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The apparent rate constant for the temperature effect on specific respiration is too large by more than an order of magnitude to be a simple metabolic response. Therefore, other covariates must be amplifying the trend. Potential covariates include a decline in BOC quality with increasing latitude caused by shifts in the dominant vegetation, and lower nutrient availability with increasing latitude due to sequestration and immobilization by stored OM. Jones (1997) reported that the abundance of FBOM is correlated with the abundance of CBOM, which in turn is correlated with the abundance of wood, which is correlated with latitude and precipitation. These trends suggest a latitudinal gradient in mean BOM particle size which might amplify the apparent temperature response of respiration, because, as a first approximation, microbial activity per unit OM is a function of the ratio of surface area to volume of the particles.

It is also possible that sampling biases are contributing to the respiration trend. I suggest that in high gradient mountain streams, it is relatively "easy" to estimate BOC because the sediments are shallow and a high fraction of the BOC consists of woody boles and associated debris dams. However, this same heterogeneity also makes it difficult to accurately estimate system respiration. Conversely, in more homogeneous, low-gradient systems, estimating BOC is complicated by shoals and deep hyporheic channels, perhaps leading to underestimates, while estimates of areal respiration may be somewhat easier to acquire.

Even without knowing the mechanisms of amplification, the large-scale pattern is interesting. If interpreted literally, it portends dramatic changes for stream ecosystems in the exigency of global warming: a 50% increase in benthic respiration for each 1°C rise in mean annual water temperature. Because streams within an ecoregion show only weak relationships with temperature, it appears that saltational changes in stream structure and function are associated with shifts in major climatic and vegetation zones. Thus, even if significant climate change occurs over the next several decades, several centuries might be required for a stream to reestablish a new equilibrium condition with its watershed.

Although current data suggest that alterations in stream respiration with temperature will be modest unless a watershed is pushed into a new biome, the database for such conclusions is sparse and there is good reason to question the adequacy of respiration data from only 22 sites. The apparent contrast between intra-biome and inter-biome patterns highlights the need for large-scale studies that focus on the mechanisms controlling the abundance and metabolism of organic matter.

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Suspended particulate organic matter concentration and export in streams

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From an ecosystem perspective, POM concentration and export are significant characteristics of streams. The transport of material links upstream and downstream communities trophically into an integrated ecosystem. Most POM transported in streams is fine material (<1 mm) (Sedell et al. 1978, Cudney and Wallace 1980,

Naiman 1982, Wallace et al. 1982, Hill et al. 1992). Coarser material (i.e., leaves and wood) tends to be retained near its point of entry, especially in smaller streams (Webster et al. 1994). POM in transport originates from biological and physical processing of leaves and wood (Webster 1983, Wotton 1984), erosion of soil organic matter (Meybeck 1982, Hedges et al. 1986), flocculation of DOM (Bowen 1984, Wotton 1984), and sloughing or grazing of periphyton (Lamberti et al. 1987). Concentrations and quantities of material exported are determined by the interaction between availability of material to be transported, stream power, and efficiency of in-stream retention devices (Naiman 1982, Golladay et al. 1987).

Although the importance of material transport is well recognized, applying the ecosystem concept to streams has proved difficult for several reasons. Longitudinal boundaries of stream ecosystems are often indistinct. Lateral boundaries can vary seasonally as streams expand and contract across their floodplains. Streams receive substantial quantities of material from the adjacent landscape, but because of the unidirectional flow of water, more material typically flows through stream segments than is stored or cycled in place. These problems are greatest for large streams; consequently most ecosystem studies of streams have focused on headwaters or individual reaches of larger rivers.

Recent studies have suggested that position within drainages and hydrologic linkages with riparian areas may determine the functional role of reaches and segments within the larger drainage (Naiman 1982, Pringle et al. 1988, Meyer and Edwards 1990, Golladay and Taylor 1995). An integrated view of stream ecosystem structure and function emerges from linking discrete units. If this view of streams is correct, then general trends should be apparent across a range of streams. This chapter examines suspended POM concentration and POM export across the data base of stream study sites described earlier in this paper.

Methods

The database included 31 streams with values for average POM concentration and sufficient information to calculate percent of total organic matter concentration [%POM = ((POM)/(POM +DOM)) × 100] (Table 1). Because streambed area estimates were not available for some (especially larger) streams, it was possible to calculate export ($g \cdot m^{-2}$ streambed area $\cdot y^{-1}$) for only 22 of these sites. Storm transport of POM was not sampled in all streams and this is noted in Table 1. Streams were also classified according to presence or absence of riparian forest (forest versus non-forest). The initial step in data analysis was to examine scatter plots of POM concentration, %POM, and export. Occasionally, a stream (or streams) appeared to be very different from other sites. Subsequent statistical analyses were performed with and without those "exceptional" streams and noted in the results. Possible explanations for exceptional streams, based on site-description chapters or other information, are provided in the Discussion.

Differences in POM concentration, % POM, and POM export in forest and non-forest streams were analyzed using a Mann-Whitney Rank Sum Test. POM concentration, %POM and POM export were regressed against physical factors listed in the database. In analyses of stream order and gradient, streams were first sorted by the presence or absence of riparian forest. Averages were then determined for streams of the same order or similar gradient. Also, correlations were performed between POM concentration, %POM, and POM export versus measures of organic matter availability (FBOM, CBOM, total benthic organic matter, and wood standing stocks). Relevant transformations were applied when necessary to meet the assumptions of the statistical procedure. Statistical analyses were conducted using SigmaStat for Windows V. 1.0 (Jandel Scientific Software, San Raphael, California).

Results

Of the physical factors analyzed, only total annual precipitation, stream order, and gradient showed any relationship with POM concentration, %POM, or POM export. There was no correlation between measures of organic matter standing stock and POM concentration, %POM, or POM export.

POM concentration

Streams draining forested areas had significantly higher average POM concentrations than those draining non-forested areas (Mann-Whit-

TABLE 1. Particulate organic matter concentration, contribution of POM to total organic concentration (% POM), and POM export (per unit streambed area) for a number of intensively studied streams. Column 6 indicates whether storms were systematically sampled during the process of estimating POM concentration and export. Stream acronyms are defined by Webster and Meyer (1997).

Site	Order	POM conc. (mg/L)	% POM	POM export (g·m⁻²·y⁻¹)	Storms sampled?
Forest					
W3OR	1	0.21	28	123	N
W4OR	1	1.41	44	817	N
AGMI	1	5.50	40	2146	N
DCOR	1	0.95	37	170	N
FCQB	1	0.63	17	1733	Y
BBGR	1	2.66	31	687	N
BBVA	1	7.17	26	1108	Y
WBTN	1	3.62	67	1087	Y
SBNC	1	2.06	67	300	Y
AKC2	1	1.10	15	586	?
AKC3	1	1.50	7	469	?
HWNC	2	7.22	71	535	Y
BCQB	2	11.15	6	—	Y
BBNH	2	1.40	77	267	Y
CSNC	3	2.06	5	—	Y
MCOR	3	0.46	40	—	N
WCPA	3	15.30	27	2317	Y
FRMA	4	1.95	24	—	Y
KCAU	4	5.89	53	1931	Y
LCOR	5	0.51	42	—	N
MRQB	5	1.50	7	—	Y
MTQB	6	1.94	6	—	Y
ORGA	6	1.14	4	181	Y
MROR	7	0.68	38	—	N
MOQB	9	1.21	9	—	Y
Mean		3.17	33	904	
Median		1.50	28	636	
Range (25–75%)		1.06–4.09	9–43	283–1420	
Non-forest					
RSWA	1	0.33	32	75	N
CSAN	1	0.33	40	6	?
KPKA	3	0.14	5	2	N
KRAK	4	1.78	8	107	Y
KGKA	5	0.21	8	2	N
SCAZ	5	0.47	2	36	Y
Mean		0.55	16	38	
Median		0.33	8	21	
Range (25–75%)		0.21–0.47	5–32	2–75	

ney Rank Sum Test, $T = 38.0$, $p = 0.004$) (Table 1). POM concentrations in forested streams ranged from 0.21 to 15.30 mg AFDM/L and in non-forested streams ranged from 0.14 to 1.78 mg AFDM/L. White Clay Creek (Pennsylvania) and Beaver Creek (Quebec) had the highest average POM concentration, approximately 1.5 to 2× greater than any other stream.

With all streams included in the analysis there was no relationship between POM concentration and average annual precipitation ($r^2 = 0.001$, $p = 0.8$). However, several sites were exceptional (Fig. 1). White Clay Creek and Beaver Creek had high POM concentrations with intermediate precipitation. Streams from the McKenzie River drainage in Oregon had relatively low POM concen-

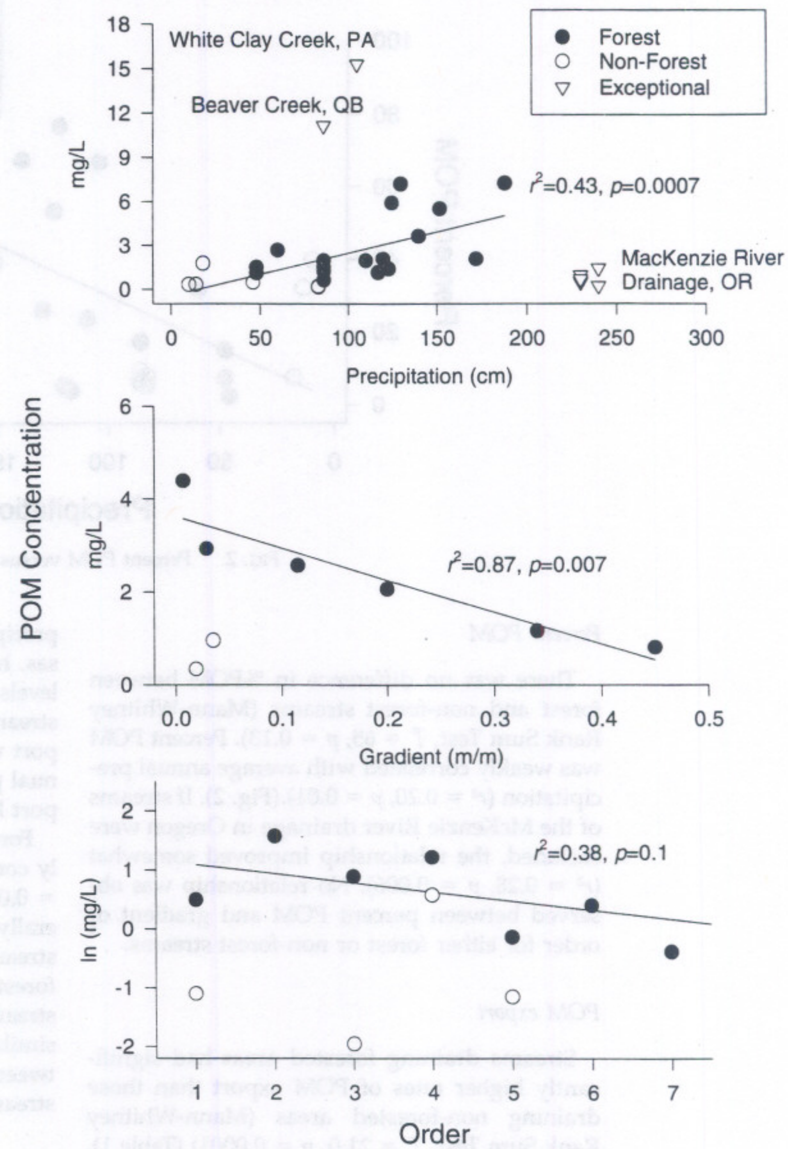

FIG. 1. POM concentration versus average annual precipitation, stream gradient, and stream order. Streams of similar order or gradient were averaged prior to regression analysis.

trations and high precipitation. With those streams excluded from the analysis, POM concentration was positively correlated with average annual precipitation ($r^2 = 0.43$, $p = 0.0007$) (Fig. 1). Streams receiving greatest amounts of precipitation generally occurred in forested areas.

For forest streams, POM concentration was negatively correlated with stream gradient ($r^2 = 0.87$ $p = 0.007$), i.e. low-gradient streams had the highest POM concentrations (Fig. 1). There were not enough non-forest streams for analysis. Generally, non-forest streams had lower POM concentrations than forest streams of similar gradient.

POM concentration in forest streams was weakly negatively correlated with stream order ($r^2 = 0.38$, $p = 0.1$, POM concentration ln transformed) (Fig. 1). No relationship was observed between POM concentration and stream order in non-forest streams.

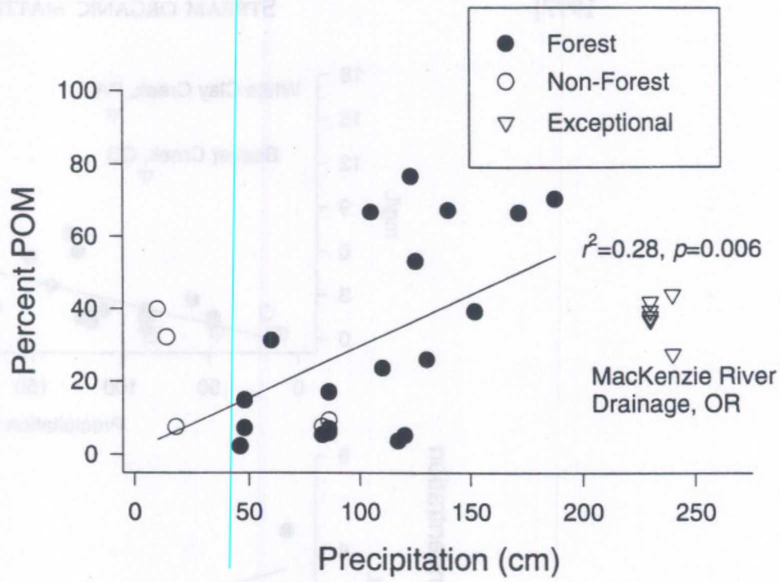

FIG. 2. Percent POM versus precipitation.

Percent POM

There was no difference in %POM between forest and non-forest streams (Mann-Whitney Rank Sum Test, $T = 65$, $p = 0.13$). Percent POM was weakly correlated with average annual precipitation ($r^2 = 0.20$, $p = 0.01$) (Fig. 2). If streams of the McKenzie River drainage in Oregon were excluded, the relationship improved somewhat ($r^2 = 0.28$, $p = 0.006$). No relationship was observed between percent POM and gradient or order for either forest or non-forest streams.

POM export

Streams draining forested areas had significantly higher rates of POM export than those draining non-forested areas (Mann-Whitney Rank Sum Test, $T = 21.0$, $p = 0.0001$) (Table 1). POM export in forest streams ranged from 123 to 2317 $g \cdot m^{-2}$ streambed area $\cdot y^{-1}$ and in non-forest streams ranged from 2 to 107 $g \cdot m^{-2}$ streambed area $\cdot y^{-1}$. White Clay Creek had the highest export.

With all streams included in the analysis there was no relationship between POM export and average annual precipitation ($r^2 = 0.11$, $p = 0.14$, POM export ln transformed). However, several sites were exceptional (Fig. 3). Streams from the McKenzie River drainage had relatively low POM export and received high levels of precipitation. Streams from Konza prairie, Kansas, had low export and received intermediate levels of precipitation. With the exceptional streams excluded from the analysis, POM export was positively correlated with average annual precipitation ($r^2 = 0.35$, $p = 0.01$, POM export ln transformed).

For forest streams, POM export was negatively correlated with stream gradient ($r^2 = 0.56$, $p = 0.08$), i.e., streams with lowest gradient generally exported more POM than high gradient streams (Fig. 3). There were not enough non-forest streams for analysis. Generally non-forest streams had lower export than forest streams of similar gradient. No relationship was found between export and order for forest or non-forest streams.

Discussion

General patterns across streams

Terrestrial vegetation appears to control organic matter concentration and export across a range of streams. In this study, forest streams had higher POM concentrations and POM export than non-forest streams. Consistently higher concentrations and export in forest streams can be linked to basic differences in organic inputs and processing between the 2 stream types. Forest streams receive high allochthonous

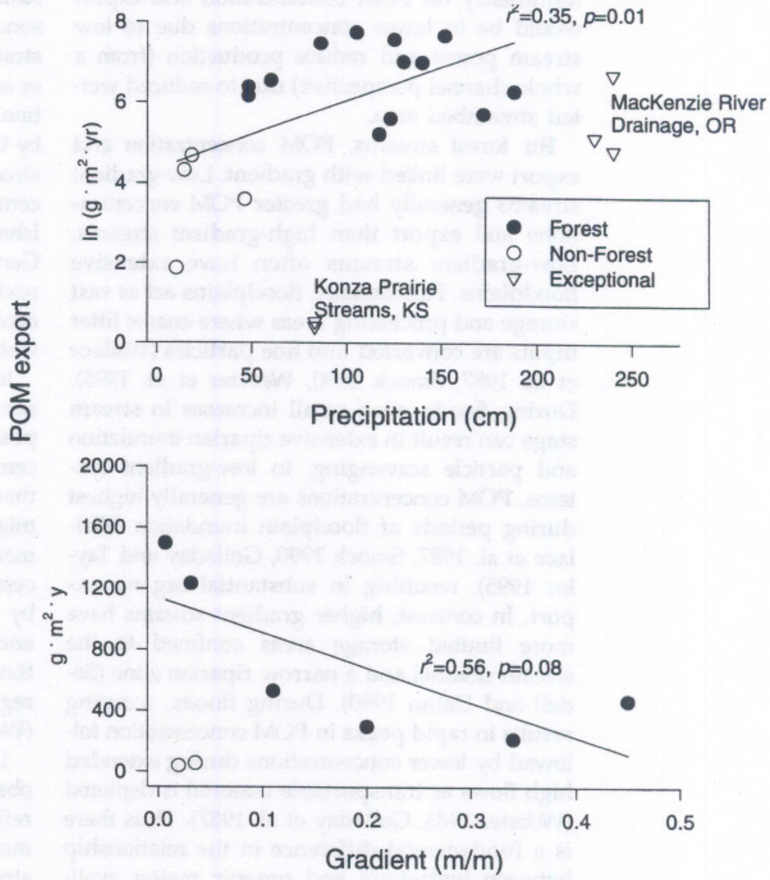

FIG. 3. POM export versus average annual precipitation and stream gradient. Streams of similar gradient were averaged prior to regression analysis.

inputs in the form of leaves and wood (Benfield 1997). Decomposition rates of this material tend to be low (Webster and Benfield 1986). Hedin (1990) reported that turnover times of allochthonous stream detritus were 26-fold longer than for organic material originating from autochthonous sources in other aquatic systems.

Assimilation efficiencies of aquatic invertebrates feeding on allochthonous detritus are also very low (Golladay et al. 1983). Thus, in forest streams, inputs generally exceed the metabolic capabilities of biota, resulting in the accumulation of organic material available for transport. Although debris dams and other retention mechanisms can be very efficient (Bilby and Likens 1980, Bilby 1981), substantial amounts of material are transported during both base flow (Webster 1983) and storm flows (Golladay et al. 1987, Webster et al. 1990). Non-forest streams can also have high organic inputs in the form of autochthonous production (Minshall 1978). However, decomposition rates and assimilation of autochthonous material by stream biota are generally high (Minshall 1978, Hedin 1990). In non-forest streams, metabolic capabilities are probably more closely matched with inputs largely due to the lability of autochthonous organic inputs.

In this analysis, POM concentration, %POM, and POM export were influenced by precipitation, being higher in areas receiving greater rainfall. This influence is probably indirect and reflects the control of climate on terrestrial vegetation. However, streams draining arid regions often have extended low flow periods where channels shrink and may become intermittent (e.g., Matthews 1988). Desiccation of stream channels decreases stream power and reduces the availability of aquatic habit. The effect of intermittency on POM concentration and export would be to lower concentrations due to low stream power and reduce production (from a whole channel perspective) due to reduced wetted streambed area.

For forest streams, POM concentration and export were linked with gradient. Low-gradient streams generally had greater POM concentrations and export than high-gradient streams. Low-gradient streams often have extensive floodplains. Functionally, floodplains act as vast storage and processing areas where coarse litter inputs are converted into fine particles (Wallace et al. 1987, Smock 1990, Webster et al. 1995). During floods, even small increases in stream stage can result in extensive riparian inundation and particle scavenging. In low-gradient systems, POM concentrations are generally highest during periods of floodplain inundation (Wallace et al. 1987, Smock 1990, Golladay and Taylor 1995), resulting in substantial organic export. In contrast, higher gradient streams have more limited storage areas confined to the stream channel and a narrow riparian zone (Sedell and Dahm 1990). During floods, scouring results in rapid peaks in POM concentration followed by lower concentrations during extended high flows as transportable material is depleted (Webster 1983, Golladay et al. 1987). Thus there is a fundamental difference in the relationship between hydrology and organic matter availability in high- and low-gradient systems. Low-gradient streams can scavenge organic matter from relatively large source areas (i.e., floodplains), which results in high POM concentrations and POM export. Higher-gradient streams have relatively small source areas, which limits the availability of material to be transported. From an ecosystem perspective, reaches with broad floodplains, whether headwater swamp forests or downstream bottomlands, can be important source areas for organic inputs to the larger stream ecosystem (Golladay and Taylor 1995).

For forest streams POM concentration tended to decrease with increasing stream order. Within individual stream drainages, downstream patterns in POM concentration have not generally been observed (e.g., Sedell et al. 1978, Wallace et al. 1982). Lack of pattern has been attributed to local variations in reach retentiveness in headwater streams and the influence of frequent storms (Wallace et al. 1982). However, previous studies may also be limited by the use of seasonal grab samples and sampling that was not stratified across the drainage network (by order or some other geomorphic character). An exception to the general lack of pattern was reported by Golladay and Taylor (1995), who observed a strong negative relationship between POM concentration and distance from headwaters in Ichawaynochaway Creek, a 5th-order stream in Georgia. Unlike other streams studied, Ichawaynochaway Creek is a low gradient stream, with extensive floodplain development in the headwaters.

In an analysis of eastern deciduous forest streams, Webster et al. (1995) reported a weak positive relationship between annual POM concentration and stream order. They suggested that increasing POM concentration downstream might result from accumulation of refractory material as organic matter is sequentially processed. However, their analysis was confounded by an interaction between POM concentration and region. Many of the larger streams (i.e., those with higher POM concentrations) were in regions with high average POM concentrations (Webster et al. 1995).

Longitudinal patterns of POM concentration observed for forested streams in this analysis reflect the differing functional roles stream segments play within stream drainages. In 2 stream drainages where segment area and length have been examined, small streams (order 1–3) represent 32–36% of total stream area (Naiman 1983, Meyer and Edwards 1990) and ~90% of stream length (Naiman 1983). In forested drainages, litter inputs generally decrease downstream as streams widen and are no longer covered by forest canopies. Thus, in a basin context, small streams act as collecting zones for CPOM because of their large contribution to stream area and length. Processing of CPOM results in POM transport downstream (Webster 1983). Assuming additional metabolism of POM occurs during downstream transport, concentration should decline downstream from headwaters through the midreaches of stream drainages. Declines in average POM particle size downstream from headwaters provide additional support for metabolism of POM during the process of transport (Naiman 1982, Webster et al. 1995). Although autochthonous inputs may increase downstream (Vannote et al. 1980), their relatively high turnover (Hedin 1990) may minimize contributions to POM concentration.

Exceptions to general patterns

Many values listed in Table 1 represent flow-weighted annual concentrations or were obtained using rating curves derived from extensive base-flow and storm sampling. Assuming sampling is adequate, those estimates incorporate the influence of storms, periods of much organic transport (Webster et al. 1990). Several streams had POM concentrations outside the range reported for most streams. Beaver Creek and White Clay Creek had relatively high POM concentrations (Table 1). In both cases, storms were systematically sampled and incorporated into estimates of average POM concentration. Streams of the McKenzie River drainage, Oregon, had relatively low POM concentrations, especially compared with other forested streams. Those streams were sampled seasonally but storms were not systematically sampled. The low POM export reported from Konza Prairie streams may also be due to a lack of storm sampling. Substantial export of organic matter has been measured during storms in other prairie streams and has been attributed to low numbers of debris dams or other retention structures (Hill and Gardner 1987). Clearly, intensive sampling over a range of hydrologic conditions is essential for accurately determining trends in stream ecosystem function. It is not clear whether high POM concentrations in Beaver Creek and White Clay Creek reflect more rigorous storm sampling than other sites, or perhaps a year with higher than average organic concentrations.

Limitations of the data base and general conclusions

This analysis clearly demonstrates that general trends in stream ecosystem structure and function exist across a range of stream sites. However, the ability to generalize is limited by the nature of the data. Most of the streams analyzed were smaller than 3rd order. Clearly more information is needed on larger streams, especially in regions like the southeastern US where many larger rivers remain relatively undisturbed and unregulated (Benke 1990). A few measurements made from streams draining arid regions (non-forested) suggest more work is needed in the Great Plains and southwestern US, again, particularly in larger rivers.

Several general trends emerge from the analysis. Terrestrial or riparian vegetation plays an important role in regulating POM concentration and export. Streams draining forested areas have high POM concentrations and export because organic inputs exceed within-reach metabolic potential; excess material is lost through downstream transport. Gradient influences POM concentration and export through an interaction with riparian geomorphology. Low-gradient streams, i.e., those with broad floodplains, have greater processing and source areas for POM than high-gradient and more constrained streams. In forested streams, position within the drainage influences POM concentration. Small streams (orders 1–3), because of their relatively large surface area and length, act as collecting zones for litter inputs within the larger stream drainage. This material is subsequently processed, transported, and further metabolized as it moves downstream, resulting in downstream declines in POM concentration. General trends emerge across a range of stream study sites and suggest that an integrated view of stream ecosystems results from examining the structure and function of individual segments and assembling them in a whole drainage context.

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Dissolved organic matter concentration and flux in streams

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Dissolved organic matter (DOM) in streams is important as an energy resource for food webs (Bott et al. 1984, Meyer 1990a), a regulator of nutrient uptake and cycling by heterotrophic microbes (Lock 1981, Meyer et al. 1988), a complexing agent for metals (McKnight and Bencala 1990, Mierle and Ingram 1991), and a determinant of pH and alkalinity (Oliver et al. 1983). DOM has been shown to be an important metabolic substrate in some streams, with DOM use contributing significantly to total stream metabolism (Naiman et al. 1987, Meyer and Edwards 1990). Sources of DOM are both the terrestrial watershed (McDowell and Likens 1988, Hornberger et al. 1994) and instream processes, such as leaching and decomposition of allochthonous particulate organic matter and release by stream algae (Kaplan and Bott 1982, Meyer 1990b). For small streams, the primary site of DOM use is the stream bottom, including the interstitial waters of streambed sediments (Dahm 1981, Hynes 1983, Ford and Naiman 1989, Fiebig and Lock 1991). In larger rivers, the water column may also be an important site for DOM use (Vannote et al. 1980).

Stream DOM is an important indicator of watershed-scale hydrologic and biogeochemical processes. Large water-soluble pools of DOM are present in the upper soil horizons of forests and grasslands (litter, O, and A horizons) and are sources of DOM to drainage waters; however, lower soil horizons (B and C horizons) often contain materials (e.g., iron and aluminum oxides) that effectively sorb and immobilize DOM (McDowell and Wood 1984, Cronan 1990). Hydrologic pathways involving lateral flow of water through or over surface soil layers often have relatively high concentrations of DOM, whereas water flowpaths that pass slowly through lower soil layers usually have low DOM concentrations (Moore and Jackson 1989, Kaplan and Newbold 1993). The commonly observed increase in DOM concentrations during periods of high discharge is at least partly due to shifts in dominant flowpaths from deeper routes to shallow subsurface or surface pathways (Tate and Meyer 1983, Mulholland et al. 1990, Hornberger et al 1994). Wetlands are also an important source of DOM to streams, and several analyses have shown that differences in baseflow DOM concentrations among streams are strongly related to the amount of wetland drainage contributing to streams (Mulholland and Kuenzler 1979, Eckhardt and Moore 1990). Saturated riparian soils and wetlands appear to be particularly important contributors to stream DOM, especially during storms (Fiebig et al. 1990, Hemond 1990).

In this paper I focus on the concentrations and flux of DOM in streams whose organic matter budgets are presented in the preceding chapters. My objective is to define the variation in annual average DOM concentrations and flux and to identify what factors might be most responsible for this variation.

Methods

The data used in this analysis are presented and described in the site-description chapters in this paper with the following exceptions. Values

STREAM ORGANIC MATTER BUDGETS

EDITED BY

J. R. WEBSTER AND JUDY L. MEYER

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Stream organic matter budgets[1,2]

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Abstract. This analysis of organic matter dynamics in streams has 3 objectives: 1) to explore the relationships between physical characteristics of streams and their watersheds (climate, geomorphology) and stream organic matter dynamics using data from a broad geographic area; 2) to compare stream organic matter dynamics in a diverse array of streams in order to suggest determinants of observed patterns; and 3) to reveal deficiencies in currently available data on organic matter dynamics in streams. Streams were included in this analysis not to represent the global diversity of stream types but because organic matter data were available. In the introductory chapter we describe the kinds of data included for each stream and provide brief descriptions of previously published organic matter data for streams included in the comparative analysis but not described in individual chapters. The next 16 chapters present organic matter data for streams from North America, Europe, Australia, and Antarctica. Most of the streams represented are in the temperate zone of North America. Data presented include climate and geomorphic variables and organic matter inputs, exports, and standing crops. The chapters on individual streams are followed by 7 chapters analyzing physical features of these streams and specific components of the organic matter budgets. Stream size, water temperature, and precipitation were the most important variables setting the physical template for organic matter processes occurring in the streams. Watershed area was the best predictor of gross primary productivity (GPP), which increased with increasing watershed area. Watershed area, discharge, and soluble reactive phosphorus concentration explained 71% of the variation in GPP. Climate (latitude) and vegetation type were more important than stream order in predicting litter inputs across a broad geographic range of streams, although, within a river basin, litterfall decreased with increasing stream order. Regression of benthic organic matter (BOM) and latitude and precipitation proved useful in predicting BOM standing crop in streams at a continental scale, although BOM was also related to channel characteristics such as gradient and woody debris. Benthic respiration increased dramatically with increasing temperature (Q_{10} = 7.6), suggesting a response related not only to metabolism but also to changes in BOM quality in response to latitudinal shifts in vegetation. Terrestrial and riparian vegetation was found to play an important role in regulating suspended particulate organic matter (POM) concentration and export, with higher values observed in forested streams and in lower gradient streams with extensive floodplains. Channel slope was the best predictor of dissolved organic matter (DOM) concentration and export, probably because of its relationship with riparian wetlands and hydrologic flowpaths. In the final chapter, a synthesis of the organic matter budgets, we reached two conclusions: 1) At a global level, stream organic matter dynamics are driven primarily by climate through its effect on terrestrial vegetation. 2) Despite significant progress in understanding organic matter processes in streams, many of the differences we found among streams reflect omissions of important components of the budget, especially accurate measures of streambed area, heterotrophic respiration, standing stock of fine BOM, and groundwater inputs of DOM.

Key words: stream, organic matter, budget, primary production, litterfall, BOM, DOM, POM, respiration.

Table of Contents

[1] Individual chapters should be cited as follows: *Author(s)*. 1997. *Chapter title*. Pages xxx–xxx *in* J. R. Webster and J. L. Meyer (editors). Stream organic matter budgets. Journal of the North American Benthological Society 16:3–161.

[2] Reprint requests for individual chapters should be sent to the appropriate senior author. Correspondence concerning the entire paper should be directed to: J. R. Webster, Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061 USA.