

Macroinvertebrate Monitoring for the Upper Missouri River: Building a Long-term Data Set 2015-2019

Prepared for:

Alan Shaw, Sherry Meador, Pete Petersen, Pat Hunter and Bailey Sory
Project Managers/Co-Chairs



Missouri River Monitoring Station below the Dearborn River Fall 2019

Prepared by:

David Stagliano, Aquatic Ecologist
Montana Biological Survey
Helena, Montana

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All photos in the report were taken by MBS, unless otherwise noted

Executive Summary

UMOWA began the Missouri River Macroinvertebrate Monitoring program in 2015 and has continued this effort into 2019. We established seven long-term, baseline monitoring stations for sampling benthic macroinvertebrates and water chemistry within the section of the Missouri River between Wolf Creek and Cascade. Aside from one long-term NWE (PPL) monitoring site below Holter Dam sampled in August from 1995-2019, and 5 sites sampled once in 2005 by MDEQ, very few macroinvertebrate samples have been collected below Wolf Creek Bridge (MDEQ 2007). Therefore, the project goals of UMOWA's program are: 1) to conduct standardized, quantitative macroinvertebrate surveys to serve as baseline standards for future monitoring efforts within this Missouri River section 2) to establish seasonal macroinvertebrate population estimates and community characteristics to assess aquatic biointegrity and 3) to understand the insect dynamics in relation to increasing aquatic macrophyte beds, algae and recent sediment-flushing lows (2018).

Record high spring flows in 2018 have played a particularly important role by flushing silts from gravels, reshaping riffles and reducing macroinvertebrate densities at many of the main stem Missouri River sites; thus, the relative composition of many benthic macroinvertebrate assemblages has been restructured. In late-September of 2019, we collected 21 quantitative macroinvertebrate samples and habitat data at 7 sites; water chemistry (WQ) samples were taken on October 1st. Total nitrogen (TN) and phosphorus (TP) levels for October 2019, as well as June & October 2018, exceeded MDEQ's numeric nutrient standard across most sites, except downstream of LPPC and below the Dearborn River (see UMOWA 2019 WQ Report).

Other than the indirect effects of increased weed bed coverage and trapping of sediments,

we can find no direct correlation between the Missouri River's excessive nutrient concentrations and macroinvertebrate population characteristics.

Spring run-off events from Little Prickly Pear Creek (LPPC) and the Dearborn River continue to have significant effects on the densities and diversity of insect communities in the Missouri River below those tributaries, especially by adding mayfly (E), stonefly (P) and caddisfly (T) taxa (total EPT taxa); although, no new species were added in 2019. In 2016, at the Missouri River u/s of LPPC we observed the highest densities of macroinvertebrates (>20,000 per m²) and New Zealand mudsnails (>300 per m²) since 2015; these densities were significantly "knocked-back" by high spring flows in June 2017 and 2018 (now benthic communities avg. ~11,000 ind. per m²). But surprisingly, even with the high flows, annual NZMS densities increased further at this site in 2019.

High densities and standing crops of *Baetis* (BWOs), *Tricorythodes* (Tricos), Chironomidae (midges), and *Ephemerella* (PMDs) in the spring samples from Wolf Creek to Craig section "hatch-out" by the summer sampling period leading to lowered summer/fall densities of these taxa, and a dominance of non-insect taxa (scuds, sowbugs, worms and snails).

EPT taxa (mostly mayflies and caddisflies) have generally been low (<40% of all inverts) during previous fall sampling at LPPC, Craig and upstream of the Dearborn (2016-2018), but the fall 2019 samples u/s of the Dearborn had a significant increase in %EPT taxa, especially with the caddisflies. Hardy Bridge has also seen an increase in the caddisfly contributions to the benthic community. Therefore, it does initially appear that the summer 2020 caddisfly hatch numbers will be increased in this reach of the river.

Of the 21 species of caddisflies that were collected across the sites, the net spinning caddis, *Cheumatopsyche* and the long-horned caddis, *Oecetis* (tan caddisflies) were usually

the most prevalent. Caddisflies were more common in the summer sampling period and had been less of a percentage of total EPT than the mayflies, but in the fall of 2019, some sites reported much higher caddisfly densities and contributions to the % EPT metric.

EPT taxa richness, in general, increases with increasing distance from Holter Dam. Highest total taxa and EPT richness were reported at sites least affected by the dam, particularly the Missouri River at Hardy Bridge and Cascade which are 28 and 37 miles downstream from Holter dam, respectively. The Cascade site also contained the most unique benthic fauna reporting four mayfly species that were collected nowhere else in the study.

While not that important in the trout diet, the riffle beetle, *Optioservus quadrimaculatus* contributes significant numbers (avg. ~1,000 ind. per m²) to the benthic macroinvertebrate communities of the Missouri River sites between Wolf Creek and Craig; these are not represented in any of the metrics analyzed, because they are non-EPT insects.

Overall, macroinvertebrate communities collected in 2019 resemble those reported in 2015-2018 with similar taxa composition. There are some continued increasing trends in Total and EPT taxa richness at the Missouri River u/s LPPC, Craig, D/S of the Dearborn River, Hardy Creek and Cascade. We recorded significant reductions in Chironomidae (midges) and the % of non-insect taxa in the summer samples, especially at sites from LPPC to upstream of the Dearborn River. Increases in the percentage of non-insect taxa in the fall samples, largely from Turbellarian flatworms, worms and sowbugs, comprising the benthic samples was substantial in the Missouri River from Craig and upstream of the Dearborn River.

This invertebrate community shift from summer to fall reflects an increase in sediment build-up in many gravel areas of the stream channel, compounded by large contributions of aquatic

vegetation trapping sediments. HBI tolerance scores indicated significant organic pollution at four of the seven (>57%) monitoring sites, and this metric has also been used as a surrogate for sediment impairment. We have documented significant nutrient concentration increases since the fall of 2017 in both TN and TP.

In 2015, New Zealand mudsnails (NZMS) had low densities at multiple sites in the Missouri River from Wolf Creek to Cascade. They began to substantially increase their populations upstream of Craig, especially upstream and downstream of LPPC. High densities of the NZMS in 2016 at the MO_LPPC_US site were reduced by 66% after the flushing flows of June 2017 and by 60% at Craig in 2018.

We postulate that NZMS population increases, overall non-insect macroinvertebrate density increases, significant caddisfly decreases and the expansion of rooted weed-beds in the Wolf Creek to Dearborn section is potentially correlated with lower spring flushing flows from Holter Dam since 2011. The 2019 monitoring samples have largely focused on determining macroinvertebrate community responses (i.e., caddisflies, NZMS, non-insect taxa) to the above average 2017 spring flows, and the larger flushing flows of 2018.

Average total species richness per sample continues to increase at some sites (MO_LPPC_US, MO_Craig, Hardy and MO_Cascade) despite not gaining any new species, so diversity is improving across the section. This is largely a result of the flushing flows of 2018, where significant disturbance of benthic sediments and silt removal has decreased abundant midges, worms and other non-insect taxa and opened up cleaner gravel substrates for the typical caddisfly and mayfly species usually present in riffle habitats. Based on these increasing densities, tan caddisfly hatches should be on rise from Craig to the Dearborn River down to Hardy Bridge in the summer of 2020

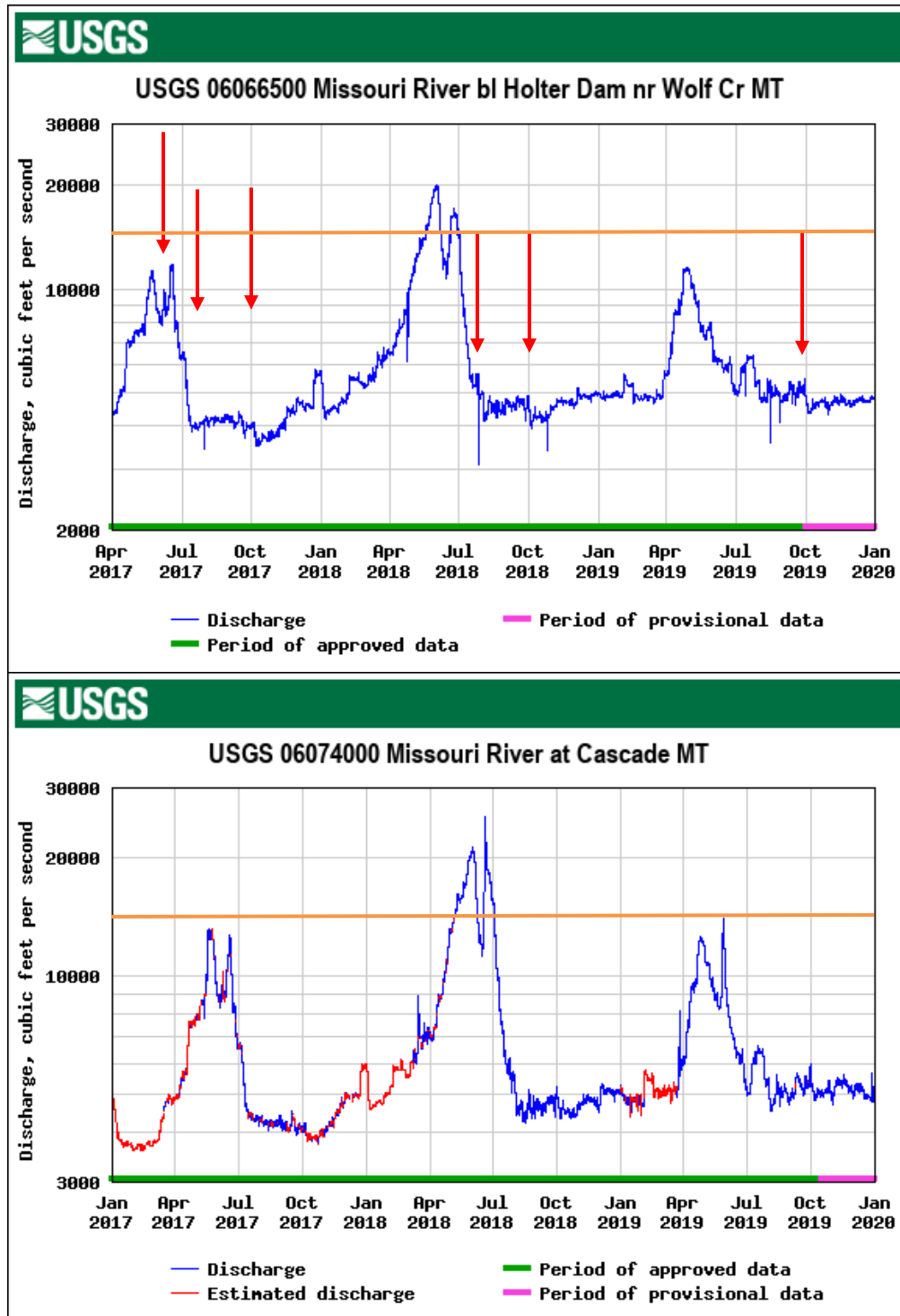
1.0 Introduction

2019 marks the 5th year that UMOWA has been collecting quantitative macroinvertebrate samples at 7-9 sites within the Upper Missouri River. We have been able to gather scientifically rigorous macroinvertebrate data during a variety of river conditions from one of the lowest mean discharge years (2016) to one of the highest (2018) (**Figure 1**). This study was designed to evaluate baseline status and continue monitoring of benthic macroinvertebrates, in the section of the upper Missouri River between Wolf Creek and Cascade. Until 2015 very few macroinvertebrate samples have been collected below the Wolf Creek Bridge, but there were four sites below Holter Dam and two sites above Canyon Ferry that MT Department of Environmental Quality (MDEQ) sampled qualitatively in the mid 2000's that are available to use as comparisons to this study (MDEQ 2007, Table 1). Benthic macroinvertebrates have been monitored at one site about 0.8 miles below Holter Dam annually by PPL (now Northwestern Energy) since 1995 (McGuire 2016). This is a highly regulated stream reach with dampened seasonal and short-term flow fluctuations, modified temperature regime, minimal flushing of sediment loads, and tremendous inputs of plankton and nutrients from upstream reservoirs. These conditions promote the extensive growth of aquatic plants (primarily water buttercup) and high benthic macroinvertebrate standing crops with limited community diversity (McGuire 2016). August density estimates at this Holter site typically range from 10-20,000 macroinvertebrates per square meter. Density estimates documented in 2015 and 2016 were at the high end of this range (McGuire 2016), but high flows from Holter in 2017 and 2018 have reduced densities to ~11,000 ind. per m² (Stagliano 2019). Our 2015-2018 sampling results corroborate these high invertebrate densities between Wolf Creek and Craig averaging ~15,000 organisms per m² across all seasons (Stagliano 2019).

Mayflies, stoneflies and caddisflies (i.e. Ephemeroptera, Plecoptera and Trichoptera {EPT taxa}) are of particular interest to fly fisherman, and are typical focal points of benthic invertebrate analysis because these orders contain some of the more sediment and "pollution" sensitive species of insects (Barbour et al 1999, Bukantis 1996). Anecdotal evidence and personal observations from this Missouri River section have indicated that caddisfly hatches are significantly reduced and that there has been a disappearance of the fall BWO hatches in the last decade or more. Scientifically collected data on these insect abundances is the only way to document current conditions and be able to say for certain how things may have changed in the future. **UMOWA's Project goals are:** 1) to conduct standardized and quantitative macroinvertebrate surveys to serve as the baseline standard against future monitoring efforts, 2) to assess aquatic biointegrity with key community indicators and compare these against

previously collected qualitative samples by MDEQ (2007), 3) to understand the insect community dynamics in relation to increasing aquatic macrophyte beds and minimal sediment flushing lows.

Figure 1. USGS Station 06066500: Missouri River below Holter Dam (top) and USGS Station 06074000 at Cascade (bottom) streamflow graph for the 2017-2019 sampling period. Red arrows are the seasonal sampling period dates. Orange line is the estimated flow (15,000 cfs) to have a sediment flushing effect (R2 Resources 1994).



2.0 Methods

2.1 Habitat and Physical Water Sampling

Temperature and basic water parameters (Total Dissolved Solids, pH, and Conductivity) were recorded at each site prior to macroinvertebrate sampling using an Oakton PC35 water quality multi-meter, calibrated for lower conductivity range (**Appendix D**). Water quality grab samples were also collected at all monitoring sites according to MDEQ protocols (MDEQ 2012b) and processed for TDS, TSS, TN, TP, NN at the Energy Laboratories in Helena (See UMOWA Water Quality Reports). A 50-meter survey tape was staked from the green-line on the stream bank to record sampling distances where samples were taken in the stream channel. Stream channel depths at each bug Hess sample (n=3) were recorded at the time of sampling (**Appendix D**).

2.2 Macroinvertebrate Sampling

Three replicate Hess (33 cm diameter) samples were taken at each site to quantitatively collect macroinvertebrates within a designated riffle at measured distances from the bank (**Photo 1 Appendix D**). Three Hess samples typically capture 90% of the total taxa present in a riffle (Vinson and Hawkins 1996). Each Hess sample constitutes a benthic area of 0.1 m². At each sampling point, the Hess sampler was pushed into the stream bottom to form an effective seal and all cobbles (>64 mm) within the sampling frame were scrubbed clean of organisms and removed; then the entire area within the sampler frame was raked (disturbed) for approximately one minute until all organic matter and macroinvertebrates were washed into the collection net of the Hess sampler (**Photo 1**). Macroinvertebrates, organic and inorganic matter were composited into a 40-liter bucket. By swirling the bucket with several water washes, organic material was elutriated from the inorganic (cobbles/gravels) portion onto a 500µm sieve, so that only macroinvertebrates and organic matter were transferred into 1 liter labeled sampling jars filled with 95% ethanol. The inorganic portion in the bottom of the bucket was thoroughly examined for caddisfly cases before being discarded back into the stream.

Photo 1. Hess sampling procedure in a Missouri River riffle near Little Prickly Pear Creek (MO_LPPC_US). Distance to the greenline was measured (redline).



2.3 Taxonomic Analysis

Samples were processed and analyzed at the Montana Biological Survey laboratory in Helena. Macroinvertebrates were picked from randomly chosen grids with the sample evenly distributed in a picking tray until at least 500 individuals are placed in vials with 95% ETOH. These were identified to the lowest taxonomic level possible (genus/species) with a dissecting microscope (10-40x) and compound microscope (100-1000x) used for the midges following standardized protocols (MDEQ 2012).

Numerous metrics were calculated from the data after it was entered into EDAS (Jessup 2006), including EPT taxa, %EPT, % Non-insect, % Chironomidae, %Crustacean-Mollusk and Hilsenhoff Biotic Index (HBI). The combined mayfly, caddisfly and stonefly species (EPT taxa) and the percentage of these in the sample (% EPT) are always informative metrics, as EPT taxa contain some of the more intolerant aquatic insects, usually requiring clean substrates. These are also the insects that most fly-fisherman are concerned about matching the hatch. Thus, EPT metrics typically decrease with increasing sediment in the benthic substrates (Barbour et al. 1999); although, Tricos (*Tricorythodes* and *Caenis*) are silt tolerant and can increase in numbers with increasing siltation. One informative stand-alone metric is the Hilsenhoff Biotic Index (HBI) which measures the tolerance of a macroinvertebrate community to organic enrichment (Hilsenhoff 1987) or sediment (MDEQ 2012). Tolerance values are based on a 0-10 scale, where zero-ranked taxa are most sensitive and 10-ranked taxa are most tolerant to pollutants. Values of 0.0-3.0 indicate no apparent organic pollution (excellent), 3.0-4.0 possible slight organic pollution (very good), 4.0-5.0 moderate pollution, 5.0-6.0 fairly significant pollution, 6.0-7.0 significant pollution (fairly poor), 7.0-8.0 very significant organic pollution 8.0-10 severe organic pollution.

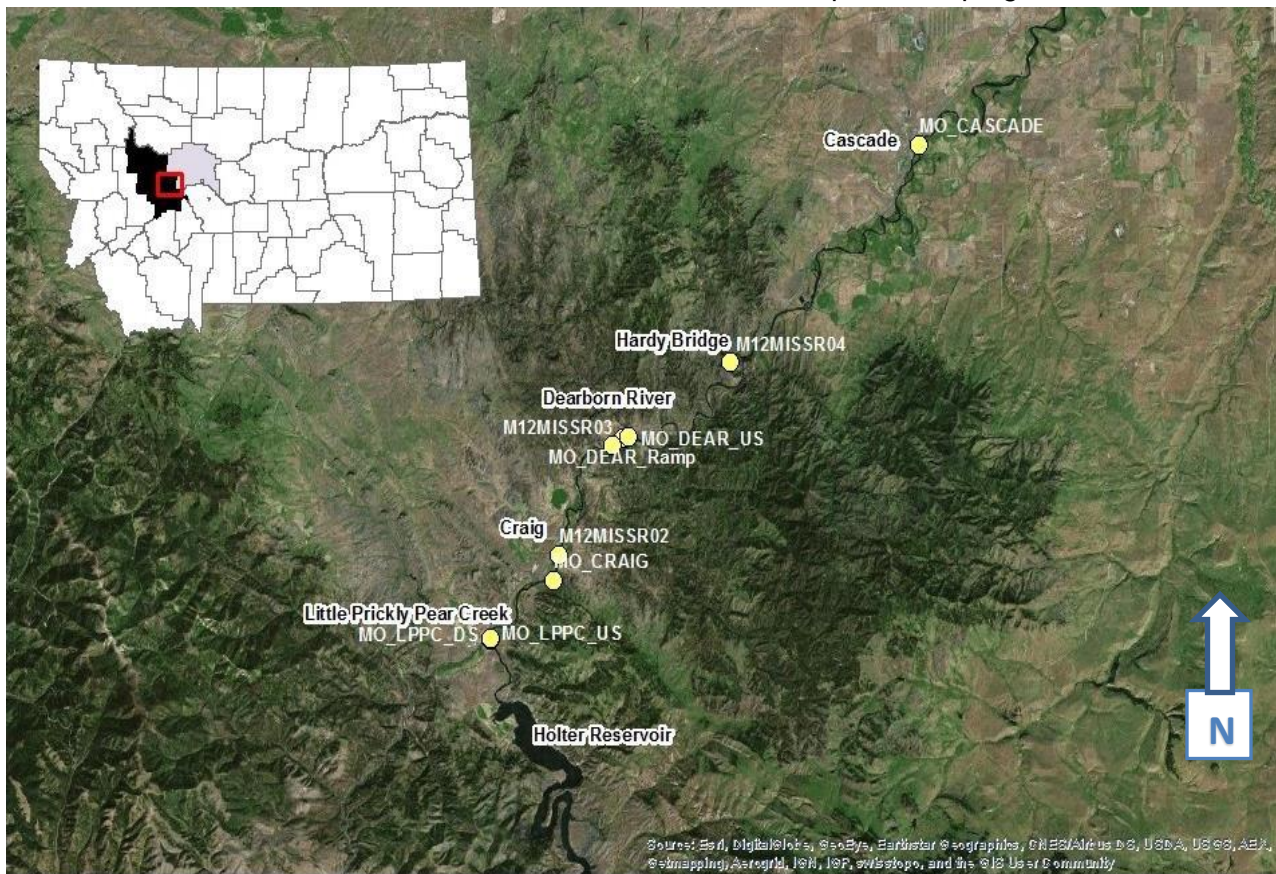
2.4 Sample Sites

We sampled macroinvertebrates and water chemistry at seven established monitoring sites between Wolf Creek and Cascade (**Table 1**). We have been trying to collect these samples during late-April (pre-runoff), spring monitoring period at flows of approximately 4,400 cfs, as in 2015-2017. Stream flows on the Missouri River during the 2019 spring sample period increased to >5,500 cfs on April 15th at the Wolf Creek Bridge and ~6,000 cfs at the Cascade site; these continued to ramp up into May, therefore, spring 2019 samples were not collected at any site (**Figure 1**). We sampled macroinvertebrates for the fall period on September 26th when flows were ~5,010cfs at Wolf Creek bridge and ~5,450cfs at Cascade (**Figure 1, Appendix D**); this was within days of the water quality sample collection on Oct 1st, 2019.

Table 1. UMOWA 2019 Sampling Study Reaches and ones that overlapped with MDEQ (2007).

Station ID	Agency	Waterbody Site Name	Latitude	Longitude
MO_LPPC_US	UMOWA	MISSOURI RIVER U/S LITTLE PRICKLY PEAR	47.02281	-112.01527
MO_LPPC_DS	DEQ/UMOWA	MISSOURI RIVER D/S LITTLE PRICKLY PEAR	47.02345	-112.01523
M12MISSR02	DEQ	MISSOURI RIVER @ CRAIG	47.06722	-111.96388
MO_CRAIG	UMOWA	MISSOURI RIVER U/S CRAIG	47.05415	-111.96701
MO_DEAR_US	UMOWA	MISSOURI RIVER U/S DEARBORN	47.12791	-111.91092
M12MISSR03 MO_DEAR_DS	DEQ/UMOWA	MISSOURI RIVER D/S DEARBORN	47.12336	-111.92396
MO_HARDYBR M12MISSR04	DEQ/UMOWA	MISSOURI RIVER U/S OF SHEEP CREEK (HARDY BRIDGE)	47.16781	-111.83366
MO_CASCADE	UMOWA	MISSOURI RIVER AT CASCADE FAS	47.28062	-111.69113

Map 1. Study locations on the Missouri River from Holter Dam to Cascade, flow direction is to the northeast from the bottom center of the map to the top right.



3.0 Results

Overall, 116 cumulative macroinvertebrate taxa were reported from the study between 2015 and 2019; Fall 2019 sampling (21 samples) did not add any new species to the cumulative taxa list. 2016 sampling added 24 taxa to the cumulative Missouri River taxa list from 2015. Most of these new taxa (10 species) were reported from weed bed sampling or observed at Missouri River sites below tributaries. We gained additional occurrences of 3 Baetidae mayfly taxa (*Callibaetis*, *Acerpenna pygmaea* and *Pseudocloeon*) by sampling the aquatic weed beds in 2016 (**Table 2**). Since 2015, the Missouri River U/S and D/S of LPPC (MO_LPPC_US) gained 7 EPT taxa each. No new taxa were added in 2018 from the 45 seasonal macroinvertebrate assessment samples collected between Wolf Creek Bridge and Cascade, but many rarer taxa were reported in higher numbers at sites below tributaries (especially salmonflies, *Pteronarcys californica* and yellow sallies, *Sweltsa* D/S of the Dearborn) (**Appendix C**). Average total taxa richness continues to increase at some sites (MO_LPPC_US, MO_Craig, Hardy and MO_Cascade) despite not gaining any new species, so diversity is improving (**Figure 2a**)

Densities of benthic macroinvertebrates varied significantly spatially and seasonally with the overall trend of higher densities from Wolf Creek to upstream of the Dearborn River and decreasing down to Cascade, except in 2017 where large increases in densities were observed at Hardy Creek and Cascade (**Figure 2a**). These densities were driven by large increases in % midges and % non-insects in the samples (**Figure 2b**). The Missouri River above Little Prickly Pear Creek (MO_LPPC_US) reported the highest benthic invertebrate densities of all sites, averaging ~24,000 individuals per m² and attained a very large standing crop, especially in the spring (~26,000 per m²) (**Figure 2a**). Macroinvertebrate densities reported at the Craig site this fall (~30,000 per m²) were the highest ever reported during this study (**Figure 2a**). The Missouri River upstream of the Dearborn reported significantly higher invertebrate densities in 2016, than in 2015 (**Figure 3**); while the Craig monitoring station reported significantly lower numbers than in 2015 (**Figure 3**). Relatively lower numbers of benthic invertebrates were reported from the Missouri River below Little Prickly Pear Creek (MO_LPPC_DS) and the Dearborn River (MO_DEAR_DS), as well as Hardy Creek, especially in the spring (**Figure 2a**). Low densities did not necessarily equate to lower taxa richness, as the Hardy Bridge and Cascade sites reported the lowest “non-tributary affected” populations 2016, but also had the highest taxa richness (**Figure 2a**).

Study-wide average macroinvertebrate taxa richness per site was 30.1 taxa in the spring, 29.6 in the summer and 33 taxa in the fall with no significant difference between seasons (T-test, p>0.05)

(**Appendix B**); this is a slight increase from 2018. The most taxa rich macroinvertebrate community was again collected at the Missouri River FAS site near Cascade; these averaged 36.2 total taxa over the three seasons with a high of 45 taxa in the fall of 2017 (**Appendix B**). The combined mayfly, caddisfly and stonefly (EPT) taxa richness for the entire sampled section totaled 50 taxa and averaged 22.3 species per site (**Table 2**), the highest cumulative EPT richness (28 spp.) was reported at Missouri River FAS site near Cascade. The next highest EPT taxa richness were reported at the Missouri River sites downstream from the Dearborn (27 spp.) and D/S of Little Prickly Pear Creek (26 spp.) (**Table 2**). Mayfly and caddisfly taxa were more diverse and abundant than stonefly taxa at all sites (**Table 2**). There were 23 species of mayflies recorded throughout the study section with the dominant three, BWO's (*Baetis tricaudatus*), Tricos (*Tricorythodes explicatus*) and Pale Morning Duns (*Ephemerella excrucians*), often exchanging dominance at any one site depending on the season and silt or weed-bed coverage in the sampling area (**Table 2**). Of the 21 species of caddisflies that were collected across all sites, the net-spinning caddis, *Cheumatopsyche*, and the long-horned caddis, *Oecetis* was usually the most prevalent (**Table 2**). Populations of other net-spinning caddis (*Hydropsyche occidentalis*, *H. morosa* group), micro-caddis (*Hydroptila*) and snail-cased caddis (*Helicopsyche borealis*) were also common, but not as abundant (**Table 2**). A couple of caddisfly taxa, including *Glossosoma* and *Ceraclea* appeared for the first time in summer of 2017 at the Missouri River Flushing Flow Study plot upstream from LPPC. High percentages of caddisflies comprising the % EPT were only documented at sites below tributaries (MO_LPPC_DS, MO_DEAR_DS) and at the Cascade site in the spring (**Figure 2d**). The large October caddis, *Dicosmoecus gilvipes*, occurred throughout the study reach, but was more common below the Dearborn River downstream to Cascade (**Table 2**). Caddisflies were more common during the spring and summer sampling periods at some sites than in the fall, but as a percentage of total EPT were usually much lower than mayflies (**Figure 2d**).

Stonefly (Plecoptera) taxa (8 species) were collected sporadically across the study reaches and increase in numbers and diversity the further distance downstream from Holter Dam; they have never been reported at PPL's site 0.8 miles below Holter Dam in the 21 years of monitoring (McGuire 2016, Stagliano 2019) (**Table 2**). *Sweltsa/Suwallia* (Yellow Sallies), *Isoperla* (Green-winged Stoneflies), *Hesperoperla pacifica* and *Claassenia sabulosa* (Golden Stones) begin to appear in the mainstem Missouri River at Mid-Cannon and Hardy Bridge and near tributary sites (especially up and downstream of the Dearborn River and Little Prickly Pear Creek) (**Table 2**). Even a couple of salmonfly (*Pteronarcys californica*) and *Skwala* individuals were reported in the

samples of the Missouri River downstream of Little Prickly Pear Creek and the Dearborn River, likely washed in from the high spring-flows (**Table 2**).

The riffle beetle, *Optioservus quadrimaculatus* contributed significant numbers (avg. ~1,000 individuals per m²) to the benthic macroinvertebrate communities (~10%) of the Missouri River sites between Wolf Creek and Craig (**Figure 5, Appendix C**); adults and larvae are always present since the adults are aquatic and remain on the bottom substrate. These are not usually represented in any of the macroinvertebrate metrics analyzed, since they are non-EPT insects.

As observed in 2018, non-insect percentages in 2019 have remained significantly lower compared to previous years (2015-2017), the only site reporting higher abundances in the fall was u/s of LPPC (**Figure 2c, Figure 5**). On an annual basis across all sites, 2017 did not report significantly more % non-insect comprising the samples than in 2015 and a few sites in 2018 reported a significant decrease in % non-insects compared to other years (**Figure 3**). Weed beds were largely dominated by non-insects during all seasons (Stagliano 2016).

In the fall of 2019, % EPT reported largely similar to slightly lower numbers across most sites than in 2018, but, as was observed in previous years, this metric significantly declined in the fall samples as non-insect populations increased in the substrates (**Figure 2b & 3b, 5**).

Table 2. The combined mayfly, stonefly and caddisfly (EPT) taxa occurrences and dominance for the entire study reach sampled. x=rare, X=common, XX=abundant, XXX=dominant at site.

Order	Species	MO_LPPC_US	MO_LPPC_US weed bed	MO_LPPC_DS	MO_Craig	MO_Deer_US	MO_Deer_DS	MO_MidCann	MO_Hardy	MO_Hardy weed bed	MO_Cascade
Mayflies	Ephemeroptera (Mayflies)										
Ameletidae	<i>Ameletus</i>						x	x	x		
Baetidae	<i>Acerpenna pygmaea</i>		x							x	x
Baetidae	<i>Acentrella insignificans</i>				x	x	x		x		
Baetidae	<i>Baetis intercalaris</i>										X
Baetidae	<i>Baetis flavistriga</i>				x						
Baetidae	<i>Baetis tricaudatus</i> (BWO)	XX		X	XX	XX	x	XX	XX		X
Baetidae	<i>Callibaetis</i>		x							X	
Baetidae	<i>Centropilum bifurcatum</i>						x				
Baetidae	<i>Diphetero hageni</i>					x	x				x
Baetidae	<i>Plauditus punctiventris</i>		x			x	x	x	x	x	X
Baetidae	<i>Pseudocloeon</i> sp.		x						x	x	x
Leptophlebiidae	<i>Paraleptophlebia</i> sp.					x	X	x	x		
Leptophlebiidae	<i>Choroterpes albiannulata</i>										XX
Leptohyphidae	<i>Tricorythodes explicatus</i> (Tricos)	XX		X	XXX	XXX	X	X	XX		XX
Ephemerellidae	<i>Attenella margarita</i>	x		x		x	x		x		x
Ephemerellidae	<i>Ephemerella exrucians</i> (PMD)	XX		x	XX	XX	XX	XXX	XX		X
Ephemerellidae	<i>Drunella coloradensis</i>			x							
Ephemeridae	<i>Ephemerella simulans</i>						x				x
Heptageniidae	<i>Epeorus albertae</i>			x		x	x				
Heptageniidae	<i>Epeorus longimanus</i>					x		x			
Heptageniidae	<i>Heptagenia</i>								x		x
Heptageniidae	<i>Maccaffertium terminatum</i>					x	x		x		x
Heptageniidae	<i>Ecdyonurus simpliciodes</i>						x		x		X
Heptageniidae	<i>Rhithrogena</i> sp.	x		X	x		X	x			
Stoneflies	Plecoptera (Stoneflies)										
Perlodidae	<i>Isoperla fulva</i>	x		x		x		X	x		
Perlodidae	<i>Skwala</i>			X		x	x	x	x		
Chloroperlidae	<i>Paraperla</i>						x				
Chloroperlidae	<i>Suwallia</i>			x		x					
Chloroperlidae	<i>Sweltsa</i>			x			x	x			
Pteronarcidae	<i>Pteronarcys californica</i>			x			x	x			
Perlidae	<i>Hesperoperla pacifica</i>			x		x	x	X	x		x
Perlidae	<i>Claassenia sabulosa</i>			x			x	X			
Caddisflies	Trichoptera (Caddisflies)										
Brachycentridae	<i>Amiocentrus aspilus</i>					x		x			
Brachycentridae	<i>Brachycentrus occidentalis</i>	x		X		x		x	x		x
Hydropsychidae	<i>Cheumatopsyche</i> (Tan Caddis)	X		X	XX	XX		XX	XX		X
Hydropsychidae	<i>Hydropsyche occidentalis</i>	x		x	X	X		XX	XXX		x
Hydropsychidae	<i>Hydropsyche morosa</i> gr.	X		x	x	x		X	XX		x
Hydropsychidae	<i>Hydropsyche cockerelli</i>					x					
Hydroptilidae	<i>Hydroptila</i>	XX	x	XX	X	X		x	X	x	x
Hydroptilidae	<i>Ochrotrichia</i>										x
Lepidostomatidae	<i>Lepidostoma</i>	x		x			x				
Leptoceridae	<i>Ceraclea</i>	x		x	x	x		x			
Leptoceridae	<i>Nectopsyche</i>										x
Leptoceridae	<i>Oecetis avara</i> (Long-horn Caddis)	X		X	XX	XX	x	X			X
Glossosomatidae	<i>Anagapetus</i>			x							
Glossosomatidae	<i>Glossosoma</i>	x		XX			X	x			
Glossosomatidae	<i>Culoptila</i>			x							
Uenonidae	<i>Neophylax splendans</i>	x		x							
Limnephilidae	<i>Dicosmoecus gilvipes</i>	x			x	x	x	x	X		x
Limnephilidae	<i>Limnephilus</i>						x		x		x
Limnephilidae	<i>Onocomoecus unicolor</i>						x		x		x
Limnephilidae	<i>Pycnopsyche</i>										x
Helicopsychidae	<i>Helicopsyche borealis</i>	x			x	x		X	x		XX
Polycentropidae	<i>Polycentropus</i>								x		x
	Total EPT per site	18	5	26	14	26	27	25	25	5	29

Figure 2a. Macroinvertebrate abundance and species richness metrics for fall 2019 sample sites. Blue arrows are major tributaries entering the Missouri River. Sites arranged in upstream to downstream orientation. Error bars are \pm SE.

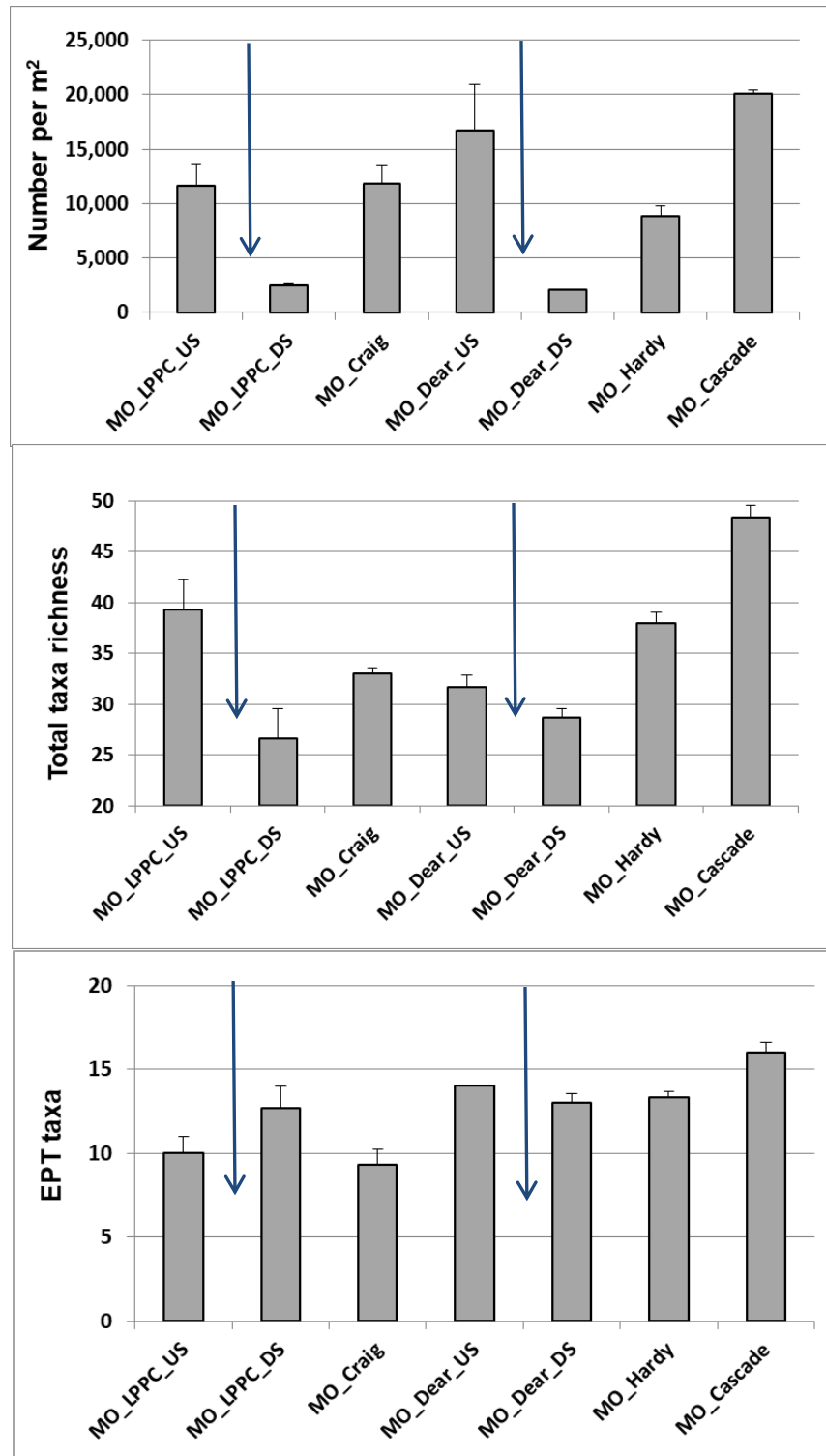


Figure 2b. Macroinvertebrate seasonal metrics for 2019 sample sites. Error bars are SE. Arrows are tributaries entering the Missouri River. Sites arranged in upstream (l) to downstream orientation.

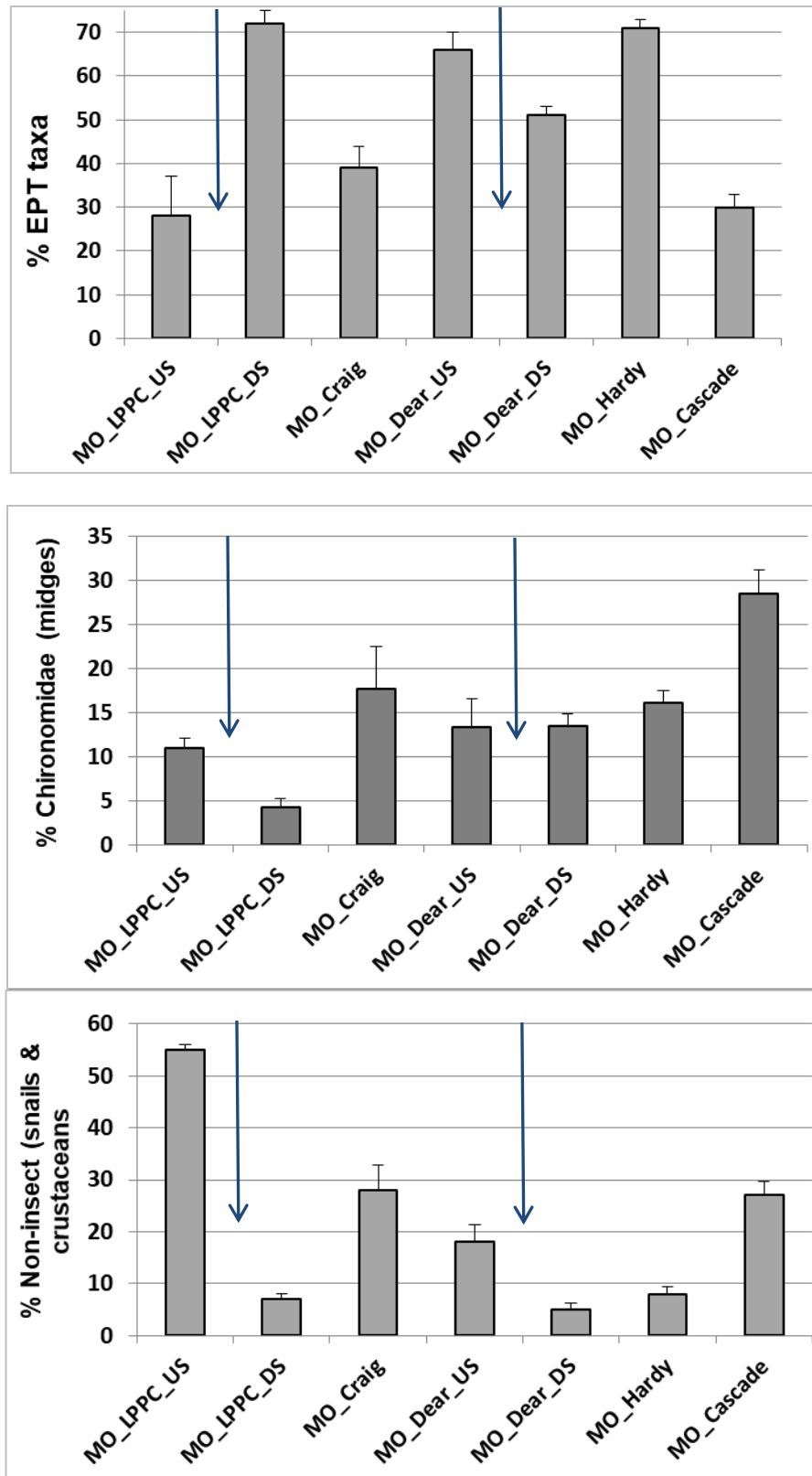


Figure 2c. %EPT (Mayfly | Stonefly | Caddisfly) metrics for 2018-2019 sample sites. Blue arrows are tributaries entering the Missouri River. Sites arranged upstream (l) to downstream (r).

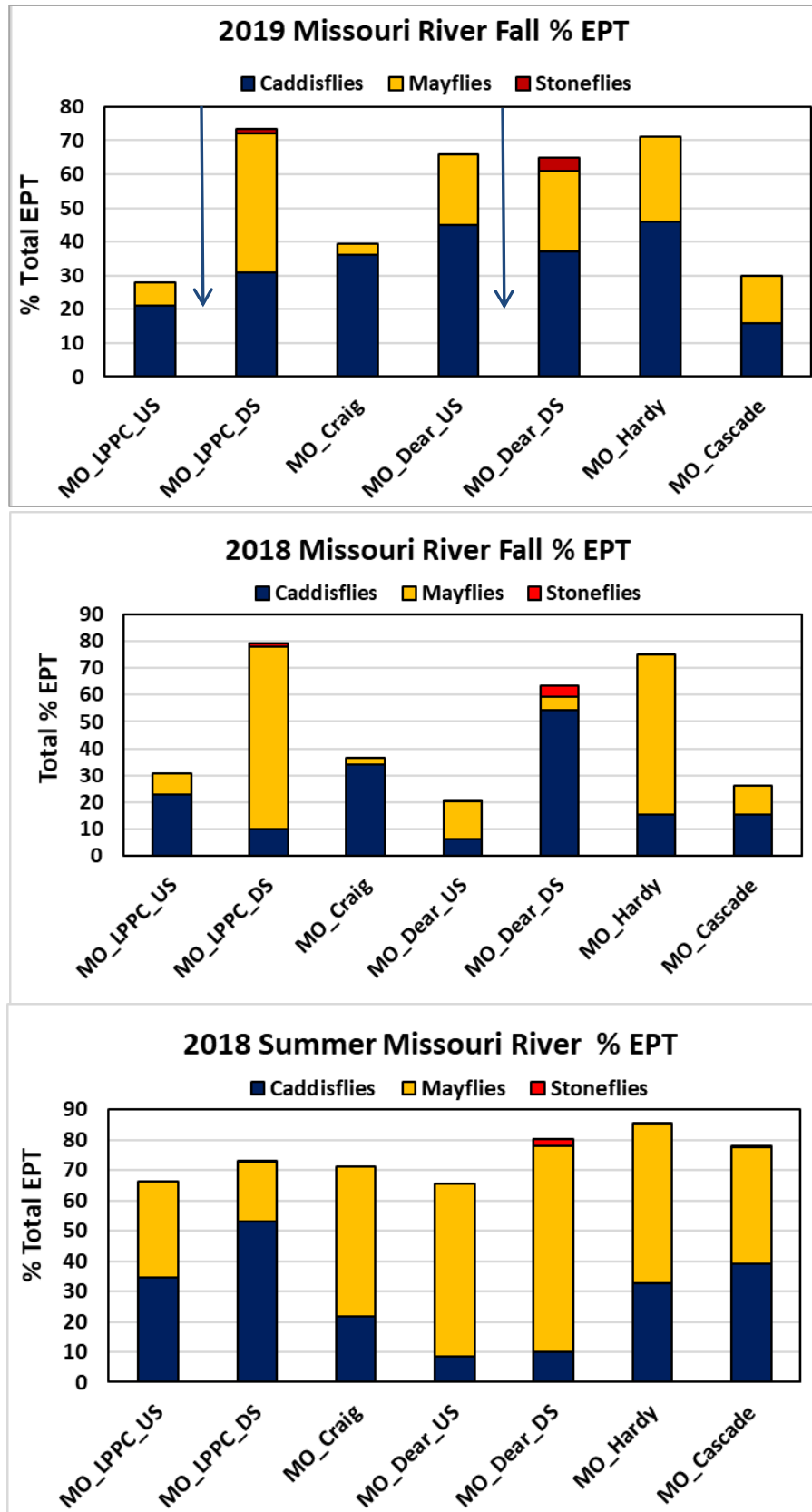
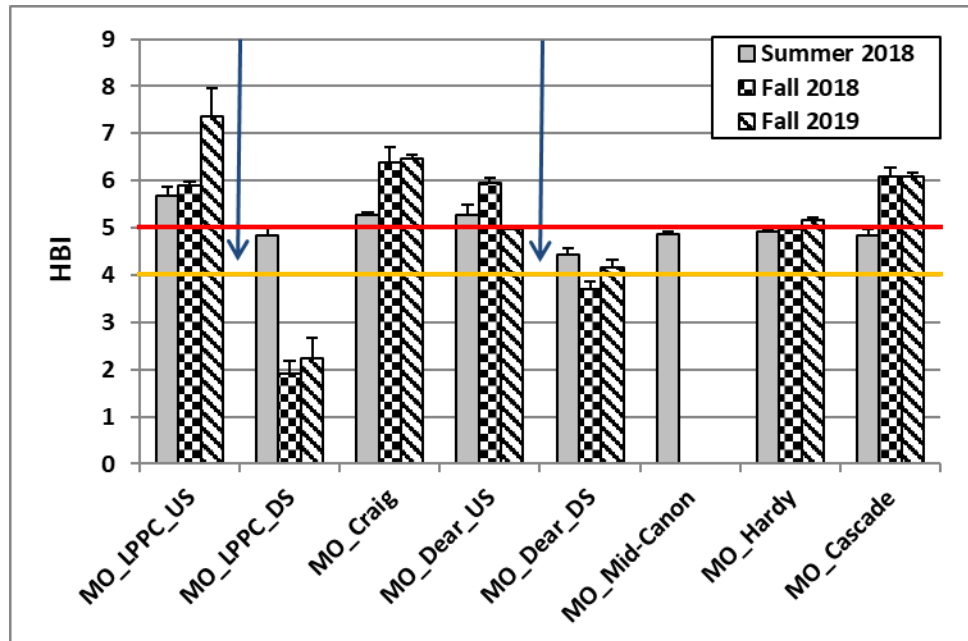


Figure 2d. Macroinvertebrate HBI metric scores for 2018 and 2019 sample sites. Error bars are SE. Blue arrows are tributaries entering the Missouri River. 4.0-5.0=moderately impaired; >5.0 significant impairment.



HBI Scores in 2018 to 2019 indicated that the macroinvertebrate communities at all Missouri River sites, except MO_LPPC_DS and MO_Deer_DS (fall 2018), are experiencing moderate (4.0-5.0) to fairly significant nutrient/organic enrichment (5.0-7.0) (**Figure 2d**). Significant organic enrichment (HBI >6.0) was detected in the macroinvertebrate communities during the fall 2018 and 2019 at MO_LPPC, Craig and Cascade (**Figure 2d**). Missouri sites below tributaries showed improvements in the tolerance-level of benthic communities, especially in the fall samples for MO_LPPC_DS and MO_DEAR_DS which dropped below 3.0 and 4.0, respectively (**Figure 2d**).

In comparing macroinvertebrate communities sampled at all sites between 2015 and 2019, we can see some highly significant trends in decreasing benthic population densities and decreases of % Midges in a sample, (T-test, $p=0.006$) and (T-test, $p=0.001$), respectively (**Figure 3**). The number of total taxa and EPT taxa recorded across all sites has been trending upwards since 2015, but this was not significant (T-test, $p=0.07$) and (T-test, $p=0.26$), respectively. Significant increases in benthic densities were detected at some sites, especially MO_LPPC_US and MO_DEAR_US ($p<0.05$) between 2015 and 2018 (**Figure 3a**). Total taxa richness has increased significantly between 2015 and 2016 (T-test, $p=0.04$), but not in 2018. The annual average %

Chironomidae (Midges) in the benthic community across all sites has significantly decreased between 2015 and 2016 (T-test $p=0.004$), then again in 2018 ($p=0.0003$) (**Figure 3a**).

We documented a significant increase in the caddisfly abundance (% caddisflies) in the 2018 samples between the summer and fall sampling periods ($p=0.004$), and this continued with fall 2019 increases, especially net-spinning caddisflies at Hardy and U/S of the Dearborn (**Figure 2c, Appendix B**). On an annual basis, % caddisflies in the samples has significantly decreased between 2015 and 2018 at MO_LPPC_US (T-test, $p=0.01$) and at MO_DEAR_US (T-test, $p=0.05$) (**Figure 2c**). Mayfly abundance in the samples has widely fluctuated between 2015 and 2019 but has not changed significantly on an annual basis (**Figure 4**). This year's increase in taxa richness seems to have negated the previously reported losses seen between 2005 and 2015 (Stagliano 2015), but these taxa were largely non-insects (snail and worm taxa).

Figure 3. Macroinvertebrate metric annual averages between 2015 and 2019. Error bars are SE. Blue arrows are tributaries entering the Missouri River.

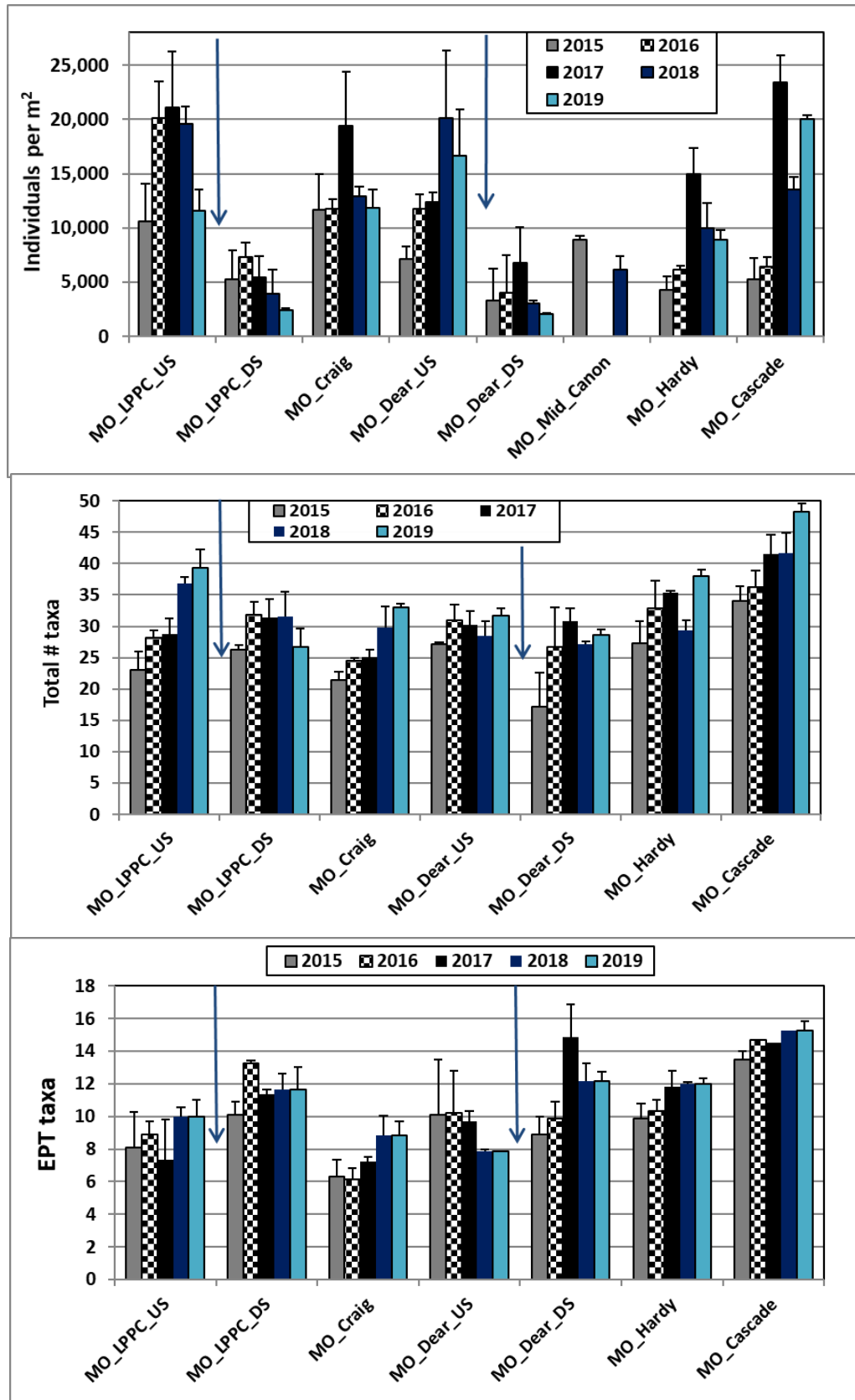
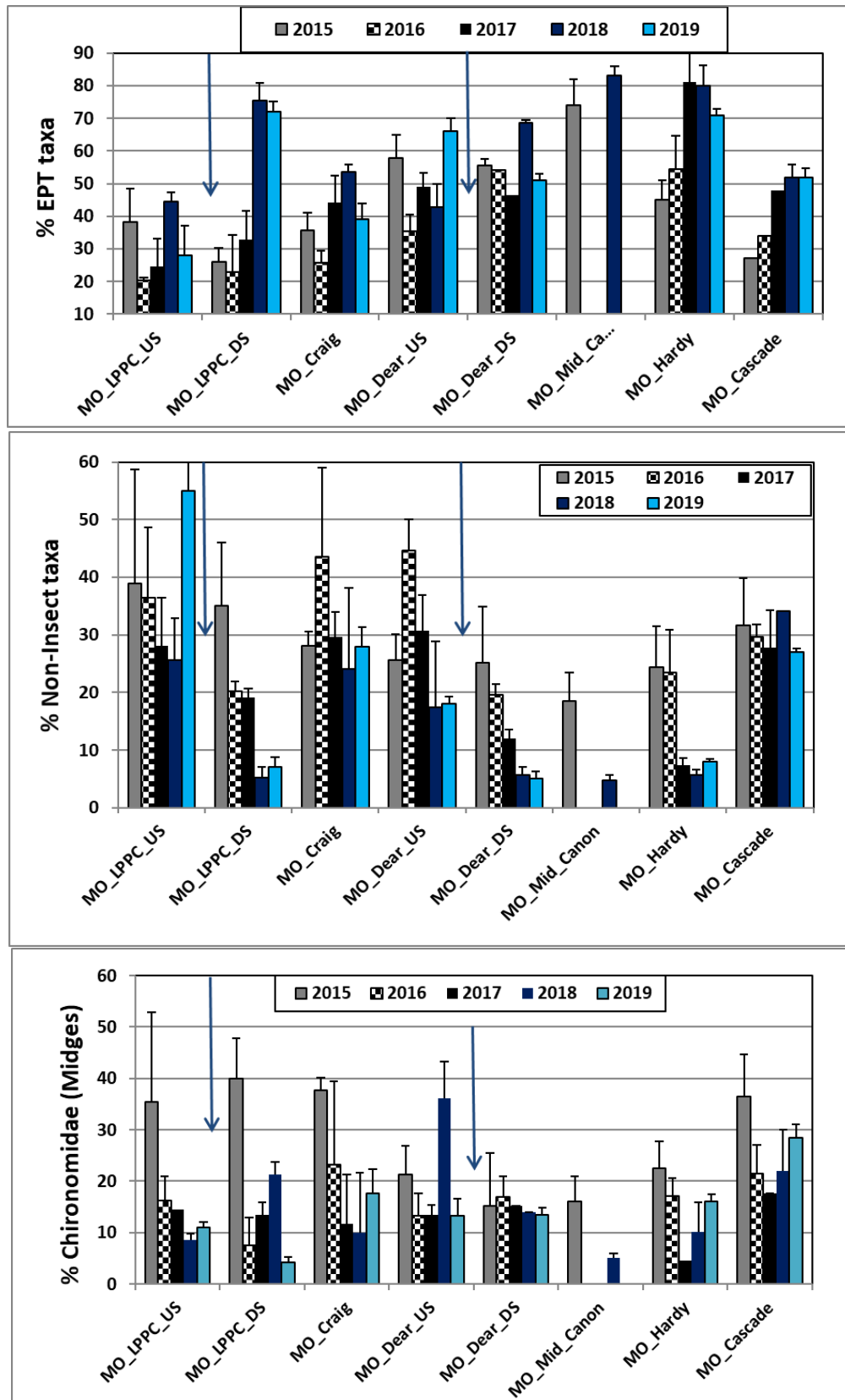


Figure 3. cont. Macroinvertebrate metric annual averages between 2015 and 2019. Error bars are SE. Blue arrows are tributaries entering the Missouri River.

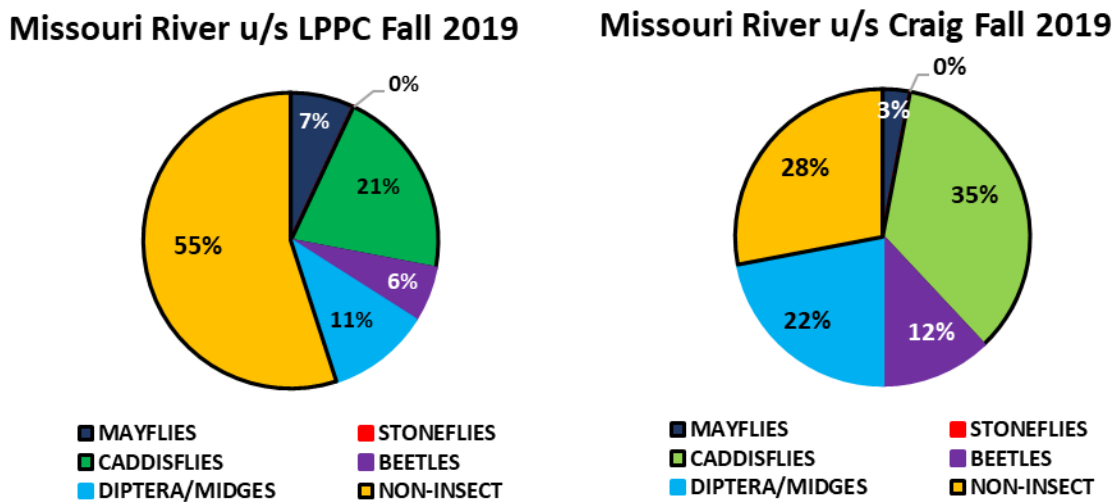


3.1 Wolf Creek Bridge to Craig Missouri River section

The macroinvertebrate communities at the Missouri River above LLPC (MO_LLPC_US) had reported the highest benthic invertebrate densities of all sites, averaging ~20,000 individuals per meter² and attained very large biomass, especially in the spring of 2017 (~26,000 per m²) (**Figure 2a and 3**). High peak run-off flows of 2018 did little to decrease the average annual macroinvertebrate densities which were still hovering around ~20,000 individuals per meter², but this site has increased total taxa, EPT and %EPT present in the samples (**Figure 3**). A significant decrease in benthic densities was noted at MO_LLPC_US in fall of 2019 and reported the lowest abundances since 2015 (avg. ~11,000 per m²). Craig’s benthic insect densities reported a significant reduction between 2017 and 2018 due to the high flushing flows and this was maintained into fall of 2019, now densities are similar to 2015 (avg. ~11,000 per m²) (**Figure 2a**).

Dominant insect taxa at the Craig site in fall 2019 included net-spinning (Tan caddisflies) *Cheumatopsyche*, and *Hydropsyche occidentalis* and the long-horned caddis, *Oecetis avara* which now surpass the non-insects (scuds, turbellarians and worms) for dominance in the benthic substrate. Based on these increasing densities, tan caddisfly hatches should be on rise from Craig to the Dearborn River in the summer of 2020 (**Figure 4, Appendix B**).

Figure 4. Macroinvertebrate composition for fall 2019 upstream of Little Prickly Pear Creek and Craig sample sites.



High percentages of EPT taxa at the MO_LPPC_US and MO_Craig sites reported in the spring and summer samples transitioned to a dominance of non-insect taxa in the fall during most years, this was particularly significant in 2018, but in 2019 at the Craig site, caddisflies remained dominant into the fall (**Figure 4**). The dominant non-insect taxa were sowbugs (*Caecidotea*), Turbellarian flatworms, roundworms Nematoda and pouch snails (*Physella acuta*).

In the Wolf Creek Bridge to Craig Missouri River section, the EPT community was primarily composed of three or four mayflies and five or six caddisflies with typically no stoneflies, except right below LPPC (**Table 2**). McGuire (2014) reported that the densities of these two insect orders (Mayflies and Caddis) have showed declines at the NWE/PPL monitoring site 0.8 miles below the dam, but these have also been trending upwards the last 3 years since the 2017 spring and 2018 flushing flows (Stagliano 2019b). Only three species of mayflies are common near the dam. *Tricorythodes* is the most abundant mayfly in the August samples, although *Baetis tricaudatus* can also attain high densities. A few *Ephemerella* (PMDs) were usually collected at this site during the 1990's, but they are seldom present in more recent collections (last found during 2011) (McGuire 2014). On average, during the 2019 Missouri River sampling, we collected substantially more invertebrate taxa than were reported in 2015 (Stagliano 2015) between Little Prickly Pear Creek and Craig sites (paired T-test, $p=0.02$) (**Figure 4**).

3.2 Missouri River upstream and downstream of the Dearborn River (MO_DEAR_US, MO_DEAR_DS)

Sampling in 2019 showed that the benthic macroinvertebrate densities in the Missouri River upstream of the Dearborn River exhibited significant increases in abundance compared to 2015-2018, and this was due to contributions of non-insect taxa, especially Turbellarian flatworms and Oligochaete worms (**Figure 3, Appendix C**). The Missouri River benthic macroinvertebrates downstream of the Dearborn River exhibited significant reductions in abundance due to the spring run-off events, but then rebounded to levels of upstream Missouri River populations by the fall sampling period (**Figure 2a**). As the numbers of insects recolonizing the MO_DEAR_DS site increased, so did the diversity of taxa until by the fall sampling period total taxa richness equaled the upstream site and EPT richness was greater than that of the upstream site (**Figure 2a**).

3.3 Missouri River near Hardy Creek Bridge (MO_HARDYBR)

The macroinvertebrate community collected at this cobble/boulder riffle of the Missouri River near Hardy Bridge was more similar to a spring creek community, likely due to the abundant aquatic weed beds (**Photo 2, Appendix A**). Due to the larger substrate in this riffle, crayfish (*Orconectes virilis*) and mottled sculpin (*Cottus bairdii*) were collected in the samples and averaged 1.0 and 0.5 individuals per m², respectively. Dominant benthic taxa at this site in 2019 were, in order of abundance, the net-spinning caddisflies, *Hydropsyche occidentalis* and *Cheumatopsyche*, BWO's, *Baetis tricaudatus*, PMDs Ephemereella excrucians, and Tricos, *Tricorythodes explicatus*. This is much improved from the 2016 dominant taxa: sowbugs (*Caecidotea*), BWOs (*Baetis tricaudatus*), midges (*Microtendipes*) and flatworms (Turbellaria). MDEQ's fall 2005 sample reported the dominant benthic taxa, in order of abundance, BWOs (*Baetis tricaudatus*), blackflies (*Simulium*), scuds (*Hyaella*), Tricos (*Tricorythodes*) and sowbugs (*Caecidotea*). The 2015-2018 samples had much lower numbers of blackflies than had been reported in 2005 (MDEQ 2007).

Cumulative total EPT for this site was the 2nd highest at 27 species, if we include the weed bed mayfly taxa (**Table 2**) (Stagliano 2019). But EPT species other than net-spinning caddisflies BWO's, PMD's and Tricos were low in abundance. Benthic abundance was in the mid-range for this section (~6,500 individuals per m²), but this number dropped by the fall sampling period to ~5,000 per m² (**Figure 3**). Overall, macroinvertebrate densities increased significantly in 2018 (**Figure 3**) largely due to increases in micro-caddisflies in increasing weed beds and algae in the riffle sampled.

Photo 2. Extensive weed beds sampled at Hardy Bridge during the summer and fall 2016 sampling period.



3.4 Missouri River near Cascade (MO_Cascade)

The macroinvertebrate communities collected at the Missouri River FAS site near Cascade were the most diverse (averaging 40.5 total taxa) and contained one of the highest average EPT taxa richness (avg. EPT taxa per sample = 14.8 species) (**Figure 2b**). Cumulative total EPT for all seasons across the years was the highest reported at 29 species (**Table 2, Figure 4**). Macroinvertebrate densities increased significantly in 2018 (**Figure 3**) largely due to increases in algae in the riffle sampled (**cover photo**). The benthic community tolerance values (HBI) indicates significant organic pollution occurring at this site, but high HBI scores can also be indicative of high sediment in the substrate. Several mayfly taxa occurring here were specific to only here or at the York's Island site above Canyon Ferry Lake, including, *Ecdyonurus simpliciodes*, *Choroterpes albiannulata*, and a *Pseudocloeon* sp. (**Appendix B**). Low densities (avg. 13 per m²) of the New Zealand mudsnail (*Potamopyrgus antipodarum*) were collected here during the 2016 samples which is a slight increase from 2015. During 2017 and 2018, NZMS have increased their populations to an annual average of 45 per m² (Figure 7).

3.5 Missouri River Focal Invasive Species

New Zealand mudsnails (*Potamopyrgus antipodarum*) (NZMS) were a perceived significant invasive species threat to the Missouri River in the early 2000's but have been collected at very low densities at the PPL Holter Dam long-term monitoring site since 2012 (McGuire 2016). During our 2015 sampling, we reported low densities of NZMS at 5 of the 7 sites with the highest density of ~40 ind. per meter² reported at the Missouri River downstream of Little Prickly Pear Creek (MO_LPPC_DS) (**Figure 6**). NZMS occurrence at two of these sites was only reported in the fall sample, while at 2 sites, Craig and Cascade, NZMS were reported during multiple seasons (**Figure 6**).

During the 2016 sampling period, we collected NZMS at 6 of the 7 monitoring sites with the highest average density of ~373 ind. per m² at the Missouri River upstream of Little Prickly Pear Creek (**Figure 6**). We estimated annual NZMS densities at this site to be 7.5 ind. per m² in 2015. NZMS occurrence at all six of these sites was reported during multiple seasons (**Figure 6**). This significant increase in NZMS site occupancy and seasonal densities observed across most sites may be directly correlated to low flows (**Figure 1b**). This can especially be observed at the Missouri River upstream of Little Prickly Creek (MO_LPPC_US) (**Figure 7**) where annual NZMS numbers have increased, as overall densities of macroinvertebrates exploded (**Figure 2a**).

During the 2018 sampling period, we collected NZMS at 5 of the 7 monitoring sites with the highest average density of ~290 ind. per m² at the Missouri River upstream of LPPC (**Figure 6**). The Missouri River at Craig saw large increases in densities between fall 2016 and spring 2018, but these decreased by the summer. Large NZMS density declines were observed between pre-run off and the summer sampling periods in 2018 at both the Missouri River sites at LLP Creek and at Craig (Figure 5) likely due to the higher spring run-off. This can be largely explained by the high flows of June 2018 (~11,600 cfs) which likely displaced NZMS out of the substrate. It appears that the population of NZMS in the reach upstream from the Dearborn River observed in 2016 has decreased to undetectable levels in 2018, since we didn't report this species in the summer or fall samples (**Figure 6**).

Figure 6. NZMS seasonal benthic densities in 2016 (top), 2017 (middle) and 2018 (bottom) from the Wolf Creek to Cascade monitoring section. Note y-axis scale differences.

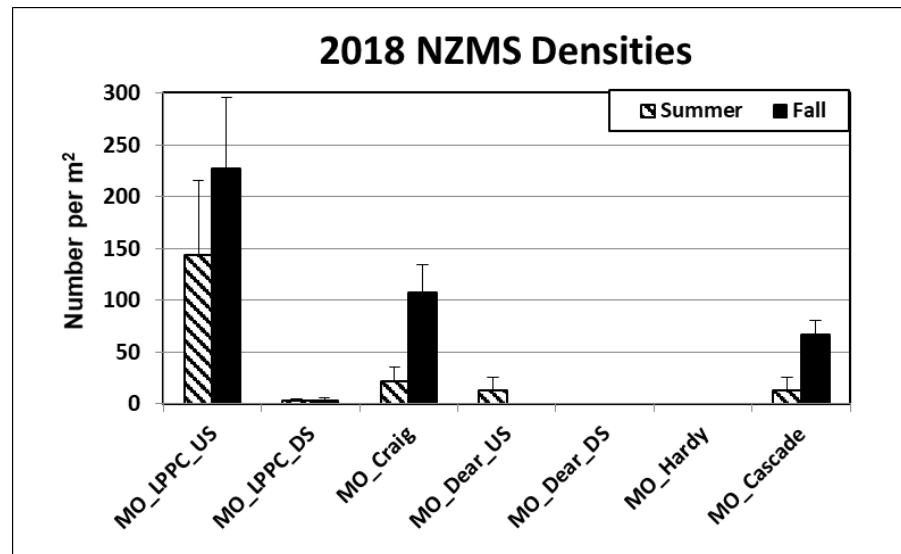
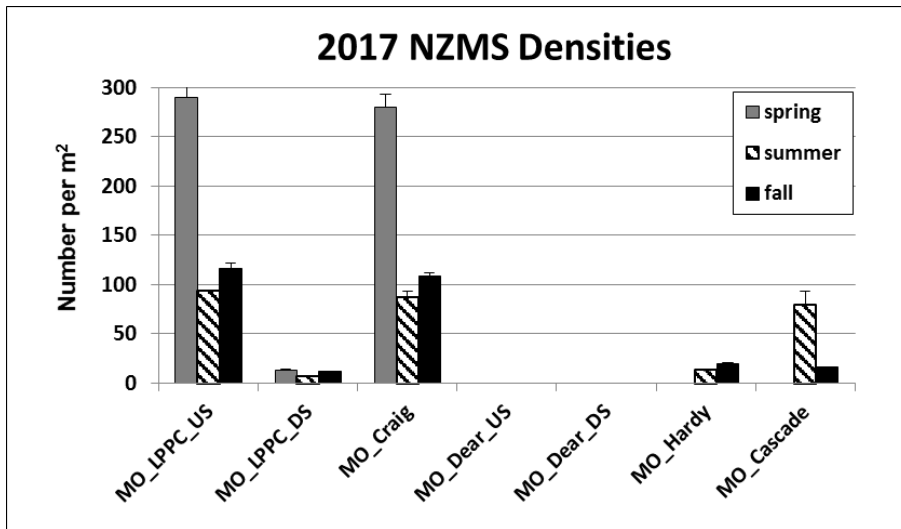
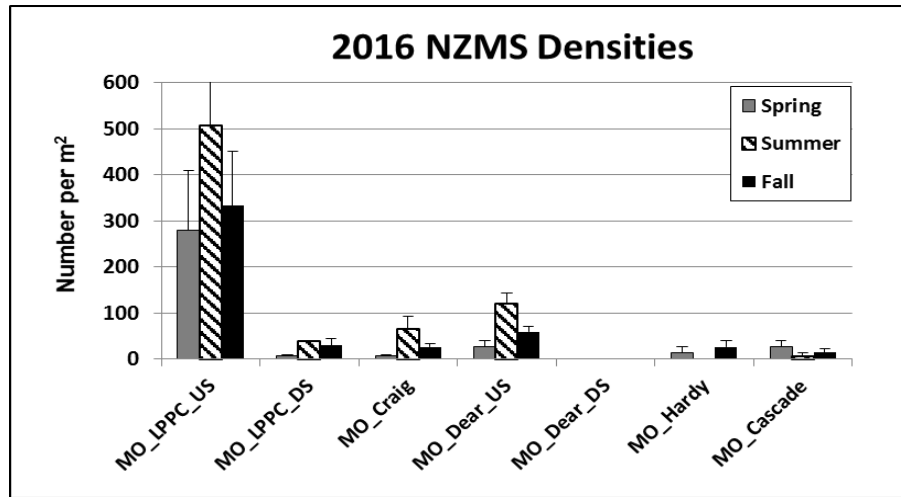
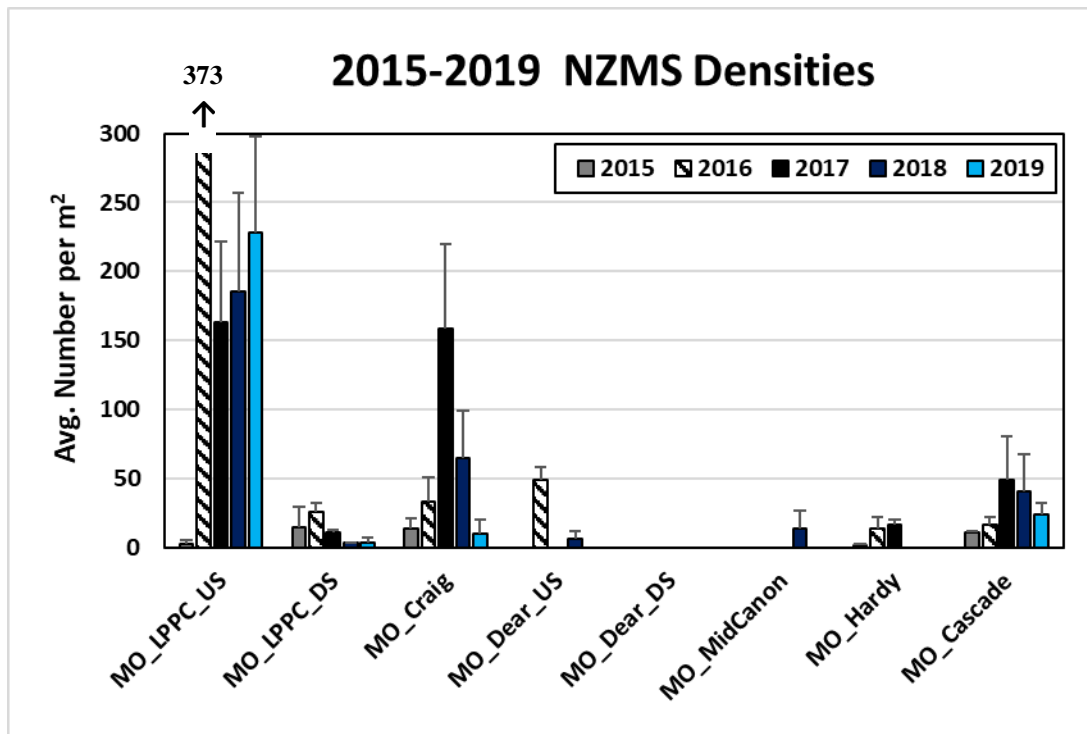


Figure 7. NZMS benthic annual average densities between 2015 and 2019 from the Wolf Creek to Cascade monitoring section with adjusted y-axis scale.



We have reported a potential new species of a non-native Planorbidae snail, *Menetus dilatatus*, from the Missouri River sites U/S and D/S of LPPC and at the Craig site at densities averaging 50-170 ind. per m² during the surveys 2016-2019. According to the NatureServe Explorer Species website, this snail is considered native in the eastern states, but there have been records reported in California, presumably introduced as well (NatureServe 2017). It had never been reported at the Holter NWE (PPL) long-term site until 2016 and was not observed in the 2005 MDEQ samples (MDEQ 2007).

4.0 Conclusions

This fall of 2019 macroinvertebrate data has added another season to the most comprehensive study evaluating the benthic communities in the Missouri River from Wolf Creek to Cascade and provides a significant dataset for future monitoring efforts. We have collected important spatial and temporal information concerning the macroinvertebrate communities, including peaks and troughs of benthic insect densities and diversity across multiple sites, and the important role tributary streams and flushing flows have on the Missouri River insect communities.

Record high spring flows in 2018 (~20,000 cfs peak discharge) at the Missouri River below Holter Dam have played a particularly important role by flushing silts from gravels, reshaping riffles and reducing invertebrate densities at many of the main stem Missouri River sites. The relative composition of many benthic macroinvertebrate assemblages has been restructured with higher caddisfly and mayfly densities observed during the summer and fall sampling periods with lower abundances of sediment-loving midges and worms. But, as in previous years, increased % EPT (Caddisflies and Mayflies) in the summer samples has yielded to % non-insect dominance in the fall samples.

Tolerance scores of the benthic communities using the HBI indicate significant organic enrichment across the sites, especially at sites closer to Wolf Creek Bridge and downstream at Cascade. Increased benthic coverage of rooted aquatic vegetation through the summer and into the fall remains an issue despite the flushing flows and favors increases of non-insect taxa, such as sowbugs (*Caecidotea*), scuds (*Gammarus and Hyalella*), aquatic earthworms (Lumbricidae, Tubificidae) and pouch snails (*Physella acuta*). Aquatic vegetation growth across clean gravel riffles can dampen the recruitment ability of caddisflies and mayflies, hence lower densities are reported across the fall seasons across all years.

1. UMOWA's macroinvertebrate study has allowed us to begin to document patterns of changing aquatic communities and set the stage for future hypothesis testing. From analyzing the past 5 years of data, it seems pretty conclusive, that on an annual basis, caddisflies have significantly declined at the Missouri River reach from Little Prickly Pear Creek to the Dearborn River, but may be on an upward trend in 2020 as they were in 2019.
2. The sites closest to Holter Dam (MO_LPPC_US and MO_CRAIG) showed the most significant benthic response to the 2018 flows with reductions in both the overall macroinvertebrate, Chironomidae (midges) and NZMS densities. Downstream sites' algae and aquatic plant beds showed some appreciable changes due to the 2018 flows (Appendix A, Photos 15 & 17).
3. The Missouri River downstream from the Dearborn River demonstrated the largest improvements in biointegrity of the macroinvertebrate community with substantial increases in the number of EPT taxa and % EPT taxa in the samples and much lower HBI.
4. Macroinvertebrate communities with the highest total taxa richness, EPT richness and % EPT were reported at sites least affected by the dam, particularly the Missouri River at Hardy Bridge and at Cascade site, 28 and 37 miles away from Holter dam. These sites

begin to take on the more natural character of the river and acquire the original compliment of macroinvertebrates.

5. New Zealand mudsnails have persisted in low to moderate densities at multiple sites in the Missouri River from Wolf Creek to Cascade and had begun to increase their populations upstream of Little Prickly Pear Creek (avg. 373 per m²), but higher flows of 2017 and 2018 temporarily dampened the increase. 2019 sampling reveals that NZMS are building up their populations in the Missouri River upstream of LLPC.
6. We postulate that NZMS population increases, overall non-insect macroinvertebrate density increases, caddisfly decreases and the expansion of rooted weed-beds in the Wolf Creek to Craig section is directly correlated with lower spring flushing flows from Holter Dam. Initial results of the high flushing flows in 2018 showed a decrease in rooted vegetation at both upper sites, lowered NZMS populations at Craig and increases in mayflies and caddisflies at the sites closest to the Holter Dam (MO_LPPC_US).
7. We believe that the natural flushing flows of >15,000cfs seen during the 2018 run-off period may have been extremely helpful in reversing some of the negative effects documented to be occurring on the benthic communities since the last flow of this magnitude in 2011. Due to compiling five years of baseline data (4 of which were below spring flushing flow levels), we are in a superb position to further evaluate macroinvertebrate responses to this “true” flushing flow event.

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Appendix A. Site Photographs

Appendix B. Macroinvertebrate seasonal summary metric tables.

Appendix B. Macroinvertebrate seasonal metrics Summer 2018 at all sites. Standard Error are SE.
Significant differences (p<0.05).

Site	Metric	Hess #1	Hess #2	Hess #3	Average	Standard Error
MO_LPPC_US	#/m2	16,303	15,868	31,336	21,169	5085.1
MO_LPPC_US	# taxa	38	36	33	35.7	1.5
MO_LPPC_US	# EPT	9	11	5	8.3	1.8
MO_LPPC_US	% EPT	64%	72%	63%	66%	3%
MO_LPPC_US	% Non-Insect	15%	19%	21%	18%	2%
MO_LPPC_US	% Chironomidae	9%	5%	15%	10%	3%
MO_LPPC_US	%Mayfly	31%	42%	22%	32%	6%
MO_LPPC_US	%Caddisfly	33%	29%	41%	35%	3%
MO_LPPC_DS	#/m2	5,600	6,340	6,400	6,113	257.3
MO_LPPC_DS	# taxa	34	36	39	36.3	1.5
MO_LPPC_DS	# EPT	13	11	13	12.3	0.7
MO_LPPC_DS	% EPT	74%	62%	82%	73%	6%
MO_LPPC_DS	% Non-Insect	5%	1%	4%	3%	1%
MO_LPPC_DS	% Chironomidae	16%	27%	11%	21%	6%
MO_LPPC_DS	%Mayfly	20%	13%	25%	20%	4%
MO_LPPC_DS	%Caddisfly	54%	49%	56%	53%	2%
MO_Craig	#/m2	13,024	12,738	10,448	12,070	815.1
MO_Craig	# taxa	32.0	33.0	37.0	34.0	1.5
MO_Craig	#EPT taxa	9.0	10.0	11.0	10.0	0.6
MO_Craig	% EPT	70%	75%	68%	71%	2%
MO_Craig	% Non-Insect Taxa	10%	9%	10%	10%	0%
MO_Craig	% Chironomidae	16%	6%	18%	13%	4%
MO_Craig	%Mayfly	55%	49%	44%	49%	3%
MO_Craig	%Caddisfly	15%	26%	24%	22%	3%
MO_Dear_US	#/m2	10,890	22,120	48,150	27,053	11035.3
MO_Dear_US	# taxa	25	28	24	25.7	1.2
MO_Dear_US	#EPT taxa	6	7	6	6.3	0.3
MO_Dear_US	% EPT	61%	56%	79%	66%	7%
MO_Dear_US	% Non-Insect Taxa	5%	9%	4%	6%	1%
MO_Dear_US	% Chironomidae	31%	29%	14%	25%	5%
MO_Dear_US	%Mayfly	59%	46%	66%	57%	6%
MO_Dear_US	%Caddisfly	2%	10%	13%	8%	3%
MO_Dear_DS	#/m2	2,580	1,040	1,620	1,760	447.4
MO_Dear_DS	# taxa	32	22	25	26.7	2.9
MO_Dear_DS	EPT	17	10	10	12.3	2.3
MO_Dear_DS	% EPT	79%	76%	81%	78%	1%
MO_Dear_DS	% Non-Insect Taxa	8%	4%	7%	7%	2%
MO_Dear_DS	% Chironomidae	3%	6%	4%	21%	6%
MO_Dear_DS	%Mayfly	62%	63%	80%	68%	5%
MO_Dear_DS	%Caddisfly	17%	13%	1%	10%	5%
MO_Hardy	#/m2	10,860	2,030	11,420	8,103	3041.0
MO_Hardy	# taxa	32	24	26	27.3	2.4
MO_Hardy	#EPT taxa	18	12	10	13.3	2.4
MO_Hardy	% EPT	91%	73%	92%	85%	6%
MO_Hardy	% Non-Insect Taxa	2%	16%	2%	7%	5%
MO_Hardy	% Chironomidae	3%	6%	4%	4%	1%
MO_Hardy	%Mayfly	66%	50%	43%	53%	7%
MO_Hardy	%Caddisfly	25%	23%	49%	32%	8%
MO_Cascade	#/m2	6,072	11,600	9,253	8,975	1601.8
MO_Cascade	# taxa	40	37	36	37.7	1.2
MO_Cascade	#EPT taxa	17	14	15	15.3	0.9
MO_Cascade	% EPT	70%	79%	83%	77%	4%
MO_Cascade	% Non-Insect Taxa	35%	42%	26%	34%	4%
MO_Cascade	% Chironomidae	1%	1%	1%	14%	3%
MO_Cascade	%Mayfly	33 41%	30%	44%	38%	4%
MO_Cascade	%Caddisfly	28%	49%	40%	39%	6%

Appendix B. (cont.) Macroinvertebrate seasonal metrics Fall 2018 at all sites. Standard Error are SE.
 *= Significant differences (p<0.05).

Site	Metric	Hess #1	Hess #2	Hess #3	Average	Standard Error
MO_LPPC_US	#/m2	22,600	16,000	15,394	17,998	2307.7
MO_LPPC_US	# taxa	35	39	40	38.0	1.5
MO_LPPC_US	# EPT	10	13	12	11.7	0.9
MO_LPPC_US	% EPT	31%	30%	31%	31%	1%
MO_LPPC_US	% Non-Insect	33%	38%	27%	33%	3%
MO_LPPC_US	% Chironomidae	5%	8%	8%	7%	1%
MO_LPPC_US	%Mayfly	8%	8%	7%	8%	0%
MO_LPPC_US	%Caddisfly	23%	22%	24%	23%	1%
MO_LPPC_DS	#/m2	2,580	2,380	2,340	1,760	447.4
MO_LPPC_DS	# taxa	32	30	36	26.7	2.9
MO_LPPC_DS	# EPT	10	10	13	11.0	1.0
MO_LPPC_DS	% EPT	79%	83%	74%	78%	1%
MO_LPPC_DS	% Non-Insect	8%	4%	13%	7%	2%
MO_LPPC_DS	% Chironomidae	3%	4%	5%	21%	6%
MO_LPPC_DS	%Mayfly	62%	47%	44%	68%	5%
MO_LPPC_DS	%Caddisfly	17%	36%	30%	10%	5%
MO_Craig	#/m2	13,714	13,664	13,947	13,775	87.1
MO_Craig	# taxa	23.0	27.0	27.0	25.7	1.3
MO_Craig	#EPT taxa	6.0	8.0	9.0	7.7	0.9
MO_Craig	% EPT	45%	14%	50%	36%	11%
MO_Craig	% Non-Insect Tax	41%	81%	27%	49%	16%
MO_Craig	% Chironomidae	9%	3%	9%	7%	2%
MO_Craig	%Mayfly	5%	0%	2%	2%	1%
MO_Craig	%Caddisfly	40%	13%	48%	34%	10%
MO_Dear_US	#/m2	11,040	15,600	13,120	13,253	1318.0
MO_Dear_US	# taxa	30	31	33	31.3	0.9
MO_Dear_US	#EPT taxa	12	13	10	11.7	0.9
MO_Dear_US	% EPT	18%	29%	13%	20%	5%
MO_Dear_US	% Non-Insect Tax	23%	40%	24%	29%	5%
MO_Dear_US	% Chironomidae	56%	27%	59%	48%	10%
MO_Dear_US	%Mayfly	12%	20%	9%	14%	3%
MO_Dear_US	%Caddisfly	6%	9%	4%	6%	2%
MO_Dear_DS	#/m2	4120	4120	4505	4248.3	128.3
MO_Dear_DS	# taxa	23	28	32	27.7	2.6
MO_Dear_DS	EPT	10	12	14	12.0	1.2
MO_Dear_DS	% EPT	58%	59%	60%	59%	0%
MO_Dear_DS	% Non-Insect Tax	5%	3%	4%	4%	1%
MO_Dear_DS	% Chironomidae	3%	10%	7%	7%	2%
MO_Dear_DS	%Mayfly	2%	7%	5%	5%	1%
MO_Dear_DS	%Caddisfly	56%	52%	55%	54%	1%
MO_Hardy	#/m2	9,741	14,949	10,970	11,887	1571.5
MO_Hardy	# taxa	27	34	33	31.3	2.2
MO_Hardy	#EPT taxa	10	10	12	10.7	0.7
MO_Hardy	% EPT	73%	73%	79%	75%	2%
MO_Hardy	% Non-Insect Tax	4%	4%	6%	5%	1%
MO_Hardy	% Chironomidae	19%	18%	11%	18%	2%
MO_Hardy	%Mayfly	65%	55%	58%	59%	3%
MO_Hardy	%Caddisfly	7%	19%	21%	16%	4%
MO_Cascade	#/m2	17,240	17,560	19,451	18,084	689.9
MO_Cascade	# taxa	45	46	46	45.7	0.3
MO_Cascade	#EPT taxa	17	14	15	15.3	0.9
MO_Cascade	% EPT	30%	24%	24%	26%	2%
MO_Cascade	% Non-Insect Tax	34%	33%	35%	34%	1%
MO_Cascade	% Chironomidae	29%	31%	30%	30%	1%
MO_Cascade	%Mayfly	14%	11%	7%	11%	2%
MO_Cascade	%Caddisfly	16%	13%	17%	15%	1%

Appendix B. (cont.) Macroinvertebrate seasonal metrics Fall 2019 at all sites. Standard Error are SE.

*= Significant differences (p<0.05).

Site	Metric	Hess #1	Hess #2	Hess #3	Average	SE
MO_LPPC_US	#/m2	15,413	10,465	8,813	11,564	1983.0
MO_LPPC_US	# taxa	34	40	44	39.3	2.9
MO_LPPC_US	# EPT	9	9	12	10.0	1.0
MO_LPPC_US	% EPT	13%	28%	44%	28%	9%
MO_LPPC_US	% Non-Insect	71%	54%	40%	55%	9%
MO_LPPC_US	% Chironomidae	13%	12%	9%	11%	1%
MO_LPPC_US	%Mayfly	6%	6%	9%	7%	1%
MO_LPPC_US	%Caddisfly	7%	21%	35%	21%	8%
MO_LPPC_US	HBI	8.5	7.1	6.4	7.3	0.6
MO_LPPC_DS	#/m2	1,870	2,420	2,130	2,433	158.9
MO_LPPC_DS	# taxa	32	36	38	26.7	2.9
MO_LPPC_DS	# EPT	10	14	14	12.7	1.3
MO_LPPC_DS	% EPT	70%	78%	68%	72%	3%
MO_LPPC_DS	% Non-Insect	8%	7%	15%	7%	2%
MO_LPPC_DS	% Chironomidae	3%	4%	6%	4%	1%
MO_LPPC_DS	%Mayfly	47%	42%	34%	58%	4%
MO_LPPC_DS	%Caddisfly	24%	36%	34%	28%	4%
MO_LPPC_DS	HBI	1.6	2.2	3.0	2.2	0.4
MO_Craig	#/m2	9,928	15,165	10,373	11,822	1676.5
MO_Craig	# taxa	34.0	32.0	33.0	33.0	0.6
MO_Craig	#EPT taxa	8.0	11.0	9.0	9.3	0.9
MO_Craig	% EPT	40%	47%	29%	39%	5%
MO_Craig	% Non-Insect Tax	26%	34%	23%	28%	3%
MO_Craig	% Chironomidae	17%	10%	26%	18%	5%
MO_Craig	%Mayfly	4%	3%	3%	3%	0%
MO_Craig	%Caddisfly	36%	44%	25%	35%	5%
MO_Craig	HBI	6.4	6.3	6.6	6.5	0.1
MO_Dear_US	#/m2	13,296	25,074	11,580	16,650	4241.0
MO_Dear_US	# taxa	34	31	30	31.7	1.2
MO_Dear_US	#EPT taxa	14	14	14	14.0	0.0
MO_Dear_US	% EPT	63%	62%	73%	66%	4%
MO_Dear_US	% Non-Insect Tax	21%	18%	17%	18%	1%
MO_Dear_US	% Chironomidae	15%	18%	7%	13%	3%
MO_Dear_US	%Mayfly	17%	23%	22%	21%	2%
MO_Dear_US	%Caddisfly	45%	39%	51%	45%	3%
MO_Dear_US	HBI	4.98	5.06	4.93	4.99	0.04
MO_Dear_DS	#/m2	1950	2150	2145	2081.7	65.8
MO_Dear_DS	# taxa	27	29	30	28.7	0.9
MO_Dear_DS	EPT	12	13	14	13.0	0.6
MO_Dear_DS	% EPT	51%	47%	55%	51%	2%
MO_Dear_DS	% Non-Insect Tax	7%	3%	4%	5%	1%
MO_Dear_DS	% Chironomidae	11%	16%	13%	13%	1%
MO_Dear_DS	%Mayfly	5%	13%	11%	10%	3%
MO_Dear_DS	%Caddisfly	46%	33%	44%	41%	4%
MO_Dear_DS	HBI	4.13	4.01	4.32	4.15	0.16
MO_Hardy	#/m2	7,687	8,206	10,740	8,877	943.3
MO_Hardy	# taxa	39	39	36	38.0	1.0
MO_Hardy	#EPT taxa	13	14	13	13.3	0.3
MO_Hardy	% EPT	70%	68%	74%	71%	2%
MO_Hardy	% Non-Insect Tax	7%	8%	9%	8%	1%
MO_Hardy	% Chironomidae	18%	17%	13%	16%	1%
MO_Hardy	%Mayfly	26%	22%	26%	25%	1%
MO_Hardy	%Caddisfly	44%	46%	48%	46%	1%
MO_Hardy	HBI	5.16	5.25	5.04	5.15	0.06
MO_Cascade	#/m2	19,600	19,880	20,720	20,067	336.5
MO_Cascade	# taxa	50	49	46	48.3	1.2
MO_Cascade	#EPT taxa	17	16	15	16.0	0.6
MO_Cascade	% EPT	37%	28%	26%	30%	3%
MO_Cascade	% Non-Insect Tax	28%	27%	26%	27%	1%
MO_Cascade	% Chironomidae	35	33%	28%	28%	3%
MO_Cascade	%Mayfly	19%	13%	11%	14%	3%
MO_Cascade	%Caddisfly	17%	15%	15%	16%	1%
MO_Cascade	HBI	5.9	6.4	5.9	6.1	0.2

Appendix C. Macroinvertebrate taxa list and abundance.

APPENDIX C. Macroinvertebrate 2019 Fall taxa lists and raw data across all sites.

MO_LPPC_US01	Fall 2019	Subsample	0.38	0.7	0.75		
Order	OTUname2	FinalID	Hess 1	Hess 2	Hess 3	Avg.	SE
Coleoptera	Optioservus	Optioservus quadrimaculatus	45	43	37	42.0	2.4
Coleoptera	Halipilus	Halipilus	5	2	3	3.3	1.0
Diptera	Chironominae	Microtendipes	99	35	15	49.4	25.3
Diptera	Chironominae	Dicrotendipes	0	0	0	0.0	0.0
Diptera	Chironominae	Phaenopsectra	32	9	4	15.0	8.6
Diptera	Chironominae	Pseudochironomus	11	9	4	7.9	2.0
Diptera	Orthocladiinae	Cardiocladius	0	5	8	4.2	2.3
Diptera	Orthocladiinae	Cricotopus	0	4	4	2.8	1.4
Diptera	Orthocladiinae	Eukiefferella	32	45	32	36.6	4.4
Diptera	Orthocladiinae	Tvetenia	0	5	4	2.9	1.4
Diptera	Orthocladiinae	Parametriocnemus	11	5	4	6.4	2.1
Diptera	Orthocladiinae	Parakiefferella	11	5	4	6.4	2.1
Diptera	Diamsinae	Pagastia	0	0	2	0.7	0.7
Diptera	Simuliidae	Simulium	0	9	9	6.1	3.1
Diptera	Tanypodinae	Thienemannimyia gr.	0	6	3	2.9	1.7
Diptera	Tipulidae	Tipula	0	0	4	1.3	1.3
Diptera	Tipulidae	Limnophila	3	2	0	1.6	0.8
Ephemeroptera	Baetis	Baetis tricaudatus	0	2	3	1.6	0.8
Ephemeroptera	Ephemerella	Ephemerella excrucians	53	27	36	39.0	7.6
Ephemeroptera	Rhithrogena	Rhithrogena	0	0	0	0.0	0.0
Ephemeroptera	Tricorythodes	Tricorythodes explicatus	40	39	40	39.7	0.3
Non-Insect taxa	Hirudina	Erpobdella punctata	21	9	4	11.5	5.1
Non-Insect taxa	Glossiphoniidae	Glossiphonia complanata	0	5	0	1.5	1.5
Non-Insect taxa	Caecidotea	Caecidotea	301	61	40	134.3	83.8
Non-Insect taxa	Hyalella	Hyalella	128	85	32	81.8	27.8
Non-Insect taxa	Acarina	Acarina (Sperchon)	21	0	4	8.5	6.5
Non-Insect taxa	Oligochaeta	Lumbriculidae	5	7	16	9.6	3.3
Non-Insect taxa	Oligochaeta	Lumbricina	0	2	1	1.1	0.6
Non-Insect taxa	Physa_Physella	Physella acuta	336	286	89	237.2	75.3
Non-Insect taxa	Valvata	Valvata humeralis	43	7	8	19	11.6
Non-Insect taxa	Stagnicola	Stagnicola	16	2	5	7.8	4.2
Non-Insect taxa	Pisidiidae	Pisidium	37	27	20	28.3	5.0
Non-Insect taxa	Potamopyrgus	Potamopyrgus antipodarum	35	7	5	15.8	9.4
Non-Insect taxa	Gyraulus	Gyraulus	3	3	1	2.3	0.5
Non-Insect taxa	Menetus	Menetus dilatatus	37	12	3	17.3	10.4
Non-Insect taxa	Oligochaeta	Tubificidae	37	2	15	18.0	10.3
Non-Insect taxa	Gammarus	Gammarus	40	10	15	21.7	9.2
Non-Insect taxa	Turbellaria	Turbellaria	27	34	93	51.5	21.0
Non-Insect taxa	Nematoda	Nematoda	8	10	4	7.5	1.9
Plecoptera	Perlodidae	Isoperla	0	0	0	0.0	0.0
Lepidoptera	Petrophila	Petrophila	0	2	1	1.1	0.6
Trichoptera	Ceraclea	Ceraclea	0	0	1	0.4	0.4
Trichoptera	Brachycentrus	Brachycentrus occidentalis	3	0	1	1.3	0.8
Trichoptera	Cheumatopsyche	Cheumatopsyche	19	135	215	122.8	56.9
Trichoptera	Glossosomatidae	Culoptila	0	0	0	0.0	0.0
Trichoptera	Limnephilidae	Dicosmoecus gilvipes	3	2	0	1.6	0.8
Trichoptera	Hydropsyche_Cer	Hydropsyche morosa gr.	0	3	3	1.9	0.9
Trichoptera	Hydropsyche_Cer	Hydropsyche occidentalis	3	4	1	2.8	0.9
Trichoptera	Helicopsyche	Helicopsyche borealis	3	0	1	1.3	0.8
Trichoptera	Hydroptila	Hydroptila	3	0	1	1.3	0.8
Trichoptera	Oecetis	Oecetis avara	72	79	84	78.5	3.5
		per sample	1541	1051	882	1158.1	197.7

APPENDIX C. Macroinvertebrate 2019 Fall taxa lists and raw data across all sites.

MO_LPPC_DS01	Fall 2019		1	1	1		
Order	OTuname2	FinalID	Hess 1	Hess 2	Hess 3	Average	SE
Coleoptera	Optioservus	Optioservus quadrimaculatus	7	4	5	5.3	0.88
Coleoptera	Zaitzevia	Zaitzevia	2	6	2	3.3	1.33
Diptera	Ceratopogonidae	Probezzia	0	1	0	0.3	0.33
Diptera	Tipulidae	Hexatoma	5	3	2	3.3	0.88
Diptera	Simulium	Simulium	7	12	9	9.3	1.45
Diptera	Tipulidae	Tipula	0	1	2	1.0	0.58
Diptera	Muscidae	Limnophora	1	1	4	2.0	1.00
Diptera	Chironominae	Microtendipes	0	1	1	0.7	0.33
Diptera	Chironominae	Rheotanytarsus	3	1	0	1.3	0.88
Diptera	Orthoclaadiinae	Tvetenia	0	1	1	0.7	0.33
Diptera	Orthoclaadiinae	Eukiefferella	1	1	2	1.3	0.33
Diptera	Orthoclaadiinae	Parakiefferella	0	2	1	1.0	0.58
Diptera	Orthoclaadiinae	Parametricnemus	1	0	0	0.3	0.33
Diptera	Orthoclaadiinae	Cardiocladius	0	2	5	2.3	1.45
Diptera	Orthoclaadiinae	Synorthocladius	1	1	2	1.3	0.33
Diptera	Tanypodinae	Thienemannimyia gr.	0	0	0	0.0	0.00
Ephemeroptera	Acentrella	Acentrella	0	0	0	0.0	0.00
Ephemeroptera	Baetidae	Baetis tricaudatus	22	17	23	20.7	1.86
Ephemeroptera	Ephemerellidae	Ephemerella excrucians	3	4	3	3.3	0.33
Ephemeroptera	Ephemerellidae	Attenella margarita	0	1	2	1.0	0.58
Ephemeroptera	Ephemerellidae	Drunella grandis	1	3	1	1.7	0.67
Ephemeroptera	Rhithrogena	Rhithrogena	61	75	43	59.7	9.26
Ephemeroptera	Tricorythodes	Tricorythodes explicatus	0	2	1	1.0	0.58
Non-Insect taxa	Acarina	Acarina (Hygrobatas)	0	0	1	0.3	0.33
Non-Insect taxa	Oligochaeta	Lumbriculidae	11	4	8	7.7	2.03
Non-Insect taxa	Oligochaeta	Lumbricidae	1	2	1	1.3	0.33
Non-Insect taxa	Physa_Physella	Physella acuta	4	3	3	3.3	0.33
Non-Insect taxa	Pisidiidae	Pisidium	0	0	0	2.0	1.15
Non-Insect taxa	Menetus	Menetus dilatatus	1	1	1	1.0	0.00
Non-Insect taxa	Gyraulus	Gyraulus	1	0	1	0.7	0.33
Non-Insect taxa	Potamopyrgus	Potamopyrgus antipodarum	0	0	1	0.3	0.33
Non-Insect taxa	Valvata	Valvata	1	0	2	1.0	0.58
Non-Insect taxa	Gammarus	Gammarus	0	0	0	0.0	0.00
Non-Insect taxa	Gammarus	Hyaella	0	2	1	1.0	0.58
Non-Insect taxa	Caecidotea	Caecidotea	0	3	6	3.0	1.73
Non-Insect taxa	Oligochaeta	Tubificidae	5	1	2	2.7	1.20
Non-Insect taxa	Turbellaria	Turbellaria	4	1	5	3.3	1.20
Plecoptera	Skwala	Skwala	1	0	2	1.0	0.58
Plecoptera	Perlidae	Claassenia sabulosa	0	1	1	0.7	0.33
Plecoptera	Pteronarcys	Pteronarcys californica	0	0	0	0.0	0.00
Trichoptera	Brachycentrus	Brachycentrus occidentalis	3	4	5	4.0	0.58
Trichoptera	Cheumatopsyche	Cheumatopsyche	0	1	5	2.0	1.53
Trichoptera	Hydropsyche_Ceratops	Hydropsyche occidentalis	2	2	1	1.7	0.33
Trichoptera	Hydropsyche_Ceratops	Hydropsyche morosa gr.	0	2	0	0.7	0.67
Trichoptera	Glossosomatidae	Glossosoma	28	70	55	51.0	12.29
Trichoptera	Lepidostoma	Lepidostoma	8	5	1	4.7	2.03
Trichoptera	Oecetis	Oecetis avara	2	1	2	1.7	0.33
		Totals	187	242	213	243.0	15.89

APPENDIX C. Macroinvertebrate 2019 Fall taxa lists and raw data across all sites.

MO_Craig_US01	Fall 2019		6/12ss	4/12ss	6/12ss		
Order	OTUname2	Final ID	Hess 1	Hess 2	Hess 3	Avg.	SE
Coleoptera	Optioservus	Optioservus quadrimaculatus	118	132	166	139	14.2
Diptera	Orthocladiinae	Cricotopus trifascia	10	0	20	10	5.8
Diptera	Orthocladiinae	Tvetenia	0	0	5	2	1.8
Diptera	Orthocladiinae	Cardiocladius	2	0	2	1.3	0.7
Diptera	Orthocladiinae	Parakiefferiella	2	0	2	1.3	0.7
Diptera	Orthocladiinae	EuKiefferiella	6	6	2	4.7	1.3
Diptera	Chironominae	Microtendipes	150	138	240	176	32.2
Diptera	Chironominae	Pseudochironomus	2	0	0	1	0.7
Diptera	Chironominae	Polypedilum	4	3	6	4.3	0.9
Diptera	Tanypodinae	Thienemannimyia gr.	12	3	16	10	3.8
Diptera	Orthocladiinae	Thienemanniella	2	0	0	0.7	0.7
Diptera	Tabanidae	Chrysops	6	6	2	5	1.3
Diptera	Empididae	Hemerodromia	2	0	2	1.3	0.7
Diptera	Simuliidae	Simulium	12	0	34	15	10.0
Diptera	Tipulidae	Tipula	0	0	0	0	0.0
Ephemeroptera	Baetis	Baetis tricaudatus	16	9	10	12	2.2
Ephemeroptera	Ephemerella	Ephemerella exrucians	8	21	8	12	4.3
Ephemeroptera	Tricorythodes	Tricorythodes explicatus	18	15	16	16	0.9
Non-Insect taxa	Caecidotea	Caecidotea	10	30	20	20	5.8
Non-Insect taxa	Orconectes virilis	Orconectes virilis	5	0	0	2	1.6
Non-Insect taxa	Hirudina	Erpobdella punctata	2	3	4	3	0.6
Non-Insect taxa	Hirudina	Helobdella stagnalis	0	0	0	0	0.0
Non-Insect taxa	Hyalella	Hyalella	100	135	30	88	30.9
Non-Insect taxa	Gammarus	Gammarus	4	21	8	11	5.1
Non-Insect taxa	Nematoda	Nematoda	26	6	24	19	6.4
Non-Insect taxa	Physa_Physella	Physella acuta	40	159	66	88	36.2
Non-Insect taxa	Valvata	Valvata humeralis	4	15	10	10	3.2
Non-Insect taxa	Menetus	Menetus dilatatus	6	12	4	7	2.4
Non-Insect taxa	Pisidiidae	Pisidium	42	45	52	46	3.0
Non-Insect taxa	Stagnicola	Stagnicola	0	15	0	5.0	5.0
Non-Insect taxa	Potamopyrgus	Potamopyrgus antipodarum	0	9	0	3	3.0
Non-Insect taxa	Oligochaeta	Tubificidae	4	15	2	7	4.0
Non-Insect taxa	Oligochaeta	Lumbriculidae	4	3	0	2.3	1.2
Non-Insect taxa	Oligochaeta	Lumbricidae	0	15	0	5.0	5.0
Non-Insect taxa	Turbellaria	Turbellaria	16	39	20	25	7.1
Lepidoptera	Petrophila	Petrophila	0	0	2	1	0.7
Trichoptera	Cheumatopsyche	Cheumatopsyche	104	345	12	154	99.4
Trichoptera	Hydropsyche_Ceratops	Hydropsyche occidentalis	48	42	16	35	9.8
Trichoptera	Hydropsyche_Ceratops	Hydropsyche morosa gr.	0	3	0	1.0	1.0
Trichoptera	Helicopsyche	Helicopsyche borealis	2	3	2	2	0.3
Trichoptera	Brachycentrus	Brachycentrus occidentalis	0	0	8	2.7	2.7
Trichoptera	Hydroptila	Hydroptila	0	9	0	3	3.0
Trichoptera	Ceraclea	Ceraclea	0	3	2	2	0.9
Trichoptera	Limnephilidae	Dicosmoecus gilvipes	2	6	0	3	1.8
Trichoptera	Leptoceridae	Nectopsyche	0	0	0	0	0.0
Trichoptera	Oecetis	Oecetis avara	204	249	224	226	13.1
		Totals	993	1517	1037	1182.2	167.7

APPENDIX C. Macroinvertebrate 2019 Fall taxa lists and raw data across all sites.

MO_Dealr_US01	Fall 2019		5/12sub	5/24sub	1/2sub		
Order	OTUname2	FinalID	Hess 1	Hess 2	Hess 3	Avg.	SE
Coleoptera	Optioservus	Optioservus quadrimaculatus	11	43	8	20.7	11.3
Coleoptera	Zaitzevia	Zaitzevia	2	10	2	4.6	2.5
Coleoptera	Ordobrevia	Ordobrevia nubifera	0	0	8	2.7	2.7
Diptera	Orthoclaadiinae	Cricotopus	9	19	8	12.0	3.6
Diptera	Orthoclaadiinae	Eukiefferiella	5	24	18	15.7	5.6
Diptera	Chironominae	Microtendipes	130	144	14	95.9	41.2
Diptera	Chironominae	Dicrotendipes	0	0	0	0.0	0.0
Diptera	Chironominae	Phaenopsectra	4	0	0	1.5	1.5
Diptera	Chironominae	Micropsectra	15	48	0	21	14.1
Diptera	Chironominae	Pseudochironomus	0	10	2	3.9	2.9
Diptera	Chironominae	Rheotanytarsus	8.8	33.6	0	14.1	10.1
Diptera	Chironominae	Polypedilum	11	110	34	51.8	30.0
Diptera	Orthoclaadiinae	Tvetenia bavarica	4.4	38.4	6	16.3	11.1
Diptera	Tanypodinae	Thienemannimyia gr.	9	29	0	12.5	8.5
Diptera	Tipulidae	Hexatoma	11	0.0	2.0	4.3	3.4
Diptera	Simuliidae	Simulium	0	0	12	4.0	4.0
Ephemeroptera	Baetis	Baetis tricaudatus	106	264	148	172.5	47.3
Ephemeroptera	Ephemerella	Ephemerella exrucians	59	211	80	116.9	47.5
Ephemeroptera	Tricorythodes	Tricorythodes explicatus	40	38	18	32.0	7.0
Ephemeroptera	Ephemera simulans	Ephemera simulans	0	0	0	0.0	0.0
Ephemeroptera	Heptageniidae	Maccaffertium terminatum	4	0	2	2.1	1.3
Ephemeroptera	Paraleptophlebia	Choroterpes	0	0	0	0.0	0.0
Ephemeroptera	Rhithrogena	Rhithrogena	19.8	57.6	12	29.8	14.1
Lepidoptera	Petrophila	Petrophila	0	0	2	0.7	0.7
Odonata	Coenagrionidae	Enallagma	0	0	0	0.0	0.0
Non-Insect taxa	Caecidotea	Caecidotea	9	0	0	2.9	2.9
Non-Insect taxa	Crangonyx	Gammarus	18	10	4	10.4	3.9
Non-Insect taxa	Hirudina	Erpobdella punctata	0	5	0	1.6	1.6
Non-Insect taxa	Hyalella	Hyalella	0	0	0	0.0	0.0
Non-Insect taxa	Oligochaeta	Lumbricina	9	0	0	2.9	2.9
Non-Insect taxa	Oligochaeta	Lumbriculidae	2	5	0	2.3	1.4
Non-Insect taxa	Oligochaeta	Tubificidae	0	0	0	0.0	0.0
Non-Insect taxa	Nematoda	Nematoda	0	0	0	0.0	0.0
Non-Insect taxa	Physa_Physella	Physella acuta	31	48	12	30.3	10.4
Non-Insect taxa	Gyraulus	Gyraulus	2.2	0	0	0.7	0.7
Non-Insect taxa	Orconectes virilis	Orconectes virilis	2.2	4.8	2	3.0	0.9
Non-Insect taxa	Turbellaria	Turbellaria	205	370	178	250.7	59.9
Plecoptera	Perlidae	Claassenia sabulosa	0	0	0	0.0	0.0
Plecoptera	Perlodidae	Skwala	3	0	2	1.7	0.9
Trichoptera	Ceraclea	Ceraclea	3	5	4	3.9	0.5
Trichoptera	Brachycentrus occiden	Brachycentrus occidentalis	0	0	0	0.0	0.0
Trichoptera	Cheumatopsyche	Cheumatopsyche	537	750	524	603.6	73.3
Trichoptera	Helicopsyche	Helicopsyche borealis	0	10	4	4.5	2.8
Trichoptera	Hydropsyche_Ceratops	Hydropsyche occidentalis	7	29	8	14.5	7.2
Trichoptera	Hydropsyche_Ceratops	Hydropsyche morosa gr.	3	15	10	9.3	3.5
Trichoptera	Hydropsyche_Ceratops	Hydropsyche cockerelli	2	14	12	9.5	3.7
Trichoptera	Glossosomatidae	Glossosoma	0	10	0	3.2	3.2
Trichoptera	Dicosmoecus	Dicosmoecus	4	0	0	1.5	1.5
Trichoptera	Polycentropidae	Polycentropus	0	4.8	0	1.6	1.6
Trichoptera	Hydroptila	Hydroptila	35	115	8	52.8	32.2
Trichoptera	Oecetis	Oecetis avara	9	34	14	18.8	7.6
		Totals per hess	1329.6	2507.4	1158	1665.0	424.1

APPENDIX C. Macroinvertebrate 2019 Fall taxa lists and raw data across all sites.

MO_Dearborn_DS01	Fall 2019		1/1 sub	1/1 sub	1/1 sub		
Order	OTUname2	FinalID	Hess 1	Hess 2	Hess 3	Average	SE
Coleoptera	Microcylloepus pusillus	Microcylloepus pusillus	0	0	0	0.0	0.0
Coleoptera	Optioservus	Optioservus quadrimaculatus	8	12	6	8.7	1.8
Coleoptera	Zaitzevia	Zaitzevia parvula	12	10	12	11.3	0.7
Diptera	Chironominae	Microtendipes	0	0	0	0.0	0.0
Diptera	Chironominae	Pseudochironomus	1	2	5	2.5	1.0
Diptera	Chironominae	Rheotanytarsus	9	16	10	11.7	2.2
Diptera	Orthocladiinae	Cricotopus	4	8	6	6.0	1.2
Diptera	Orthocladiinae	Eukiefferella	4	4	6	4.7	0.7
Diptera	Orthocladiinae	Tvetenia bavarica	4	4	2	3.3	0.7
Diptera	Simuliidae	Simulium	2	4	2	2.7	0.7
Diptera	Tipulidae	Limnophila	10	5.0	8.0	7.7	1.5
Diptera	Atherix	Atherix	2	1.0	4.0	2.3	0.9
Diptera	Empididae	Hemerodromia	1	2	2	1.7	0.3
Ephemeroptera	Baetis	Baetis tricaudatus	8	16	12	12.0	2.3
Ephemeroptera	Ephemerellidae	Ephemerella excrucians	1	4	2	2.3	0.9
Ephemeroptera	Tricorythodes	Tricorythodes explicatus	0	6	8	4.7	2.4
Ephemeroptera	Baetidae	Dipheter hageni	0	2	2	1.3	0.7
Ephemeroptera	Rhithrogena	Rhithrogena	25	33.0	21	26.3	3.5
Ephemeroptera	Paraleptophlebia	Paraleptophlebia	0	8	4	4.0	2.3
Non-Insect taxa	Physa_Physella	Physella acuta	1	2	2	1.7	0.3
Non-Insect taxa	Oligochaeta	Lumbriculidae	12	2	6	6.7	2.9
Non-Insect taxa	Turbellaria	Turbellaria	1	2	1	1.3	0.3
Plecoptera	Perlidae	Claassenia sabulosa	3	4	2	3.0	0.6
Plecoptera	Perlidae	Hesperoperla pacifica	1	1	1	1.0	0.0
Plecoptera	Perlodidae	Skwala	2	3	2	2.3	0.3
Plecoptera	Chloroperlidae	Sweltsa	1	2	2	1.7	0.3
Trichoptera	Brachycentrus occiden	Brachycentrus occidentalis	4	0	2	2.0	1.2
Trichoptera	Hydropsychidae	Cheumatopsyche	44	33	40	39.0	3.2
Trichoptera	Leptoceridae	Oecetis avara	5	4	6	5.0	0.6
Trichoptera	Leptoceridae	Ceraclea	0	0	0	0.0	0.0
Trichoptera	Hydroptila	Hydroptila	0	0	0	0.0	0.0
Trichoptera	Hydropsychidae	Hydropsyche	25	18	27	23.3	2.7
Trichoptera	Hydropsychidae	Hydropsyche morosa gr.	4	5	8	5.7	1.2
Trichoptera	Helicopsyche	Helicopsyche borealis	1	2	4	2.3	0.9
		Totals per hess	195	215	214.5	208.2	6.6

APPENDIX C. Macroinvertebrate 2019 Fall taxa lists and raw data across all sites.

MO_Hardy_DS01	Fall2019		4/12 sub	4/12 sub	3/12 sub		
Order	OTUname2	FinalID	Hess 1	Hess 2	Hess 3	Avg.	SE
Coleoptera	Optioservus	Optioservus quadrimaculatus	85	100	60	81.6	11.7
Coleoptera	Stenelmis	Stenelmis	0	3	8	3.7	2.3
Coleoptera	Microcylloepus	Microcylloepus	6	3	12	7.0	2.6
Diptera	Simuliidae	Simulium	18	33	28	26.5	4.4
Diptera	Orthocladiinae	Cricotopus	9	12	28	16.4	5.9
Diptera	Orthocladiinae	Synorthocladus	6	3	0	3.0	1.7
Diptera	Chironominae	Pseudochironomus	12	18	36	22.1	7.2
Diptera	Tanypodinae	Thienemannimyia gr.	6	12	8	8.7	1.8
Diptera	Tanypodinae	Pentanura	3	6	0	3.0	1.7
Diptera	Chironominae	Polypedilum	67	45	44	52.0	7.3
Diptera	Chironominae	Phaenopsectra	3	6	12	7.0	2.6
Diptera	Chironominae	Cryptochironomus	9	6	0	5.1	2.7
Diptera	Chironominae	Microtendipes	79	91	96	88.6	5.1
Diptera	Orthocladiinae	Eukiefferella	36	24	24	28.2	4.1
Diptera	Orthocladiinae	Tvetenia bavarica	9	14	8	10.5	2.0
Diptera	Chironominae	Rheotanytarsus	12	12	4	9.4	2.7
Ephemeroptera	Attenella	Attenella margarita	0	0	0	0.0	0.0
Ephemeroptera	Baetis	Baetis tricaudatus	167	194	200	186.9	10.3
Ephemeroptera	Baetis	Baetis intercalaris	0	0	0	0.0	0.0
Ephemeroptera	Ephemerella	Ephemerella excrucians	121	100	208	9.0	33.0
Ephemeroptera	Paraleptophlebia	Paraleptophlebia	3	6	12	7.0	2.6
Ephemeroptera	Heptagenidae	Maccaffertium	3	9	20	10.7	5.0
Ephemeroptera	Heptagenidae	Heptagenia	0	3	4	2.3	1.2
Ephemeroptera	Plauditis	Plauditis punctiventris	6	0	8	4.7	2.4
Ephemeroptera	Pseudocloeon	Pseudocloeon	0	0	0	0.0	0.0
Ephemeroptera	Tricorythodes	Tricorythodes explicatus	97	52	108	85.5	17.3
Ephemeroptera	Ephemera simulans	Ephemera simulans	3	1	0	1.3	0.9
Lepidoptera	Petrophila	Petrophila	4	0	0	1.3	1.3
Non-Insect taxa	Oligochaeta	Tubificidae	0	0	0	0.0	0.0
Non-Insect taxa	Hirudinea	Erpobdella punctata	6	0	4	3.4	1.8
Non-Insect taxa	Pisidiidae	Sphaerium	3	3	8	4.7	1.7
Non-Insect taxa	Pisidiidae	Pisidium	6	3	12	7.0	2.6
Non-Insect taxa	Hyalella	Hyalella	15	29	44	29.3	8.3
Non-Insect taxa	Gammarus	Gammarus	6	12	24	14.1	5.3
Non-Insect taxa	Caecidotea	Caecidotea	24	36	16	25.5	5.9
Non-Insect taxa	Turbellaria	Turbellaria	15	12	44	23.8	10.2
Non-Insect taxa	Physa_Physella	Physella acuta	12	14	8	11.5	1.9
Non-Insect taxa	Gyraulus	Gyraulus	6	12	16	11.4	2.9
Non-Insect taxa	Orconectes virilis	Orconectes virilis	6	9	8	7.7	0.9
Trichoptera	Hydropsyche_Ceratops	Hydropsyche occidentalis	379	505	656	513.3	80.1
Trichoptera	Hydropsyche_Ceratops	Hydropsyche morosa gr.	30	15	36	27.2	6.2
Trichoptera	Brachycentrus occiden	Brachycentrus occidentalis	3	6	0	3.0	1.7
Trichoptera	Cheumatopsyche	Cheumatopsyche	203	182	288	224.3	32.4
Trichoptera	Leptoceridae	Ceraclea	0	14	0	4.8	4.8
Trichoptera	Hydroptila	Hydroptila	21	14	12	15.9	2.8
Trichoptera	Helicopsyche	Helicopsyche borealis	36	18	32	28.8	5.5
Trichoptera	Polycentropidae	Polycentropus	0	0	12	4.0	4.0
		Totals	1537	1641	2148	1775.5	188.7

APPENDIX C. Macroinvertebrate 2019 Fall taxa lists and raw data across all sites.

MO_Cascade_US01	Fall 2019		1/8ss	1/4ss	1/4ss		
Order	OTUname2	FinalID	Hess 1	Hess 2	Hess 3	Avg.	SE
Coleoptera	Dubiraphia	Dubiraphia	28	64	40	44.0	10.6
Coleoptera	Microcylloepus	Microcylloepus pusillis	56	44	72	57.3	8.1
Coleoptera	Optioservus	Optioservus quadrimaculatus	100	152	128	126.7	15.0
Coleoptera	Zaitzevia	Zaitzevia parvula	32	48	68	49.3	10.4
Diptera	Chironominae	Microtendipes	64	80	112	85.3	14.1
Diptera	Chironominae	Phaenopsectra	32	64	144	80.0	33.3
Diptera	Chironominae	Polypedilum	64	48	16	42.7	14.1
Diptera	Chironominae	Pseudochironomus	112	124	140	125.3	8.1
Diptera	Chironominae	Rheotanytarsus	16	20	16	17.3	1.3
Diptera	Chironominae	Tanytarsus	28	32	8	22.7	7.4
Diptera	Diamsinae	Potthastia	16	16	0	10.7	5.3
Diptera	Orthocadiinae	Cricotopus	68	120	144	110.7	22.4
Diptera	Orthocadiinae	Eukiefferiella	4	4	12	6.7	2.7
Diptera	Orthocadiinae	Nostococcladius	4	8	8	6.7	1.3
Diptera	Orthocadiinae	Orthocladius	0	16	16	10.7	5.3
Diptera	Orthocadiinae	Thienemaniella	4	0	0	1.3	1.3
Diptera	Tanypodinae	Pentaneura	4	4	0	2.7	1.3
Diptera	Tanypodinae	Thienemannimyia gr.	20	16	32	22.7	4.8
Diptera	Simuliidae	Simulium	8	12	8	9.3	1.3
Ephemeroptera	Baetidae	Acerpenna pygmaea	8	16	32	18.7	7.1
Ephemeroptera	Baetis	Baetis intercalaris	16	4	0	6.7	4.8
Ephemeroptera	Baetidae	Baetis tricaudatus	104	68	52	74.7	15.4
Ephemeroptera	Choroterpes	Choroterpes	28	16	48	30.7	9.3
Ephemeroptera	Heptagenia	Ecdyonurus simpliciodes	4	4	16	8.0	4.0
Ephemeroptera	Ephemerella	Ephemerella excrucians	4	8	12	8.0	2.3
Ephemeroptera	Heptagenia	Heptagenia	8	0	0	2.7	2.7
Ephemeroptera	Heptagenia	Maccaffertium terminatum	12	24	12	16.0	4.0
Ephemeroptera	Plauditus	Plauditus punctiventris	20	20	8	16.0	4.0
Ephemeroptera	Tricorythodes	Tricorythodes explicatus	176	96	48	106.7	37.3
Lepidoptera	Petrophila	Petrophila	24	16	20	20.0	2.3
Non-Insect taxa	Caecidotea	Caecidotea	116	132	160	136.0	12.9
Non-Insect taxa	Hirudinea	Erpobdella punctata	4	8	8	6.7	1.3
Non-Insect taxa	Ferrissia	Ferrissia rivularis	8	8	12	9.3	1.3
Non-Insect taxa	Gammarus	Gammarus	28	16	16	20.0	4.0
Non-Insect taxa	Hyaella	Hyaella	48	64	88	66.7	11.6
Non-Insect taxa	Oligochaeta	Lumbricina	40	36	24	33.3	4.8
Non-Insect taxa	Oligochaeta	Lumbriculidae	16	20	12	16.0	2.3
Non-Insect taxa	Orconectes	Orconectes virilis	4	12	8	8.0	2.3
Non-Insect taxa	Physa_Physella	Physella acuta	132	112	72	105.3	17.6
Non-Insect taxa	Potamopyrgus	Potamopyrgus antipodarum	8	8	4	6.7	1.3
Non-Insect taxa	Pisidiidae	Sphaerium	28	8	20	18.7	5.8
Non-Insect taxa	Oligochaeta	Tubificidae	56	32	36	41.3	7.4
Non-Insect taxa	Turbellaria	Turbellaria	68	80	88	78.7	5.8
Odonata	Ophiogomphus	Ophiogomphus severus	4	4	8	5.3	1.3
Trichoptera	Brachycentrus occi	Brachycentrus occidentalis	8	4	8	6.7	1.3
Trichoptera	Cheumatopsyche	Cheumatopsyche	32	40	48	40.0	4.6
Trichoptera	Helicopsyche	Helicopsyche borealis	108	96	124	109.3	8.1
Trichoptera	Hydropsyche_Cera	Hydropsyche morosa gr.	20	16	20	18.7	1.3
Trichoptera	Hydroptila	Hydroptila	32	48	32	37.3	5.3
Trichoptera	Nectopsyche	Nectopsyche	4	8	16	9.3	3.5
Trichoptera	Oecetis	Oecetis avara	132	92	56	93.3	21.9
		Totals	1960	1988	2072	2006.7	33.7

Appendix D. Site Habitat and Physical Conditions

Appendix D . Habitat and Water Quality Parameters measured for the UMOWA sites visited.

2019	MO_LPPC_US			MO_LPPC_DS			MO_Craig			MO_DEAR_US			MO_DEAR_DS			MO_HARDY_BR			MO_Cascade		
	Apr	July	Oct	Apr	July	Oct	Apr	July	Oct	Apr	July	Oct	Apr	July	Oct	Apr	July	Oct	Apr	July	Oct
Water Temp °C	na	na	15.6	na	na	11.1	na	na	15.4	na	na	15.1	na	na	12.5	na	na	14.5	na	na	14.6
Conductivity (µs/cm)	na	na	313	na	na	329	na	na	315	na	na	313	na	na	363	na	na	322	na	na	333
TDS (mg/l)	na	na	201	na	na	220	na	na	200	na	na	195	na	na	215	na	na	195	na	na	200
pH	na	na	7.9	na	na	7.9	na	na	8.0	na	na	8.0	na	na	8.0	na	na	8.1	na	na	8.0
Discharge (cfs)			5010			5020			5020			5080			5200			5450			5450
Avg. Sample Depth (cm)	na	na	28	na	na	25	na	na	27	na	na	30	na	na	30	na	na	35	na	na	24
Avg. Sample Dist. From Bank (m)	na	na	14	na	na	7	na	na	15	na	na	6	na	na	9	na	na	5	na	na	7
% Fines in Hess	na	na	15	na	na	25	na	na	10	na	na	10	na	na	5	na	na	5	na	na	25
% Gravel Hess	na	na	75	na	na	50	na	na	70	na	na	50	na	na	40	na	na	15	na	na	55
% Cobble Hess	na	na	10	na	na	25	na	na	20	na	na	40	na	na	55	na	na	60	na	na	30
% Boulder Reach	na	na	0	na	na	0	na	na	0	na	na	0	na	na	0	na	na	20	na	na	0
Avg. Riparian Shade	na	na	0	na	na	0	na	na	20	na	na	10	na	na	0	na	na	5	na	na	5