BIOLOGICAL ASSESSMENT OF SITES IN THE GALLATIN RIVER WATERSHED: GALLATIN COUNTY, MONTANA 2008 - 2016

Report to
The Gallatin River Task Force
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INTRODUCTION

This report reviews and analyzes data associated with macroinvertebrate samples that were collected at 2 sites in the Gallatin River watershed, Gallatin County, Montana over a span of 8 years, from 2008 until 2016. The study sites are the West Fork of the Gallatin River upstream of Big Sky spur bridge, and the West Fork of the Gallatin River.

The objectives of the study include using the invertebrate biota to detect impairment to biological health, using a series of biological metrics. With increased development in the watershed, the integrity of the Gallatin River and its tributaries may be threatened by impacts to channel structure and riparian zones as well as by degradation of water quality. The taxonomic and functional composition of benthic macroinvertebrate assemblages are known to respond to the effects of stressors that may be associated with accelerating human influences. Such stressors may include pollutants, sediment, thermal impacts and hydrologic alterations, and changes to the natural morphology of river channels and riparian zones. This analysis examines common stressors known to influence the Gallatin River watershed, including water quality degradation, loss and impairment of instream habitats caused by sediment deposition, and disturbance to reach-scale habitat features such as streambanks, channel morphology, and riparian zones.

Often canonical procedures are used for stressor identification; however, the substantial data required for such procedures (e.g., surveys of habitat, historical and current data related to water quality, land use, point and non-point source influences, soils, hydrology, geology) were not readily available for this study. Instead, attributes of invertebrate taxa that are well-substantiated in diverse literature, published and unpublished research, and that are generally accepted by regional aquatic ecologists, are combined into descriptions of probable water quality and instream and reach-scale habitat conditions. The approach to this analysis uses some assemblage attributes that are interpreted as evidence of water quality and other attributes that are interpreted as evidence of habitat integrity.

METHODS

All composition data were generated by Rhithron Associates, Inc. in Missoula, Montana: sample processing methods, taxonomic resolution, and quality control systems were generally consistent over all years' data. While there were some differences in taxonomic resolution over the years of study, these were determined to have minimal effect on metrics and interpretations and where possible corrections were made to alleviate any potential problems.

The analyses rely on the responses of the taxonomic and functional composition of the macroinvertebrate assemblages collected in 12 sampling events. Sampling events are summarized in Table 1. A series of several biological metrics are used to describe trends over the years of the study, and to predict probable stressors which may be influencing the benthic communities. We use graphical displays of trends in metric expressions when appropriate and narrative ecological interpretations to describe probable stressors and trends in biological condition.

Mayfly taxa richness has been demonstrated to be significantly correlated with chemical measures of dissolved oxygen, pH, and conductivity (e.g. Bollman 1998, Fore et al. 1996, Wisseman 1996). The HBI has a long history of use and validation (Cairns and Pratt 1993, Smith and Tran 2010, Johnson and Ringler 2014). The index uses the relative abundance of taxa and the tolerance values associated with them to calculate a score representative of the tolerance of a benthic invertebrate assemblage to organic pollution. Higher HBI scores indicate more tolerant assemblages. In one study, the HBI was demonstrated to be significantly associated with conductivity, pH, water temperature, sediment deposition, and the presence of filamentous algae (Bollman 1998). Nutrient enrichment often results in large crops of filamentous algae (Watson 1988). Thus in these samples, when macroinvertebrates associated or dependent on filamentous algae (e.g. LeSage and Harrison 1980, Anderson 1976) are abundant, the presence of filamentous algae and nutrient enrichment are also suspected.

Table 1. Sampling events and locations Gallatin River watershed, Gallatin County, Montana.
* Two replicate samples were taken.

Year		West Fork of the Gallatin River upstream of Big Sky Spur Bridge	South Fork of the West Fork of the Gallatin River
2008	Spring	4/14	
	Fall	9/12*	
2009	Spring	4/13*	4/13*
	Fall	9/8	
2010	Spring	4/11	
	Fall	9/5	
2011	Spring	4/10	
	Fall		
2012	Spring	3/27	
	Fall		
2013	Spring		
	Summer		8/13*
2014	Spring		
	Fall		
2015	Spring		
	Fall		
2016	Spring		
	Fall	9/7	9/7

Pollution-sensitive taxa exhibit intolerance to a wide range of stressors (e.g. Wisseman 1996, Hellawell 1986, Barbour et al. 1999), including nutrient enrichment, acidification, thermal stress, sediment deposition, habitat disruption, and other causes of degraded ecosystem health. These taxa are expected to be present in predictable numbers in well-functioning streams.

Stress from sediment is evaluated by caddisfly richness and by “clinger” richness (Kleindl 1995, Bollman 1998, Karr and Chu 1999, Wagenhoff et al. 2012, Leitner et al. 2015). The Fine Sediment Biotic Index (FSBI) (Relyea et al. 2001) is also used. Similar to the HBI, tolerance values are assigned to taxa based on the substrate particle sizes with which the taxa are most frequently associated. Scores are determined by weighting these tolerance values by the relative abundance of taxa in a sample. Higher values of the FSBI indicate assemblages with greater fine-sediment sensitivity. However, it appears that FSBI values may be influenced by the presence of other deposited material, such as large organic material, including leaves and woody debris.

Functional characteristics of the macroinvertebrate assemblages may also reveal the condition of instream and streamside habitats. Alterations from predicted patterns of the functional characteristics may be interpreted as evidence of water quality or habitat disruption. Predicted patterns are based on the morphology and behaviors associated with feeding, and are interpreted in terms of the River Continuum Concept (Vannote et al. 1980) in the narratives. For example, the diversity of stonefly predators is likely to be related to the diversity of invertebrate prey species, and thus the stability and complexity of streamside habitats. Sites with fewer than expected stonefly species are likely to have reduced habitat complexity. Also, the absence of long-lived species (those that take 2 years to mature in the stream) is likely related to catastrophes like periodic scour, thermal stress or toxic pollutants that could interrupt long life cycles. In addition, shredders and the microbes they depend on are sensitive to modifications of the riparian zone vegetation (Plafkin et al. 1989).

RESULTS

West Fork of the Gallatin River upstream of Big Sky Spur Bridge

a. Water Quality

Mayfly taxa richness declined from highs in 2008 (7 in both spring and fall) that were within expectations for a montane stream and appeared to indicate good water quality to lows of 3 taxa in spring 2011 and only 1 taxon in fall 2016 suggesting that water quality was impaired (Figure 1). Examining only the spring data, in 2008 the mayfly fauna included 1 baetid (*Baetis tricaudatus*), 3 ephemerellids (*Drunella doddsii, D. grandis*, and *Ephemerella inermis*, and 3 heptageniids (*Cinygmula* sp., *Epeorus longimanus*, and *Rhithrogena* sp.). Mayflies composed 13.6% of the fauna and 4 of these taxa were common each composing between 1.8% and 5.7% of the fauna. Most of these taxa persisted through spring 2010; however, by spring of 2011 only 2 ephemerellids (*E. excrucians* and an unknown taxon*)* and 1 heptageniid (*Epeorus* sp.) remained and by 2012 only 1 baetid (*B. tricaudatus*) and 2 ephemerellids (*D. grandis* and *E. excrucians*) remained. In both years, mayflies composed only about 3.0% of the fauna and only *E. excrucians* (around 2.0%) was common. Samples were collected in fall only 4 times and results were very similar to spring; however, in fall 2016, *D. grandis* (3.6%) was the only mayfly taxon collected. These results suggest that water quality became increasingly impaired over time at this site.

Over both seasons the HBI varied between a low of 2.47 (spring 2008) and a high of 6.07 (fall 2016) (Figure 2). When examining Figure 2, it is tempting to say that a trend of increasing HBI values exists; however, any trend would be based on the two points listed above. Conservatively given these data, there appears to be no real trend of increasing HBI values. However, one trend that did exist is that in years when samples were taken in both the spring and fall (2008, 2009, 2010), the HBI value was always higher in the fall than in the spring. Overall these data indicate that nutrient enrichment was mild to moderate at this site except for spring 2008.

The taxonomic composition of the assemblage also suggested that mild to moderate nutrient enrichment occurred in this reach. The occurrence filamentous algae are often considered a signal of nutrient enrichment. Midges often associated with filamentous algae (e.g, *Micropsectra* sp. and *Orthocladius* sp.) were extremely abundant in almost every sample suggesting that filamentous algae were abundant as well. For example, *Micropsectra* sp. was the dominant organism in the samples taken in the springs of 2009 through 2012. Its relative abundance varied between 22.2% and 55.7% of the sampled organisms. In addition, *Orthocladius* sp. composed > 10.0% of the sampled organisms in 7 of 9 samples.

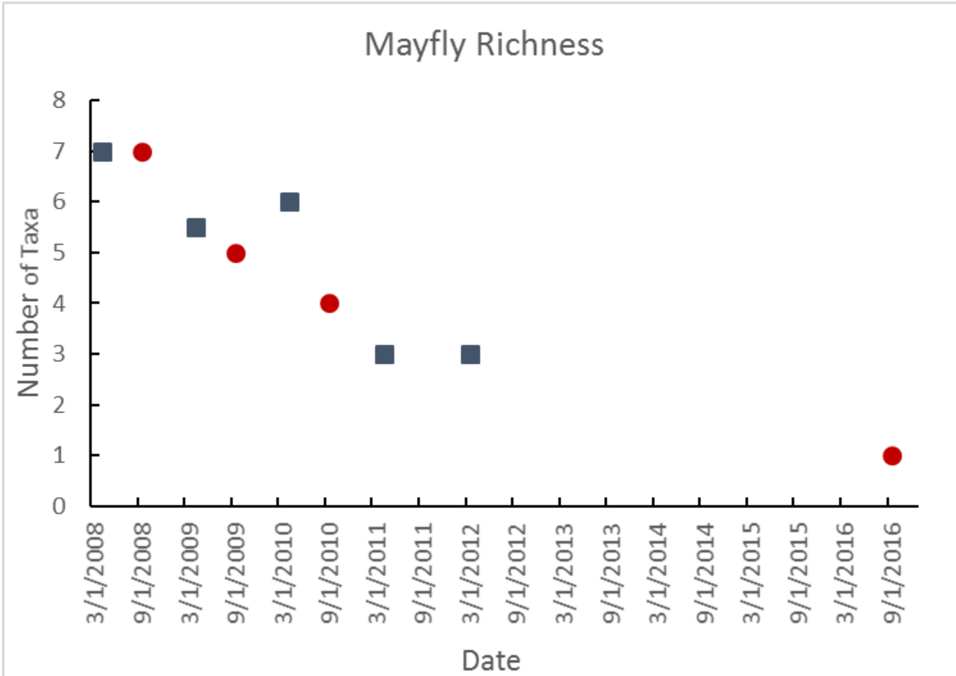

Figure 1. Mayfly taxa richness calculated from samples taken on West Fork of the Gallatin River upstream of Big Sky Spur Bridge. Blue squares indicate spring samples and red circles indicate fall samples. Values for 9/2008 and 4/2009 are averages of 2 replicates. All other points are based on 1 replicate.

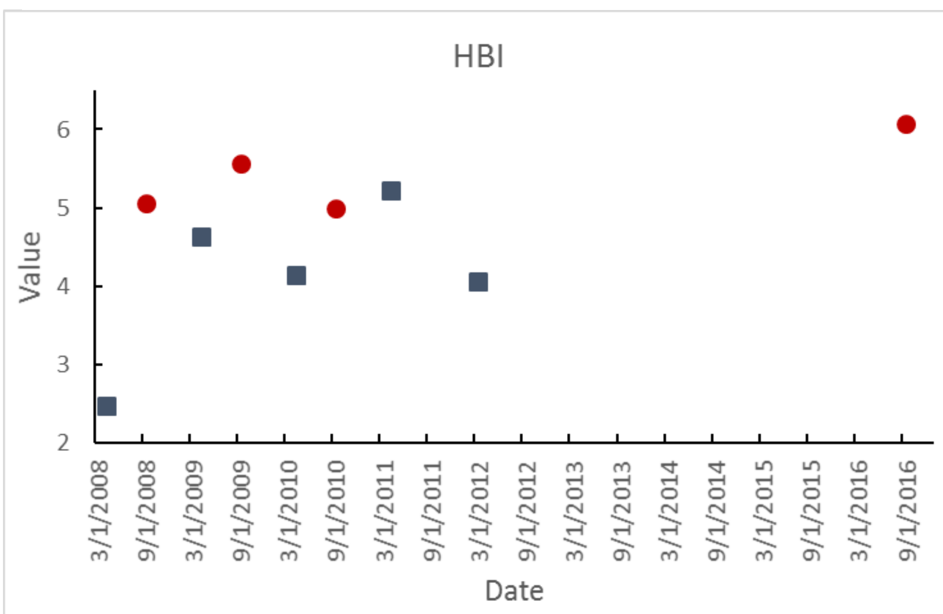

Figure 2. The HBI values calculated from samples taken on West Fork of the Gallatin River upstream of Big Sky Spur Bridge. Blue squares indicate spring samples and red circles indicate fall samples. The HBI values for 9/2008 and 4/2009 are based on composites of the 2 replicates taken at those times. All other points are based on 1 replicate.

Other indicators of nutrient enrichment include the percentages of hemoglobin-bearing organisms and the relative abundance of collector-filterers (Table 2). Neither of these indicators supported the contention of impairment through nutrient enrichment. In the case of this site, hemoglobin-bearing organisms composed < 2.0% of the assemblage during all sampling periods thus, there was no suggestion of hypoxic sediments resulting from nutrient enrichment here. In addition, collector-filterers composed < 4.0% of the assemblage during all sampling periods.

Table 2. Ecological indicators calculated from samples taken on the West Fork of the Gallatin River upstream of Big Sky Spur Bridge. *Indicator values are based on averages of the 2 replicates. § Indicator values are based on the composite of the 2 samples. Values for all other indicators are based on 1 replicate.

Potential Stressor	Metric	2008		2009		2010		2011	2012	2016
		Spring	Fall	Spring	Fall	Spring	Fall	Spring	Spring	Fall
Water quality	% Tolerant taxa	11.2%	4.1%§	4.8%§	2.6%	2.7%	2.4%	1.6%	1.2%	7.6%
	% Hemoglobin-bearers	0%	0.6%§	0%§	1.9%	0%	0.7%	0%	0.9%	0.3%
	% Collector-filterers	3.9%	0.8%§	0.9%§	0.7%	1.5%	3.7%	0.7%	0%	1.7%
	MTI	1.76	3.56§	2.79§	4.45	3.44	4.65	2.85	1.68	4.26
Thermal condition	Cold-stenotherm taxa richness	2	2*	1*	1	0	0	0	2	0
	% Cold-stenotherms	0.9%	2.4%§	0.5%§	1.0%	0%	0%	0%	0.6%	0%
	Assemblage temperature preference	13.6 °C	13.9 °C§	13.1 °C§	13.9 °C	13.4 °C	14.3 °C	12.2 °C	11.9 °C	15.1 °C
Sediment deposition	FSBI	3.28	5.80§	5.18§	5.32	4.90	5.54	5.00	4.19	5.47
Habitat	% Collector-gatherers	23.9%	72.8%§	78.9%§	75.5%	67.5%	65.0%	87.0%	92.0%	71.9%
	% Collector-filterers	3.9%	0.8%§	0.9%§	0.7%	1.5%	3.7%	0.7%	0%	1.7%
	% Scrapers	6.0%	5.7%§	3.7%§	5.5%	7.6%	2.4%	2.6%	0.3%	2.0%
	% Shredders	55.9%	5.9%§	8.0%§	9.0%	14.0%	20.2%	7.8%	5.3%	1.7%
	% Predators	10.3%	14.1%§	8.0%§	9.4%	9.4%	7.4%	2.0%	2.2%	17.9%

Other indicators of impaired water quality are the number of pollution-sensitive species collected and the percentage of pollution-tolerant organisms in the assemblage. The number of pollution-sensitive taxa exhibited a steady decline from a high of 5, which is within expectations for a montane stream, in fall 2008 to a low of 1 in 2011 (Figure 3) suggesting some stress on the fauna. There appeared to be some recovery in the spring of 2012 and in the fall of 2016; however, with only two data points the recovery is ambiguous at best and the taxa number did not recover to expectations. Sensitive taxa collected in 2008 included the mayflies *Drunella doddsi* and *D. grandis*, the midge *Potthastia longimana* Gr., and the caddisflies *Oligophlebodes* sp. in spring and *Apatania* sp. in fall. The caddisflies were the first taxa lost and were never collected again after 2008. *D. doddsi* was collected again in 2009, but never after that. *Potthastia longimana* Gr. (in 1 year replaced by *P. gaeddi*) was collected from all samples. The mayfly *D. grandis* was collected in all samples except 2010 and 2011 and was found in the last spring (2012) and fall (2016) samples. One stonefly taxon in the family Leuctridae was collected in spring 2012. Consequently, the decline in the numbers of pollution-sensitive taxa appears to be the result of the loss of the two caddisfly taxa and *D. doddsi.* Although it is purely speculative, the loss of the caddisflies could be the result of increasing water quality degradation, increasing fine sediment deposition in the reach (see Figure 4), or to the loss of cold-stenotherm taxa (Table 2) as all 3 taxa are cold-lovers. The percentage of pollution-tolerant organisms was only high twice in spring of 2008 and in the last sample in fall of 2016 (Table 2): the abundance of tolerant taxa actually declines over the other samples. Thus, the pollution-sensitive taxa richness indicator suggests increasing impacts over most of the time period, whereas the percentage of pollution tolerant organisms does not support this contention. There was no evidence for metals' contamination as the MTI was below the HBI in all sampling dates (Table 2)

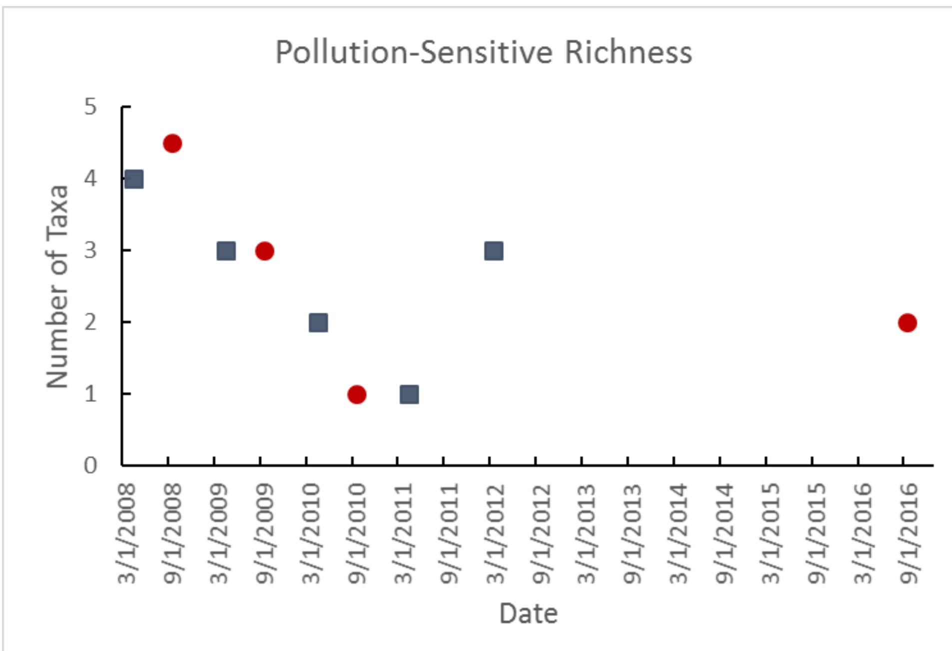

Figure 3. The number of pollution-sensitive taxa calculated from samples taken on West Fork of the Gallatin River upstream of Big Sky Spur. Blue squares indicate spring samples and red circles indicate fall samples. Values for 9/2008 and 4/2009 are averages of 2 replicates. All other points are based on 1 replicate.

b. Thermal condition

The calculated temperature preference of the assemblage varied between 11.9°C and 15.1°C (Table 2) and there appeared to be no discernable pattern over time except that spring temperatures (average 12.8°C) tended to be lower than fall temperatures (average 14.3°C). However, cold-stenotherm diversity was always low and seemed to decline over most of the sampling period (Table 2). Two cold-stenotherm taxa were collected in spring (*Drunella doddsi*, *Oligophlebodes* sp.) and fall (*D. doddsi, Apatania* sp.) 2008. In 2009, only *D. doddsi* was recorded during both sample periods. No cold-loving taxa were found in 2010, 2011 and 2016. Two cold-loving taxa (the stonefly *Diura* sp. and another taxon in the family Leuctridae) were recorded from the 2012 sample, which is the exception to the trend of declining taxa richness. In addition, when cold-stenotherms were collected their portion of the assemblage was always low (Table 2). Interestingly, the loss of the cold-stenotherm taxa between 2009 and 2011 appears to be reflective of the same pattern as the loss of pollution-sensitive taxa (see Figure 3).

c. Sediment deposition

There seemed to be a general trend of decreasing caddisfly (Figure 4) and “clinger” (Figure 5) taxa richnesses from 2008 through 2016 especially in the spring samples. In samples taken in the early years, both of these indicators were within expectations for a montane stream; however, by 2011, diversity had declined to below expectations. Typically, caddisflies composed between 1.5% and 8.5% of the assemblage; however, they were very abundant in spring 2008 (55.3%, due to the extremely high abundance of *Lepidistoma* sp.) and rare in 2011 (0.7%). “Clinger” percentages also varied considerably. During most sample periods, the FSBI indicated an assemblage that was moderately tolerant of fine sediment with no discernable pattern of increase or decrease over time (Table 2). Interestingly, spring assemblages (FSBI average 4.51) appeared to be more sediment-tolerant than fall assemblages (FSBI average 5.53). These results suggest that the deposition of fine sediments may be impeding the colonization of invertebrates at this site with the effect perhaps increasing over time.

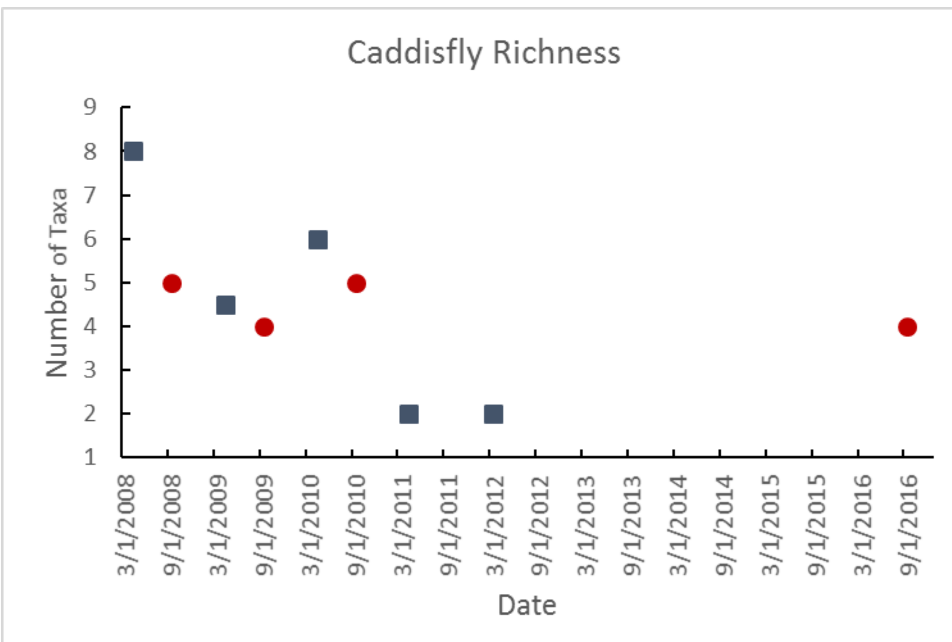

Figure 4. The number of caddisfly taxa calculated from samples taken on West Fork of the Gallatin River upstream of Big Sky Spur. Blue squares indicate spring samples and red circles indicate fall samples. Values for 9/2008 and 4/2009 are averages of 2 replicates. All other points are based on 1 replicate.

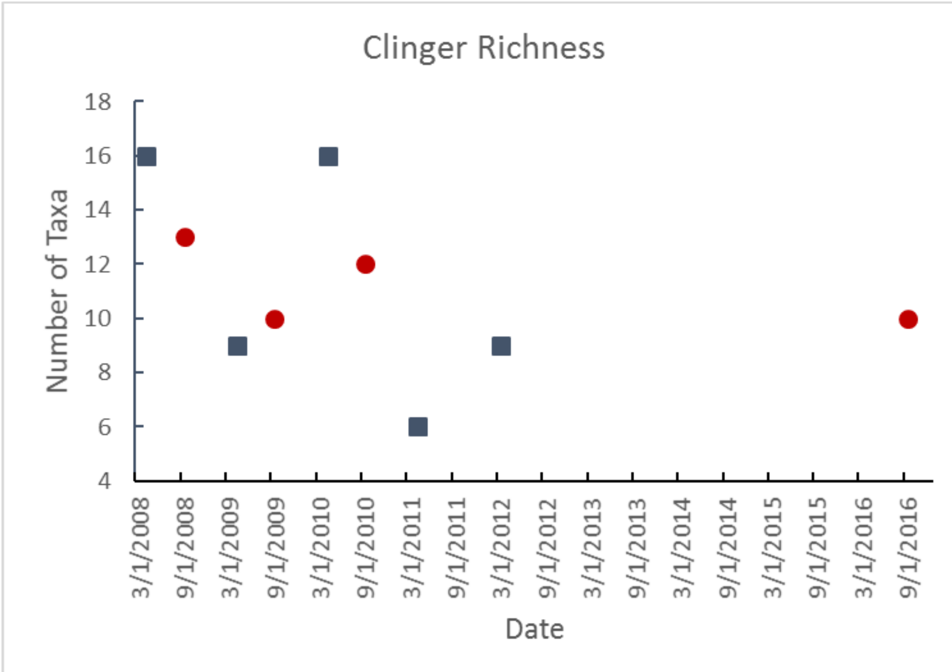

Figure 5. The number of "clinger" taxa calculated from samples taken on West Fork of the Gallatin River upstream of Big Sky Spur. Blue squares indicate spring samples and red circles indicate fall samples. Values for 9/2008 and 4/2009 are averages of 2 replicates. All other points are based on 1 replicate.

d. Habitat diversity and integrity

Overall taxa richness was moderately high (except for the spring 2009 sample) from 2008 through 2010 (Figure 6), suggesting diverse instream habitats. However, in spring 2009 and beginning in spring 2011, taxa richness was low perhaps reflecting monotonous or disturbed instream habitats during these sampling periods. Whether this decline reflects an ongoing trend is difficult to discern because there are so few data points beginning with the sample taken in spring 2011

Stonefly taxa richness tended to be lower in the fall than in the spring samples across all sampling times (Figure 7). Over all sampling dates, stonefly diversity was within expectations for a montane stream only 3 times (the spring samples in 2008, 2010, and 2012). Low richness in this group may be related to disruption of riparian vegetation, alteration of natural channel morphology, or unstable streambanks which may have occurred during or prior to sampling in most years. Although it may be tempting to describe a pattern to stonefly diversity over time, suggesting a general decline would be based on one high point (spring 2008) and one low point (fall 2016). Stoneflies were never a large component of the assemblage and there was no discernable pattern in changes in relative abundance over time, but there appeared to be more stoneflies in spring (average 4.1% of the fauna) than in fall (average 1.0% of the fauna).

Semivoltine taxa persisted at expectation levels until 2010 suggesting year-round surface flow and the absence of thermal extremes or scouring sediment pulses (Figure 8). During these years at least one taxon (the caddisfly *Arctopsyche*) was common. In the springs of 2011 and 2012 long-lived taxa were represented by only 1 taxon with only 1 individual in each year. Near absence of these long-lived taxa suggests that the site may have been influenced by dewatering, thermal extremes, or scouring sediment pulses during those years. Long-lived taxa diversity rebounded in fall 0f 2016.

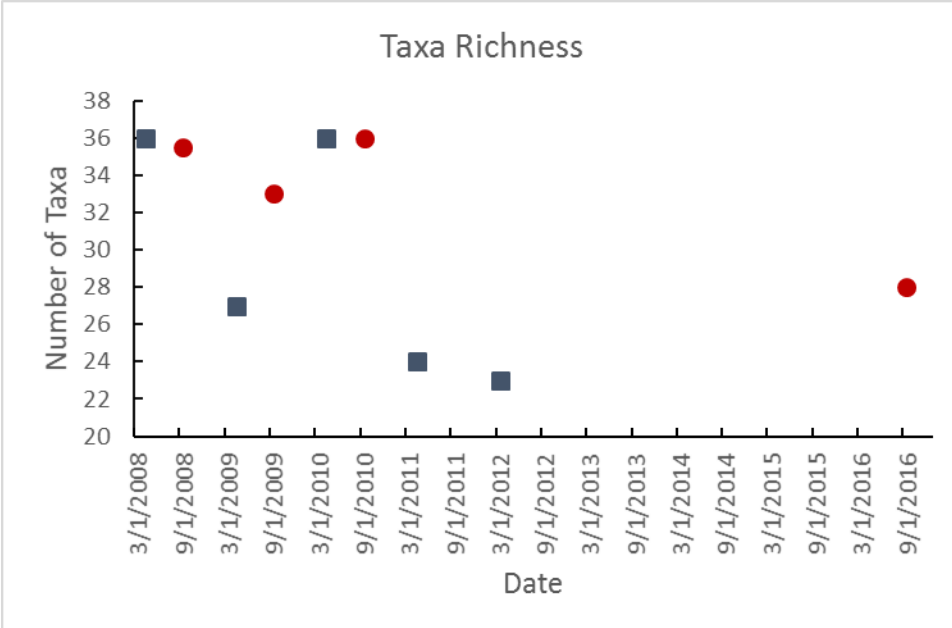

Figure 6. The total number of taxa calculated from samples taken on West Fork of the Gallatin River upstream of Big Sky Spur. Blue squares indicate spring samples and red circles indicate fall samples. Values for 9/2008 and 4/2009 are averages of 2 replicates. All other points are based on 1 replicate.

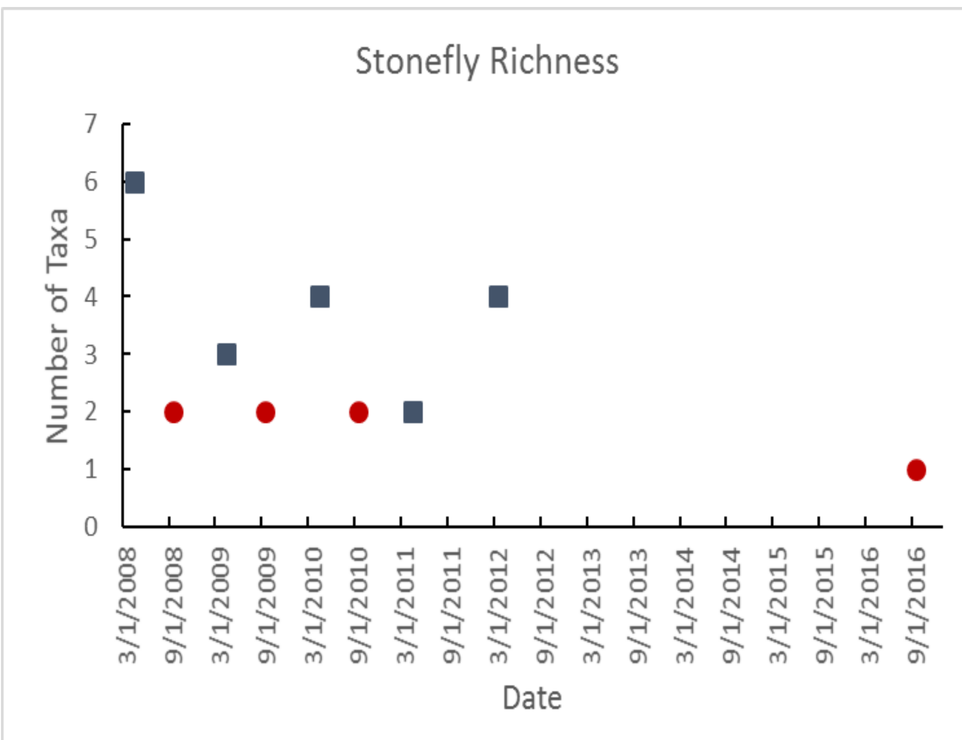

Figure 7. Stonefly taxa richness calculated from samples taken on West Fork of the Gallatin River upstream of Big Sky Spur. Blue squares indicate spring samples and red circles indicate fall samples. Values for 9/2008 and 4/2009 are averages of 2 replicates. All other points are based on 1 replicate

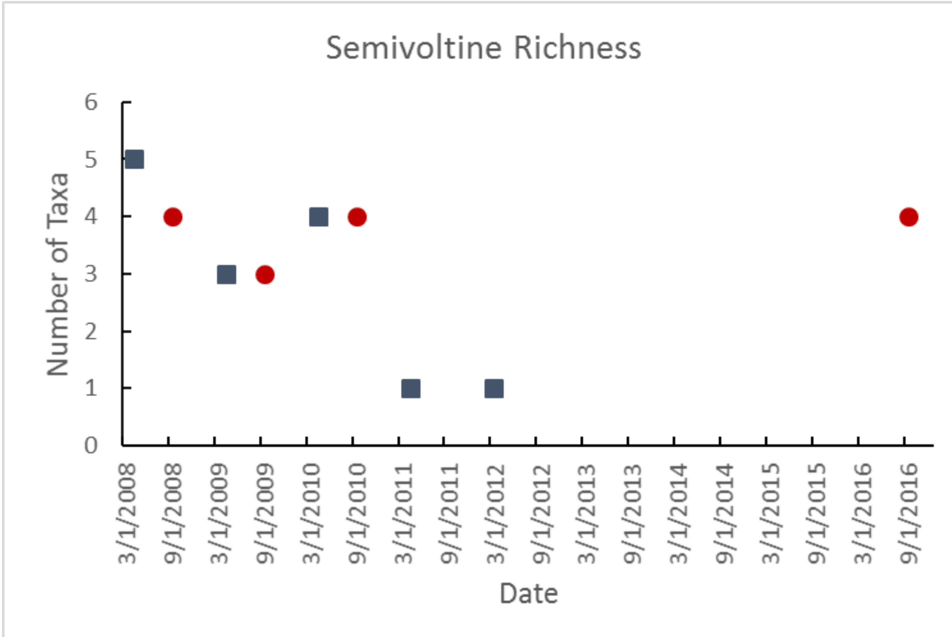

Figure 8. The number of semivoltine taxa calculated from samples taken on West Fork of the Gallatin River upstream of Big Sky Spur. Blue squares indicate spring samples and red circles indicate fall samples. Values for 9/2008 and 4/2009 are averages of 2 replicates. All other points are based on 1 replicate.

Except for spring 2008, when shredders dominated the functional composition of the assemblage because of the abundance of the caddisfly *Lepidistoma*, collector-gatherers were the dominant functional group (Table 2). Interestingly, collector-filterers were typically one of the least common functional groups varying between 0% and 3.9% of the assemblage. The proportions of shredders and scrapers were within expectations although they were not extremely abundant (Table 2). These results suggest that allochthonous fine particulate organic matter deposited on the stream bottom plays a large role in the dynamics of the food web and energy flow in this system, whereas such material that is suspended in the water column plays only a minor role. Contributions to the food web also occur from streamside vegetation and autochthonous instream production.

South Fork of the West Fork of the Gallatin River

a. Water Quality

Mayfly diversity was within expectations for a montane stream and relatively consistent at this site (Table 2). In 2009, the composite sample included 1 baetid (*Baetis tricaudatus*), 4 ephemerellids (*Caudatella edmundsi*, *Drunella doddsii,* D. *grandis*, and *Ephemerella inermis*), 3 heptageniids (*Cinygmula* sp., *Epeorus longimanus,* and *Rhithrogena* sp.), and 1 leptophlebiid (*Paraleptophlebia* sp.). Mayflies composed 26.7% of the fauna and many taxa were abundant or common (e.g., *E. inermis* was the second most abundant taxon and composed 10.1% of the sampled organisms). The taxonomic composition of the mayflies in 2013 and 2016 was relatively similar to the composition in 2009; however, the mayflies only composed 13.0% and 14.2% of the assemblages in 2013 and 2016. These samples were taken in August and September of those years whereas the sample in

2009 was collected in April, consequently the percentages cannot be directly compared to the 2009 values.

Table 3. Ecological indicators determined from samples taken on South Fork of the West Fork of the Gallatin River. *Indicator values are based on averages of 2 replicates. § Indicator values are based on a composite of the 2 replicates. All values for 9/2016 are based on 1 sample.

Potential Stressor	Indicator	Spring 2009	Summer 2013	Fall 2016
Water Quality	Mayfly Richness	7.5*	7.0*	6.0
	HBI	3.65§	5.67§	5.08
	Pollution-Sensitive Taxa Richness	5.0*	3.5*	3.0
	% Pollution-Tolerant Organisms	1.4%§	0.3%§	9.4%
	% Hemoglobin-Bearing Organisms	0%§	0.2%§	1.3%
	% Collector-Filterers	5.6%§	6.7%§	1.6%
	MTI	2.65§	4.17§	3.74
Thermal Condition	Cold-Stenotherm Taxa Richness	2.5*	3.0*	2.0
	% Cold-Stenotherm Organisms	2.1%§	2.9%§	2.3%
	Assemblage Temperature Preference	12.5°C§	13.4°C§	13.8°C
Sediment Deposition	Caddisfly Richness	7.0*	3.5*	7.0
	"Clinger" Richness	13.5*	14.5*	16.0
	FSBI	4.83§	4.95§	5.71
Habitat Diversity & Integrity	Total Taxa Richness	37.0*	34.0*	35.0
	Stonefly Richness	4.0*	2.5*	2.0
	Semivoltine Taxa Richness	4.0*	4.5*	4.0
	% Collector-Gatherers	59.7%§	47.9%§	46.7%
	% Collector-Filterers	5.6%§	6.7%§	1.6%
	% Scrapers	9.3%§	6.9%§	4.2%
	% Shredders	15.3%§	3.7%§	5.8%
	% Predators	9.5%§	34.0%§	37.7%

In 2009 the HBI was within expectations for a montane stream; however, in 2013 and 2016 the HBI indicated that the site was slightly to moderately impaired by nutrient enrichment (Table 2). The taxonomic composition of the assemblage also suggested that mild to moderate nutrient enrichment occurred in this reach. As mentioned previously, when taxa that are often associated with filamentous algae are abundant nutrient enrichment is suspected. Some midges (e.g, *Micropsectra* sp. and *Orthocladius* sp.) and worms (e.g., *Nais* sp.) that are often associated with filamentous algae were abundant at this site. For example, *Micropsectra* sp. (20.6%) was the dominant organism in the composite sample in 2009 and *Nais* sp. (13.6%) was the second most common taxa in 2016. Midges *Tvetenia bavarica* Gr. and *Orthocladius* sp. composed > 10.0% of the assemblage in 2013. In addition, caddisflies in the family Hydroptilidae, which are also associated with filamentous algae, were present in 2009.

Similar to the West Fork of the Gallatin River site other indicators of nutrient enrichment did not support the contention of impairment through nutrient enrichment (Table 3). The relative abundance of hemoglobin-bearing organisms was low, thus sediments do not appear to be hypoxic. In addition, collector-filterers composed between 1.6% and 6.7% of the assemblage. Neither of these indicators suggest that nutrient enrichment is a problem at this site.

Other indicators of impaired water quality are the number of pollution-sensitive taxa collected, the percentage of pollution-tolerant organisms in the assemblage and the MTI. These indicators suggest good water quality during most years (Table 3). Pollution-sensitive taxa included the mayflies *Drunella doddsi* and *Caudatella* sp*.* and the midges *Potthastia Gaedii* Gr. or *P. Longimanus* Gr. These taxa were present during all 3 sampling periods, although only *D. doddsi* was common (1.4% to 2.1% of the assemblage). Only in 2016 was the percentage of pollution-tolerant organisms above expectations (Table 3). The MTI did not indicate any contamination by metals as its value was below the HBI in all 3 years.

b. Thermal condition

The number of cold-stenotherm taxa recorded from this site varied between 2 and 3 (Table 3). These taxa included the mayfly *Drunella doddsi* and the caddisflies *Apatania* sp. and *Oligophlebodes* sp. and, as mentioned above, *D. doddsi* was common in all 3 samples. Cold-stenotherm taxa were common with the number of organisms varying between 2.1% and 2.9%. The calculated thermal preference of the assemblage varied between 12.5 and 13.8°C (Table 3).

c. Sediment deposition

Caddisfly and "clinger" taxa richnesses were within expectations for a montane stream during all 3 years (Table 3) suggesting that fine sediment deposition did not hinder the colonization of invertebrates here. At least some of the caddisfly taxa were common in every year (i.e., *Arctopsyche* sp. (2.3%), *Brachycentrus* sp. (4.3%) and *Lepidostoma* sp. (2.1%) in 2009; *Arctopsyche* sp. (1.3%) in 2013; *Arctopsyche* sp. (5.2%) and *Lepidostoma* sp. (2.6%) in 2016). The FSBI suggested that the assemblage varied between moderately tolerant and moderately intolerant of fine sediment (Table 3).

d. Habitat diversity and integrity

Overall taxa richness was moderately high in all years (Table 3), thus instream habitats appeared to be diverse and intact. Diversity of stoneflies was within expectations for a montane stream in 2009, but not in 2013 and 2016 (Table 3). Consequently, it appears that there may have been some impact to reach-scale habitat features such as riparian zones, stream banks or channel morphology. Diversity of long-lived taxa was high and within expectations. In addition, 2 semivoltine taxa were common (*Brachycentrus americanus* (4.3%) *Arctopsyche grandis* (2.3%)) in 2009, *A. grandis* was common in 2013, and *Arctopsyche* sp. (5.2%)and *Brachycentrus* sp. (1.3%) were common in 2016. These results suggest that catastrophes like dewatering, scouring flows or thermal extremes were unlikely to disrupt the life cycles of long-lived organisms here.

Similar to the West Fork of the Gallatin River upstream of Big Sky Spur Bridge, collector-gatherers were the dominant functional group at this site in all years (Table 3). Other functional groups were well represented with shredders and scrapers being abundant in 2009 and less so in 2013 and 2016. Interestingly, predators were the second most abundant functional group in 2013 and 2016 probably the result of mites (Acari) that composed > 20.0% of the organisms in the samples in those years. Also similar to the West Fork, these results suggest that allochthonous fine particulate organic matter deposited on the benthic sediments plays an extremely large role in the food web and energy flow in this system. Contributions to the food web also occur from streamside vegetation, fine particulates in the water column, and autochthonous instream production.

CONCLUSIONS

West Fork of the Gallatin River upstream of Big Sky Spur Bridge

- In 2008 and 2009 water quality appeared to be good or, at worst, slightly impaired at this site: mayfly taxa richness was within expectations for a montane stream, whereas the HBI indicated moderate impairment and taxa that indicated the presence of filamentous algae were abundant, both suggesting that the impairment was due to nutrient enrichment. However, beginning in fall 2010 mayfly taxa richness had decreased below expectations. These data suggest that after fall 2010, water quality was moderately impaired by nutrient enrichment.
- The calculated water temperature preference of the assemblage was lower in spring samples than in fall samples and there appeared to be no real trend over time. Cold-stenotherm diversity and relative abundance were low and diversity declined over most of the sampling period. However, this decline may be the result of water quality changes over time or increased sedimentation over time.
- The deposition of fine sediment appeared to increasingly impact the colonization of invertebrates over time. Prior to 2011 both the number of caddisfly and "clinger" taxa were within expectations for a montane stream; however, diversity of both indicators fell below expectations in 2011 in the spring samples.
- There is evidence that the habitat has been periodically disturbed at this site perhaps through disruption of instream habitats, dewatering, thermal extremes or scouring sediment pulses or through disruption of riparian vegetation, alteration of natural channel morphology, or unstable streambanks.

South Fork of the West Fork of the Gallatin River

- Impacts to water quality through nutrient enrichment cannot be ruled out at this site. Although mayfly taxa richness was within expectations, the HBI was elevated in 2 of the 3 years that samples were taken and taxa that are often associated with filamentous algae were abundant.
- Cold-stenotherm taxa richnesses and relative abundances were within expectations for a montane stream suggesting little impact of thermal pollution.
- Colonization of this site by invertebrates does not appear to be influenced by fine sediment deposition.
- In general, the habitat appears to be good at this site; however, there was some indication that reach-scale habitat features may have been somewhat disturbed.

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