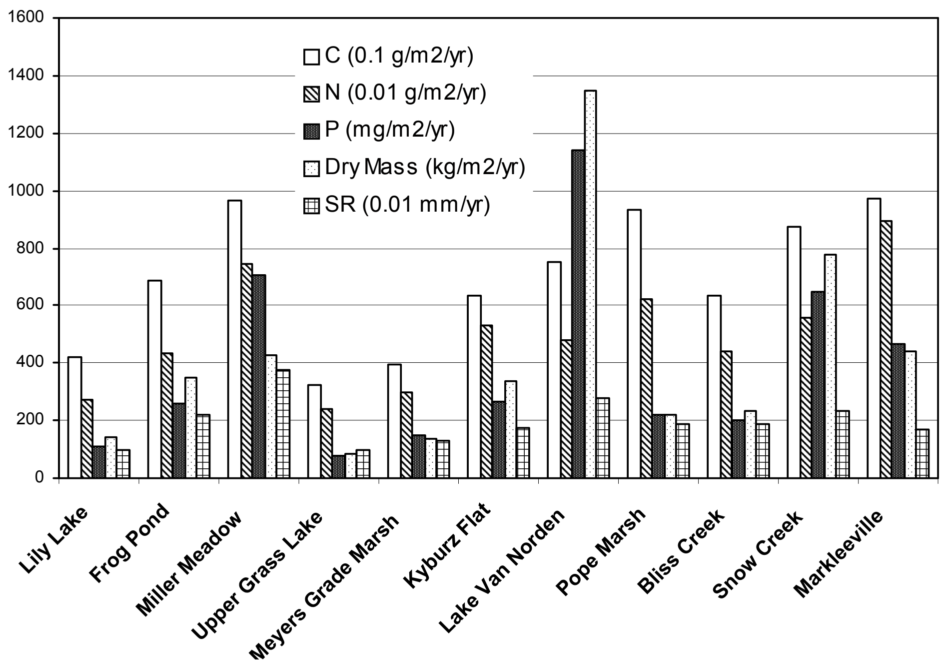

Fig. 5 Comparison of sedimentation/accumulation rates among 11 montane marshes. Data from Kim et al. (2001) and Kim and Rejmankova (2001)

Table 1 Correlation coefficients between N and P in water and decay rate of cellulose, C, N, P contents in sediment, and C, N, P accumulation rates

		Content in water			
		NH_4+NO_3	NH_4	NO_3	PO_4
Decay rate	Cellulose	**0.760	*0.702	***0.821	***0.913
Content in Sediment	C	-0.311	-0.279	-0.411	-0.313
	N	-0.175	-0.132	-0.455	-0.257
	P	0.126	0.160	-0.234	-0.007
	C/N	-0.320	-0.363	0.237	-0.042
	N/P	-0.305	-0.278	-0.367	-0.312
Accumulation rate	C	0.540	0.538	0.251	0.450
	N	*0.650	*0.668	0.125	0.434
	P	0.325	0.311	0.264	0.267

P value: * < 0.05, ** < 0.01, *** < 0.001

3.5 Relationship among water quality and decomposition rate, sediment quality, and sedimentation rate

Decay rate was highly correlated with nitrate and phosphorus (Table 1). Human activities are the important source of these two elements. Paludan and Blicher-Mattiesen (1996) speculated the intensified carbon turnover responding to increased anthropogenic input of nitrate. This result also suggests that anthropogenic input of these elements enhance decomposition process in wetland ecosystems. Even though nitrogen and phosphorus input into wetland system increases primary production rate, it is very difficult to speculate the increased sedimentation rate because of potential increase in decomposition rate. This was supported by the relationship between water quality and sediment quality or accumulation rate. Only nitrogen accumulation rate was slightly correlated with ammonium.

4. Conclusion

This study showed that increased nitrogen and phosphorus content in water is related with decomposition rate and suggested a possibility that increased nutrients enhance ecosystem processes, especially production and decomposition. Two processes can explain the fate of increased nutrients in these wetland systems. One possible process is the escalated increase of nutrient in water with rapid turnover and nutrient input from outside. The other process is the removal of nutrient in water by water outflow. This opens an important question: how can a wetland be processing wastewater treatment in this situation?

This study stresses the importance of eco-physiological research on the response of microbial community to increased nutrient input and environmental change because the microbial community is responsible for the decomposition process and ultimately the water purification process through wetland.

Substrate quality and microbial community decide nutrient turnover rate (Schlesinger, 1997; Murphy et al., 1998) and high quality substrates have an accelerating effect on the rate of nutrient cycling (Aerts and Caluwe, 1997). For the purpose of nutrient removal, uptake efficiency of plant should be considered. On the other hand, decomposition potential of this plant should be considered unless plant biomass is removed by human.

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