Spatial and Temporal Variability in DOC-mediated UV-B exposure in Rocky Mountain National Park.

Project Report, 9/30/02

Paul D. Brooks & Catherine A. O'Reilly

Hydrology and Water Resources

University of Arizona

Tucson, AZ 85721

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PROJECT SUMMARY

This research was designed to improve our basic understanding of ecosystem function in a changing environment and to evaluate how these changes may affect species of special concern. Specifically, we 1) identified patterns in spatial and temporal of Dissolved Organic Carbon (DOC) cycling and export in high elevation aquatic ecosystems, and 2) evaluated how variability in climate (both precipitation and UV) can affect aquatic organisms.

Three years of research and monitoring in Rocky Mountain National Park have yielded significant insights into how the amount and composition of DOC control UV exposure in aquatic habitats. Consistent with original hypotheses, the primary control on the penetration of UV in surface water is the presence of terrestrially derived fulvic acids in the DOC pool. However, our conceptual model, that had terrestrial DOC peaking shortly after snowmelt due to a hydrologic flush of soils and then declining throughout the summer, turned out to be too simple. Our results indicate that while this spring pulse of DOC is indeed an important temporal control on potential UV exposure, other factors, both biological and physical may be equally important in controlling DOC and UV radiation in aquatic habitats. We have two manuscripts currently in review from this work, with two more planned for the near future.

The extension of funding for this work allowed our project to sample 10 high priority sites (defined as areas with historical records of amphibian decline) to determine how these areas responded to one of the driest summers in the last century. The chemical analyses of these samples (the last collected in the latter part of August) is ongoing. We expect the findings from these samples to be extremely important in determining the response of these high elevation water bodies to climate change.

INTRODUCTION

Observed declines in amphibian populations have raised concerns that large-scale environmental perturbations (e.g. climate change, acid deposition, increased UV radiation) may be damaging protected ecosystems. However, it has been difficult to ascribe these observed declines to any single cause. For example, recent studies designed to evaluate the effects of UV radiation on amphibian populations have ranged from reports of no deleterious effects to complete mortality. While the explanations for this wide range of findings can, and are, argued, enough information exists indicating that UV-B radiation is a significant stressor to amphibians. Consequently, recent research has been devoted to the question: *What are the controls on UV exposure to amphibians in natural systems?*

Within the atmosphere, ozone is the major control on the amount of UV radiation reaching the surface of the earth. Once UV has reached the surface of a water body the primary control on how deep it penetrates is the amount and composition of dissolved organic carbon (DOC). Concern over the composition of DOC arises because the photoreactivity/ absorbtivity is largely determined by the chemical structure of the diverse compounds that comprise natural dissolved organic matter. The majority of UV protection is thought to be due to the operationally defined “hydrophobic” DOC fraction, composed primarily of fulvic acids. In general, DOC derived from terrestrial sources is higher in hydrophobic, photoreactive compounds than aquatic-derived DOC. Therefore, controls on the delivery of terrestrial DOC to aquatic systems may have significant effects on UV-B penetration in surface water, and the question becomes; *What are the controls on the amount of photoreactive, terrestrial-derived DOC in surface water?*

RESEARCH GOALS

We had four main goals for the three years of this project. The first goals were largely addressed in funding under PRIMENet. During the final year our focus was to verify the findings from previous seasons and to address goal number four, causes of spatial variability in DOC composition and amount.

1) To quantify the total amount of DOC and the percentage of hydrophobic,

potentially photoreactive fulvic acids in DOC in at sites throughout the major ecosystem type in ROMO.

2) To evaluate the importance of the hydrophobic component of DOC to the extinction of UV radiation *in situ*,

3) To assess the temporal variability in amount and composition of DOC in amphibian habitats,

4) To identify causes of spatial variability in the amount and composition of DOC.

RESULTS

The amount and composition of DOC are controlled by a number of processes including; 1) transport of allochthonuos DOC into the systems from neighboring environments, 2) authochnous production of DOC, 3) heterotrophic consumption within the water column, 4) photochemical degradation, and 5) export out of the system. Physical transport (processes 1&5) is controlled by the hydrology of the site, while biogeochemical modifications (processes 2,3&4) are controlled by a variety of factors including vegetation, geology, temperature, nutrients, insolation, pH. In these snowmelt dominated systems, however, transport processes often exert the greatest control on amount of DOC in surface water. Specifically, a snowmelt pulse of DOC from soil to water each spring provides an episodic input of carbon that may vary between sites (based largely on vegetation structure and soil development) and between years (based largely on climate variability, especially snowfall). Consequently, interannual variability in climate may have a significant impact on the UV exposure animals in the same pond/ environment from year to year.

Controls on spatial patterns of DOC

Long-term, frequent sample collection has demonstrated high temporal variability in DOC concentration and composition at several sites in ROMO. Not only may there be large changes in DOC concentration within one site, but patterns of DOC concentration throughout the summer season vary between different sites, with some sites initially having higher concentrations than others (Fig. 1).

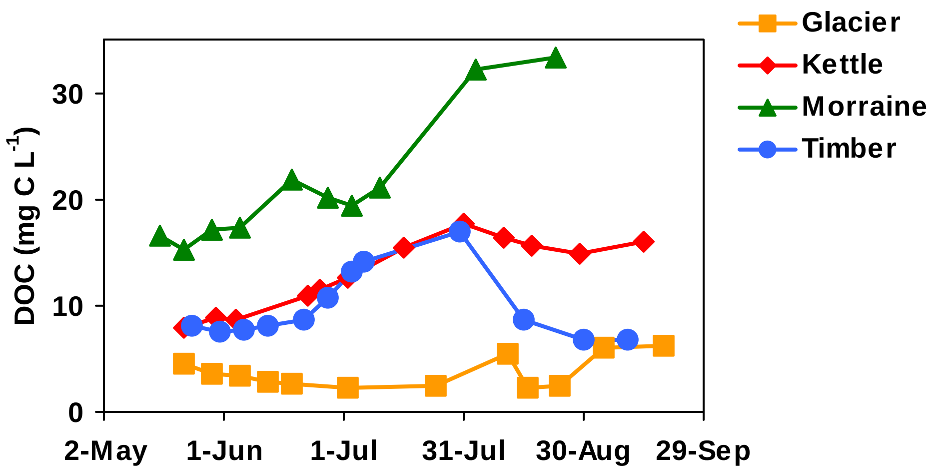

Figure 1. DOC concentrations at four sites in ROMO. Not only are initial DOC concentrations at each site very different, but the pattern of DOC change throughout the summer differs among sites.

To further investigate the reason for these inter-site differences, we have been examining the role of several watershed characteristics in controlling DOC composition and concentrations. We have analyzed water samples from the fall and spring at 23 sites in ROMO in both 1999 and 2001. Specifically, we expect that vegetation patterns and soil type may play an important role in controlling DOC in surface waters. Hydrological factors such as flushing time may also be important.

Incorporating GIS information to characterize watersheds

We obtained information on vegetation patterns and geology from the GIS database at ROMO. This allowed us to characterize each watershed by its dominant vegetation and underlying bedrock, which served as a proxy for soil type. There were significant differences in mean DOC among watersheds both with respect to rock and vegetation type (Table 1 and 2).

Table 1. Mean and standard deviation of DOC for different watershed geology.

	Mean DOC (mg/L)	Std Error
Quaternary alluvium	13.6	3.5
Pleistocene Glacial deposits	7.0	1.3
Middle Proterozoic granite and pegmatite	2.8	06

Table 2. Mean and standard deviation of DOC for different watershed vegetation patterns. Vegetation types are defined as in the ROMO GIS database.

	Mean DOC (mg/L)	Std Error
Tundra	1.9	0.3
Evergreen forest	4.0	0.9
Forested wetland	6.0	0.9
Mixed forest	8.4	1.7
Wetland	18.0	5.2

These results are consistent with what we had expected, with wetland vegetation associated with higher DOC concentrations, and areas characterized by granites and tundra associated with low DOC concentrations.

Hydrological characteristics

We further classified each watershed by drainage type as being either flushed or perched. Flushed watershed show little change in ANC throughout the summer, as residence time of the water and evaporative effects are low. In contrast, perched watershed are dominated by evaporation, and show increases in ANC throughout the summer as ions become concentrated. The % cover of emergent vegetation also provided a way of characterizing watersheds.

Relationship between watershed characteristics and DOC

We used the watershed characteristics in ANOVA models to identify the strongest controls on DOC (Table 3).

Table 3. P-values from ANOVA model. Values less than 0.05 suggest a significant correlation.

	Geology	Elevation	Vegetation	Veg. * Elev.	Drainage	% Emergent Veg
DOC (mg/L)	0.47	0.63	*0.03*	*0.04*	*0.03*	0.12
Fluoresence Index	0.15	0.72	*0.02*	*0.02*	0.6	*0.03*

Further examination of these relationships showed temporal differences in the main controlling factor. In the spring, DOC was more closely related to differences in vegetation characteristics, presumably because of high terrestrial inputs due to snowmelt and runoff. This is supported by the lower FI ratios found during this time. In the fall, DOC was more closely related to drainage type, suggesting the hydrological characteristics of the waterbodies become important as precipitation inputs decrease, particularly in drier years. Furthermore, it is important to note that elevation is merely a confounding factor; it is the effect of elevation of vegetation patterns, not elevation itself, which is related to DOC patterns.

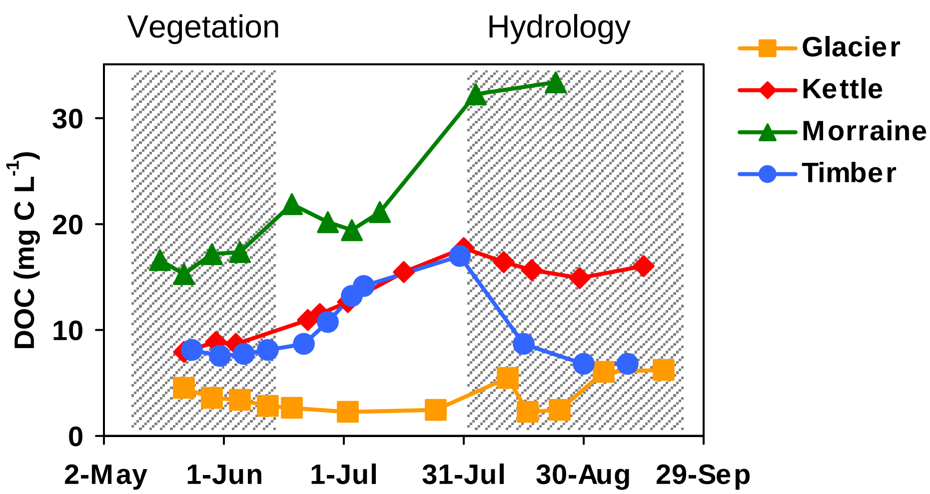

Figure 2. DOC concentrations for 4 sites in ROMO. Watershed vegetation patterns control the intial DOC concentrations, while hydrologic characteristics influence DOC patterns in the late summer season.

INFORMATION TRANSFER

SUMMARY

Variability in climate, primarily precipitation, coupled with local hydrologic flowpaths and landscape position exert a significant control on UV exposure in the aquatic environment. This control is mediated through the amount and composition of DOC transported from the terrestrial environment to the aquatic ecosystem. Future work should focus on quantifying both the spatial and temporal variability in the DOC mediated UV exposure to these, and other aquatic ecosystems characterized by episodic hydrological inputs of terrestrial DOC to surface water.

Major findings

1. Watershed vegetation exerts strong control on initial DOC concentrations.
2. Watershed drainage patterns (perched vs. flushed) effects DOC concentrations in late summer.
3. Both watershed vegetation type and % macrophyte cover influence the composition of DOC.

4. These results provide the structure to make estimates of DOC concentrations and seasonal patterns in locations for which there is no data, using watershed characteristics which can be easily determined using GIS.

APPENDIX 1. DATA