City of Seattle 2017 and 2018 Benthic Macroinvertebrate Sampling Results

July 2020

King County

Department of Natural Resources and Parks
Water and Land Resources Division
Science and Technical Support Section
King Street Center, KSC-NR-0704
201 South Jackson Street, Suite 704
Seattle, WA 98104
206-477-4800 TTY Relay: 711
www.kingcounty.gov/EnvironmentalScience

Alternate Formats Available
206-477-4800 TTY Relay: 711

City of Seattle 2017 and 2018 Benthic Macroinvertebrate Sampling Results

Prepared for:

City of Seattle, Seattle Public Utilities
Katherine Lynch, Project Manager

Submitted by:

Elizabeth Sosik and Kate Macneale
King County Water and Land Resources Division
Department of Natural Resources and Parks

King County
Department of
Natural Resources and Parks
Water and Land Resources Division

Acknowledgements

We would like to thank King County Stream Team staff for their dedication in collecting the 2017 and 2018 samples. Team members include Stephanie Eckard, Paige Morris, Jessica Andrade, Mark Quick, KayLani Siplin, Mimi Reed, Megan Rodden, Erin Horkan, and Ashley Townes.

Citation

King County. 2020. City of Seattle 2017 and 2018 Benthic Macroinvertebrate Sampling Results. Prepared by Elizabeth Sosik and Kate Macneale, Water and Land Resources Division. Seattle, Washington.

Table of Contents

Figures

Tables

Appendices

EXECUTIVE SUMMARY

Seattle Public Utilities (Seattle) has conducted stream biological monitoring since 1994. Benthic macroinvertebrate samples are collected from most perennial creeks within the City of Seattle (Thornton, Mapes, Taylor, Mohlendorph, Pipers, Venema, Longfellow, Fauntleroy, Puget, Venema, and Schmitz creeks). This monitoring program was designed to evaluate the short-term biological impact of various creek and watershed restoration activities and to track the status and trends of biological health of the creeks. Beginning in 2013, Seattle contracted with King County Water and Land Resources (WLR) Division to provide technical support and conduct sampling within the existing monitoring program.

The purpose of this report is to briefly summarize results of the 2017 and 2018 benthic macroinvertebrate sampling efforts. This includes a characterization of the current health of each sample site, using the Puget Lowland Benthic Index of Biotic Integrity (B-IBI), and the emerging trends observed in some streams over time. Additionally, due to the rising concern about the regional spread of invasive New Zealand mudsnails (NZMS) (*Potamopyrgus antipodarum*), this report also evaluates their distribution at the sampling locations.

In 2017 and 2018, benthic macroinvertebrate sampling was conducted by two-person crews between early September and early October. In 2017 and 2018, crews sampled 10 annual sites. In 2017, samples were collected from 15 additional sites in the northern part of the city, and in 2018, samples were collected from 14 additional sites in the southern part of the city. At each site, crews collected three, 1-ft^2 samples from three distinct riffles using a 500-*u*m mesh Surber sampler (9 ft^2 total sample collection area). The nine individual samples were composited into one sample which was preserved in the field with 95% ethanol. The samples were then sent to a taxonomic laboratory for identification. The resulting taxonomic and count data were uploaded to the Puget Sound Stream Benthos data management system.

Results of the macroinvertebrate sampling indicate Seattle streams are highly degraded, though there have been some small signs of improvement over time. B-IBI scores ranged from 0 (very poor) to 41.7 (fair). Mean B-IBI scores were lowest in Puget, Longfellow, Thornton and Mohlendorph creeks and highest in Venema and Fauntleroy creeks. No declining trends in B-IBI score were observed city-wide, by stream, or by individual site; scores in Fauntleroy Creek and the NFCC site (Thornton Creek) significantly improved over time since monitoring began. As of the 2018 sampling season, New Zealand mudsnails have been detected in Thornton, Mapes, Pipers, Longfellow, and Taylor creeks. In some samples, NZMS comprised over 70% of the organisms in a sample. Continued education and implementation of appropriate decontamination procedures for recreational stream users and professionals conducting maintenance and monitoring are essential to prevent further spread of this invasive species.

1.0 INTRODUCTION

Freshwater benthic macroinvertebrates are small but visible animals without backbones that live among the rocks and wood debris in streams, lakes, and wetlands. Macroinvertebrates are key components of aquatic food webs, where they consume detritus and periphyton, and are the primary prey of juvenile salmonids and other aquatic vertebrates. In addition to their ecological importance, aquatic macroinvertebrates are excellent indicators of stream health. The Puget Lowlands Benthic Index of Biotic Integrity (B-IBI) was developed to characterize stream condition, based on changes in macroinvertebrate communities observed along an urban gradient (e.g., Karr 1998, Morley and Karr 2002). This scoring system has been used for decades to characterize stream health in the region, including Seattle (Morley 2000).

Seattle Public Utilities (Seattle) has conducted stream biological monitoring annually since 1994. Macroinvertebrate samples are collected from the City of Seattle's perennial creeks including Thornton, Mapes, Taylor, Mohlendorph, Pipers, Venema, Longfellow, Fauntleroy, Puget, Venema, and Schmitz. Seattle's monitoring program was designed to evaluate short-term biological impact of various creek and watershed restoration activities and to track the status and trends of the creeks' biological health over time. Beginning in 2013, Seattle contracted with King County Water and Land Resources (WLR) Division to conduct the annual sampling as part of the existing monitoring program.

The purpose of this report is to briefly summarize the results of the 2017 and 2018 benthic macroinvertebrate sampling, report on preliminary trends observed in B-IBI scores and specific taxa within the watersheds since monitoring began, and evaluate the distribution of New Zealand mudsnails (NZMS) (*Potamopyrgus antipodarum*) at these Seattle locations.

2.0 METHODS

Methods for field sample collection, taxonomic analysis, B-IBI calculation, and data download are summarized in the subsections that follow.

2.1 Sample Sites

Sampling sites were previously established by Seattle. Ten sites are sampled annually from Thornton, Taylor and Mapes creeks, while other sites are sampled in alternate years (Figure 1, Table 1). In addition to collecting samples from the annual sites in 2017 and 2018, crews sampled 15 sites in Thornton, Mohlendorph, Pipers, and Venema creeks in 2017, and 14 sites in Mapes, Taylor, Longfellow, Puget, Schmitz, and Fauntleroy creeks in 2018.

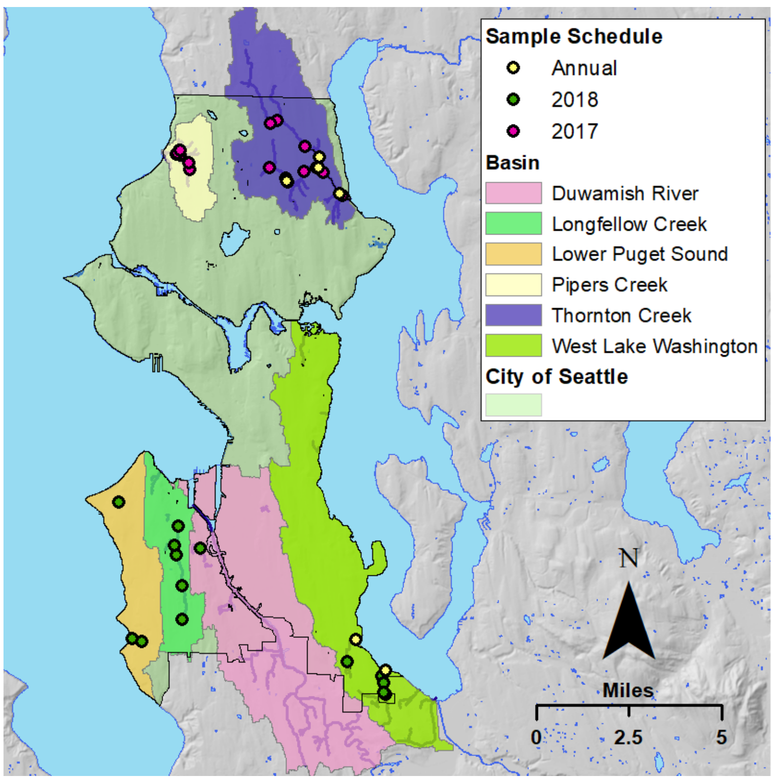

Figure 1. Location of sampling sites and year of sampling.

Table 1. Sampling site names and locations and year sampled.

Sampling Interval	Stream	Site Code	WRIA	Latitude	Longitude
Annual (2017 and 2018)	Thornton	95T	8	47.6967	-122.2777
		KNKC	8	47.70232	-122.30861
		KNKT_D	8	47.70109	-122.30756
		KNKT_U	8	47.701401	-122.30841
		NFCC	8	47.71071	-122.2895
		NFCT	8	47.7069	-122.2899
		SFCC	8	47.70692	-122.29115
		SFCT	8	47.706912	-122.290087
	Taylor	TAMA_MOUTH	8	47.512	-122.246
	Mapes	MA01	8	47.523639	-122.263647
Odd Years (2017)	Mohlendorph	MOHL	8	47.71256	-122.370743
	Pipers	PI01	8	47.710954	-122.372315
		PI02	8	47.705213	-122.364284
		PIMA6462	8	47.710676	-122.370107
		PIMA7729	8	47.707693	-122.365004
	Venema	PIVE1895	8	47.711465	-122.371743
		VENE	8	47.712379	-122.369959
	Thornton	TMMA1199	8	47.706374	-122.290034
		TMMA3168	8	47.696096	-122.276095
		TMMA8751	8	47.705096	-122.287017
		TNMA0609	8	47.724785	-122.314558
		TNMA6462	8	47.714962	-122.298236
		TNMA7673	8	47.723404	-122.318472
		TSMA6612	8	47.706561	-122.318321
		TSMA7774	8	47.704987	-122.298361
Even Years (2018)	Longfellow	LF04	9	47.566307	-122.366733
		LFMA0954	9	47.529961	-122.363695
		LFMA2559	9	47.543087	-122.363956
		LFMA3396	9	47.555002	-122.367783
		LFMA3490	9	47.55878	-122.368681
	Puget	PU01	9	47.557726	-122.353826
	Fauntleroy	FA02	9	47.522438	-122.392214
		FAMA0851	9	47.521366	-122.386388
	Schmitz	SCMA9065	9	47.575194	-122.401214
	Mapes	MAMA6255	8	47.515104	-122.267926
	Taylor	TA03	8	47.509709	-122.248071
		TAEF6250	8	47.502649	-122.245946
		TAMA7468	8	47.506984	-122.247134
		TAWF4847	8	47.503047	-122.246759

2.2 Sample Collection Methods

Benthic macroinvertebrate sampling was conducted by two-person crews between mid-September and early October following the recommended sampling protocols outlined by Karr and Chu (1999) and summarized here. At each location, a Surber sampler (500-μm mesh, 1-ft^2 frame) was used to collect three, 1-ft^2 samples from three distinct riffles (9 ft^2 total collection area) starting at the downstream end of the sampling reach and working upstream. For each 1-ft^2 collection, all large material (e.g., large gravel, cobble, and woody debris) within the sampling area was scrubbed by hand in front of the net so that any organisms or debris washed loose flowed into the collection net. Each piece of large material was visually examined after being scrubbed to ensure no organisms were still attached and then the material was placed outside the Surber frame. A sturdy metal gardening hand tool was used to agitate the substrate within the perimeter of the frame to a depth of approximately 10 cm (3.9 in) for 60 seconds. The nine, 1-ft^2 samples were composited into one sample for processing, which included placing the sample into a 500-μm mesh sieve and then using filtered water to rinse any remaining material too big to fit into the sample bottle. In addition, the net was visually examined for any organisms. The remaining materials were then transferred to a labeled sample container and preserved in the field with 95% ethanol.

2.3 Taxonomic Laboratory Methods

Following completion of sample collection each year, all samples were sent to a taxonomic laboratory, Aquatic Biology Associates Inc., in Corvallis, Oregon, for identification to the lowest possible taxonomic resolution for insect taxa. Most non-insect invertebrates (e.g., mites, crustaceans, mollusks) were identified to the standard taxonomic resolution defined as “fine,” which is generally genus or species (https://benthos.kingcounty.gov/Standard-Taxonomic-Effort.aspx). Worms were identified to subclass (Oligochaeta), which is considered the “coarse” standard taxonomic effort level. This distinction has implications for the B-IBI scoring discussed below. Each sample was subsampled to count and identify at least 500 organisms, but if fewer than 500 organisms were present, the entire sample was processed. Taxonomic data were uploaded to the Puget Sound Stream Benthos (PSSB) database (pugetsoundstreambenthos.org).

2.4 Benthic Index of Biotic Integrity

The primary tool used in the Puget Sound region to evaluate benthic macroinvertebrate monitoring results is the B-IBI, which is an integrative measure of the biological health of wadeable streams. It was originally developed in the 1990s (Karr 1998; Fore et al. 2001, Karr and Chu 1999, Kleindl 1995, Morley and Karr 2002) and was updated in 2014 (King County 2014). Macroinvertebrate taxa vary widely in their sensitivity to environmental stressors, and therefore the composition of the community and relative abundance of sensitive taxa at a site reflect the cumulative impacts of multiple stressors in a watershed (Morley and Karr 2002; Walsh 2006). B-IBI is an index composed of 10 metrics that characterize aquatic macroinvertebrate communities by measuring taxa richness, relative abundance, and other ecological characteristics of stream macroinvertebrates

(Appendix A). The scores from the ten metrics (ranging from 0 to 10 for each metric) are summed to provide an overall B-IBI score ranging from 0 to 100. The overall B-IBI score corresponds to biological condition ranging from very poor to excellent (Appendix B).

2.4.1 Puget Sound Stream Benthos Data Download

The PSSB database calculates B-IBI based on several user defined criteria. For this report, the following criteria were selected to download scores and taxa lists:

- Area: all streams
- Project: Seattle: all projects
- Aggregation: Don't aggregate
- Score Type: 0-100 B-IBI
- Replicate Handling: Combine replicates, then calculate
- Taxonomic resolution/standard taxonomic effort (STE): as defined by metadata
- Taxa Attributes: Fore Wisseman 2012
- Number of Organisms: Count per visit selected, max number = 500, and Omit/subsample selected
- Year: All in Range

2.5 Trend Analysis

Trends in B-IBI scores, individual B-IBI metrics, and the abundance of individual taxa were analyzed at multiple spatial scales (city-wide, by stream, and by site) using a Mann-Kendall trends test. To better capture trends among rare taxa, the taxonomic data were also analyzed for trends in presence/absence using logistic regression. Trend analyses included all data for samples collected since 1994. Samples collected outside of the typical sampling period (July-October) were excluded. On two occasions, a collection site was sampled twice in the same year; in these instances, the values were averaged (for B-IBI score, individual B-IBI metrics and abundance of individual taxa).

Trends in the number of individuals per taxa present were based on the subsampled (i.e., 500 count max) quantity from the PSSB database. Changes in the naming convention or standard taxonomic effort over the years limit the ability to analyze trends in some taxa. For example, one group of mayflies was previously identified as *Baetis tricaudatus,* but more recently has been identified as *Baetis tricaudatus complex*. These taxa are flagged in the results section.

Changes in taxonomic identification of mites (Acari) also affects the trends analysis of B-IBI scores and the taxa richness metric. Prior to 2012, mites were identified to subclass, but in 2012, Aquatic Biology Associates began identifying mites to subfamily or genus. This change may have increased the taxa richness count and score slightly (usually less than 1 point) in samples processed in 2012 and beyond.

2.5.1 City-wide B-IBI Trend Analysis

To conduct the city-wide trend analysis, data from all Seattle sites sampled as part of Seattle's monitoring program were aggregated to biennium to account for the even/odd-year sampling schedule of many of the sites. If a site was sampled every other year, the value for the given biennium was retained; if a site was sampled in both years of a given biennium, the average value was retained. To maintain statistical power, only streams with at least 10 sampled bienniums were included. Finally, to account for differences in number of sites within stream systems, the median value for each stream in each year was considered in the trend analysis. Thus, the city-wide trend is reflective of the bi-annual median values for the following seven streams: Fauntleroy, Longfellow, Pipers, Schmitz, Taylor, Thornton and Venema creeks.

An additional analysis was conducted for the frequency of occurrence of taxa across the Seattle sampling area, to examine trends in spatial extent. This analysis is based on the annual number of streams (max = 7) in which a taxon was detected. Taxa that initially were found in only one stream but then spread to additional streams would have a positive trend for this analysis.

2.5.2 Stream-Specific B-IBI Trend Analysis

For stream-specific trend analysis, only streams with at least 10 sampled years from any combination of sites, and that had also been sampled in 2017 or 2018, were considered. Ten streams met these criteria and were included in this analysis: Fauntleroy, Longfellow, Mapes, Mohlendorph, Puget, Pipers, Schmitz, Taylor, Thornton and Venema creeks.

2.5.3 Site-Specific B-IBI Trend Analysis

For site-specific trend analysis, only sites with at least 10 sampled years that had also been sampled in 2017 or 2018 were considered. Of the 39 sites sampled in 2017 and 2018, only 6 sites met these criteria: KNKC, NFCC, NFCT, PI01, SFCC, and SFCT.

3.0 RESULTS

Results indicate that Seattle streams were generally in poor or very poor condition in 2017 and 2018, although trends across the city and for some streams and sites indicate conditions have improved slightly over time. Results for the 2017 and 2018 sample events, and the long-term trend analyses are described below.

3.1 B-IBI Results for 2017 and 2018 Samples

Macroinvertebrate sampling was conducted at 39 sites across Seattle between 2017 and 2018. B-IBI scores ranged from a low of 0 in Thornton Creek to a high of 41.7 in Fauntleroy Creek (Scale 0-100; Table 2, Figures 2 - 5). Scores at all sites except one (FA02) indicate conditions at sites are poor or very poor.

B-IBI scores were based on at least 500 organisms except for two samples (Table 2). Low counts in a sample can be an additional source of variance associated with taxa richness metrics. See Appendix C for component metric results. Average scores for each stream, based on sampling in 2017 and/or 2018, are summarized in Table 3.

Table 2. B-IBI score, subsample count and B-IBI category by sites: 2017 and 2018. Projects include Project Evaluation (PE) and Status and Trends (S&T).

Stream	Project	Site	Year	B-IBI	Subsample Count	Category
Mapes	PE	MA01	2017	10.4	500	Very Poor
			2018	21.6	500	Poor
Mapes	S&T	MAMA6255	2018	38.2	500	Poor
Taylor	S&T	TA03	2018	16.7	500	Very Poor
Taylor	S&T	TAEF6250	2018	20.7	500	Poor
Taylor	PE	TAMA_MOUTH	2017	11.3	500	Very Poor
			2018	11.7	500	Very Poor
Taylor	S&T	TAMA7468	2018	26.2	500	Poor
Taylor	S&T	TAWF4847	2018	14.8	500	Very Poor
Thornton	PE	95T	2017	8.0	500	Very Poor
			2018	10.4	500	Very Poor
Thornton	PE	KNKC	2017	3.9	500	Very Poor
			2018	14.0	500	Very Poor
Thornton	PE	KNKT_D	2017	4.9	500	Very Poor
			2018	7.5	500	Very Poor
Thornton	PE	KNKT_U	2017	9.3	500	Very Poor
			2018	8.7	500	Very Poor
Thornton	PE	NFCC	2017	9.7	500	Very Poor
			2018	27.6	500	Poor
Thornton	PE	NFCT	2017	9.2	500	Very Poor
			2018	6.2	500	Very Poor

Stream	Project	Site	Year	B-IBI	Subsample Count	Category
Thornton	PE	SFCC	2017	14.0	500	Very Poor
			2018	14.2	500	Very Poor
Thornton	PE	SFCT	2017	4.5	500	Very Poor
			2018	8.1	500	Very Poor
Thornton	S&T	TMMA1199	2017	7.7	500	Very Poor
Thornton	S&T	TMMA3168	2017	15.6	500	Very Poor
Thornton	S&T	TMMA8751	2017	15.5	500	Very Poor
Thornton	S&T	TNMA0609	2017	7.5	500	Very Poor
Thornton	S&T	TNMA6462	2017	16.2	500	Very Poor
Thornton	S&T	TNMA7673	2017	2.0	500	Very Poor
Thornton	S&T	TSMA6612	2017	0	500	Very Poor
Thornton	S&T	TSMA7774	2017	10.2	500	Very Poor
Fauntleroy	S&T	FA02	2018	41.7	500	Fair
Fauntleroy	S&T	FAMA0851	2018	30.9	408	Poor
Schmitz	S&T	SCMA9065	2018	15.7	176	Very Poor
Mohlendorph	PE	MOHL	2017	9.9	500	Very Poor
Pipers	S&T	PI01	2017	18.5	500	Very Poor
Pipers	S&T	PI02	2017	25.8	500	Poor
Pipers	S&T	PIMA6462	2017	10.9	500	Very Poor
Pipers	S&T	PIMA7729	2017	1.2	500	Very Poor
Venema	S&T	PIVE1895	2017	30.1	500	Poor
Venema	PE	VENE	2017	33.7	500	Poor
Longfellow	S&T	LF04	2018	6.5	500	Very Poor
Longfellow	S&T	LFMA0954	2018	6.6	500	Very Poor
Longfellow	S&T	LFMA2559	2018	1.4	500	Very Poor
Longfellow	S&T	LFMA3396	2018	0.6	500	Very Poor
Longfellow	S&T	LFMA3490	2018	6.7	500	Very Poor
Puget Creek	S&T	PU01	2018	2.5	500	Very Poor

Table 3. Average B-IBI results by stream.

Stream	# of Sites	Mean B-IBI	Min	Max	Standard Deviation	Mean Category
Fauntleroy	2	36.3	30.9	41.7	7.6	Poor
Longfellow	5	4.4	0.6	6.7	3.1	Very Poor
Mapes	3	23.4	10.4	38.2	14.0	Poor
Mohlendorph	1	9.9	9.9	9.9	NA	Very Poor
Pipers	4	14.1	1.2	25.8	10.5	Very Poor
Puget	1	2.5	2.5	2.5	NA	Very Poor
Schmitz	1	15.7	15.7	15.7	NA	Very Poor
Taylor	6	16.9	11.3	26.2	5.7	Very Poor
Thornton	24	9.8	0	27.6	5.7	Very Poor
Venema	2	31.9	30.1	33.7	2.6	Poor

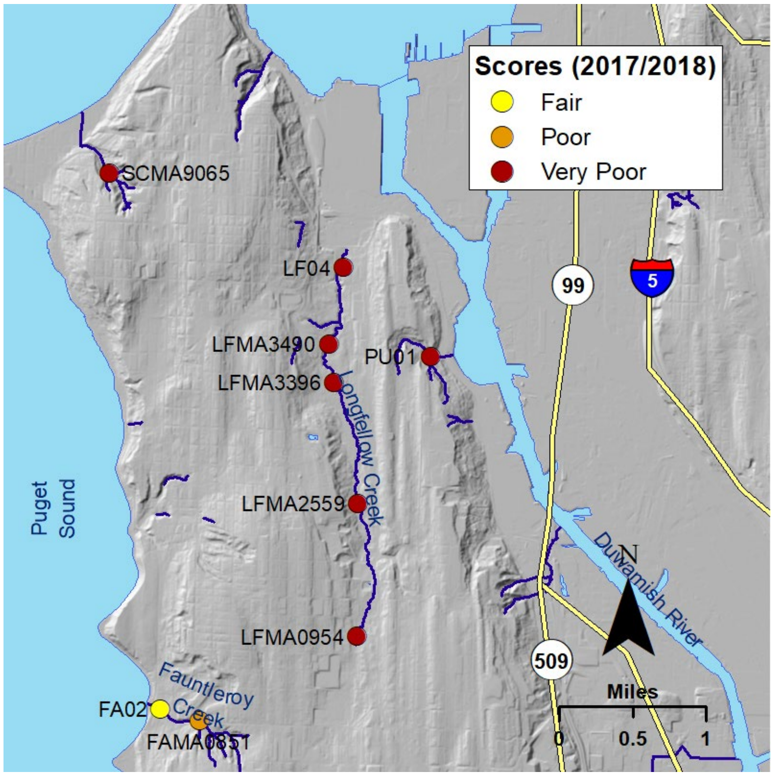

Figure 2. B-IBI results for Fauntleroy, Longfellow, Schmitz and Puget creeks

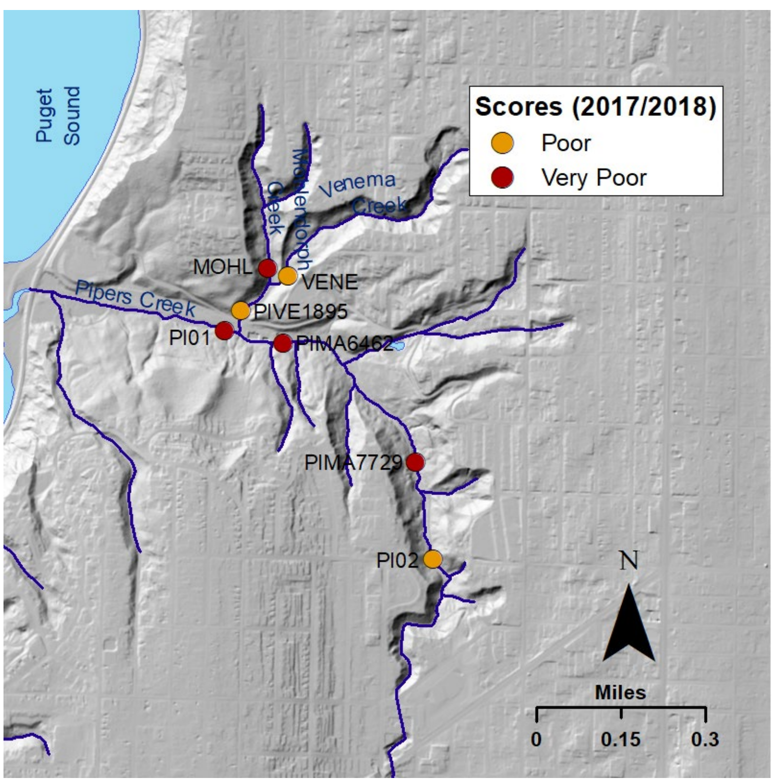

Figure 3. B-IBI results for Pipers Creek

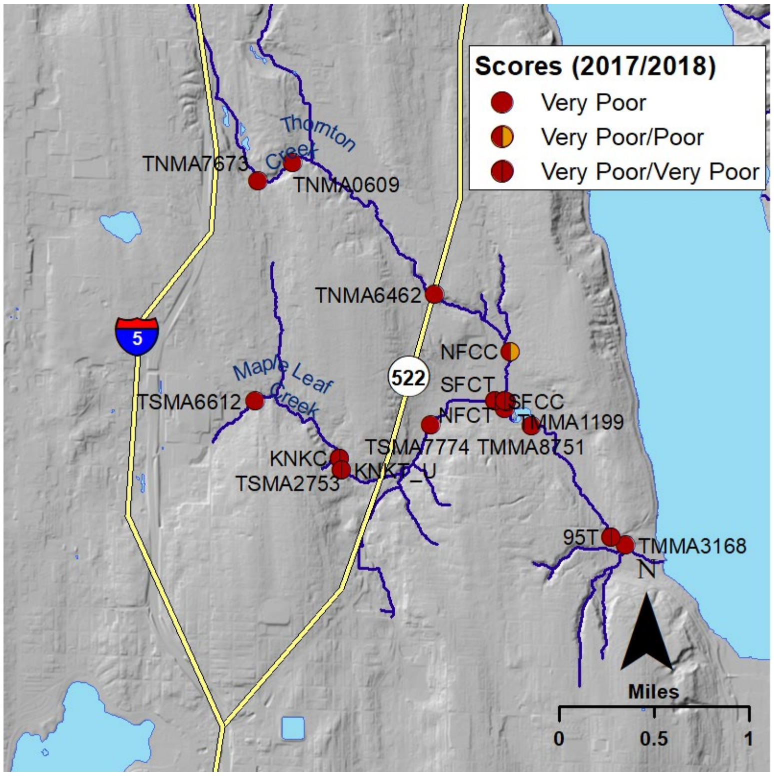

Figure 4. B-IBI results for Thornton Creek

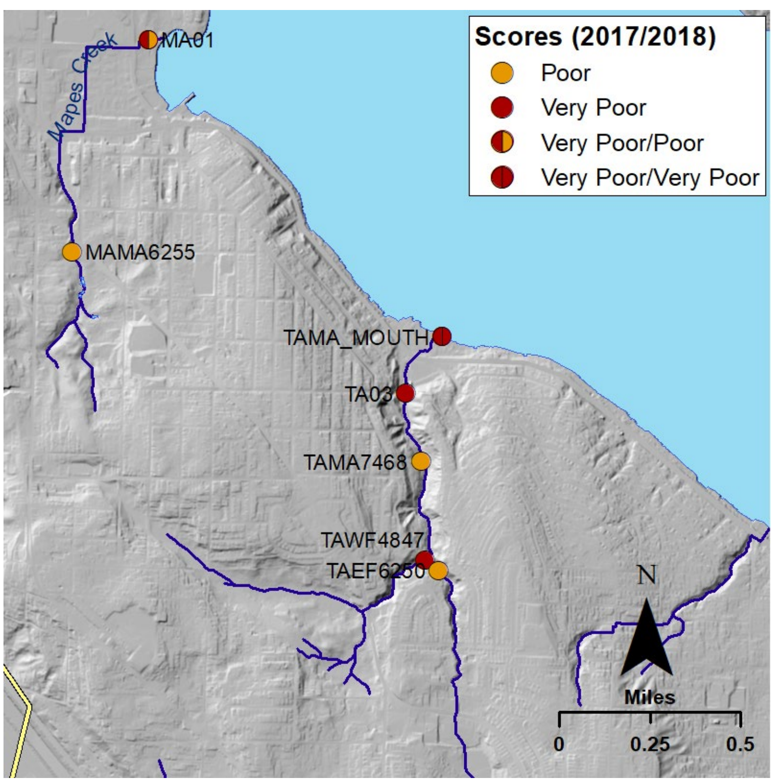

Figure 5. B-BIB results for Mapes and Taylor creeks

3.2 Trends

Trend analyses results for overall B-IBI scores, individual metric scores, and individual taxa are summarized in the following sections. For this report, trends are considered significant at the p<0.05 level, and near-significant at the p<0.1 level. Though not traditionally considered statistically significant, a p-value of less than 0.1 can be considered ecologically significant.

Analyzing trends in taxa help explain which taxa may be contributing to the trends in B-IBI metrics and overall B-IBI scores. The taxonomic trends were interpreted based on their potential impact on overall B-IBI score and the component metric scores, except for Percent Dominant. Interpreting the effect of a taxon's impact on Percent Dominant is difficult, as it depends on which taxa are dominant at a site. Thus, an increasing or decreasing in abundance in a taxon could have a positive or negative effect on the Percent Dominance score. In general, a trend in a taxon's presence/absence or frequency of occurrence is interpreted to impact richness scores, while a trend in a taxon's abundance is interpreted to impact scores that are based on percent of a sample (for example, Percent Tolerant). Taxa were assigned attribute information based on Fore and Wisseman, 2012.

3.2.1 Trends at the City-wide Scale

3.2.1.1 Trends in Overall B-IBI and Metric Scores across the City

Across all Seattle streams, richness metric scores for Taxa, Trichoptera, Clinger and Long-Lived have all significantly improved since 1994 (Table 4). However, Percent Tolerant scores significantly decreased over the same timeframe.

Table 4. Significant trends in overall B-IBI and component metric scores across Seattle streams. "+" indicates a positive trend, "-" indicates a negative trend. (*) = p < 0.05.

Overall B-IBI	Taxa Richness	Ephemeroptera Richness	Plecoptera Richness	Trichoptera Richness	Clinger Richness	Long-Lived Richness	Intolerant Richness	Percent Dominant	Percent Predator	Percent Tolerant
	+ (*)			+ (*)	+ (*)	+ (*)				- (*)

3.2.1.2 City-wide Taxonomic Trends

No significant trends in presence/absence were observed for any taxa at the city-wide scale.

Fifty-six taxa had significant (p<0.05) or near-significant (p<0.1) trends in city-wide frequency of occurrence (spatial extent) or abundance (Appendix D). This number excludes taxa where trends are likely due to changes in naming convention or taxonomic level of effort.

The analysis indicates twenty-nine taxa had a clear improving influence on B-IBI score and metrics, while twelve taxa had a clear declining influence. However, one of the B-IBI improving taxa is NZMS, which are included in the taxa richness count. Six taxa had a mixed effect on overall B-IBI score: these positively trending tolerant taxa cause declines in Percent Tolerant scores while also counting towards improved Taxa Richness; three of these taxa also count towards improving at least one other B-IBI richness metric such as Trichoptera, Clinger, and Long-Lived, or Percent Predator. For all B-IBI metrics, except Intolerant Richness, at least one trending taxa contributed to an improving score. Taxa Richness, Long-Lived Richness, Percent Tolerant and Percent Predator had at least one trending taxa that counted towards declining scores. No trend in intolerant taxa was observed.

3.2.2 Trends at the Stream Scale

3.2.2.1 Trends in Overall B-IBI and Metric Scores in Streams

Of the ten streams analyzed, a significant positive trend in overall B-IBI scores over time was only observed in Fauntleroy Creek (Figure 6). No significant declines in overall B-IBI scores over time were observed in any stream, though six streams had declining scores in at least one of the ten B-IBI metrics (Table 5). In five of those streams, the percentage of tolerant taxa present appears to be increasing, which leads to a declining metric score (Table 5).

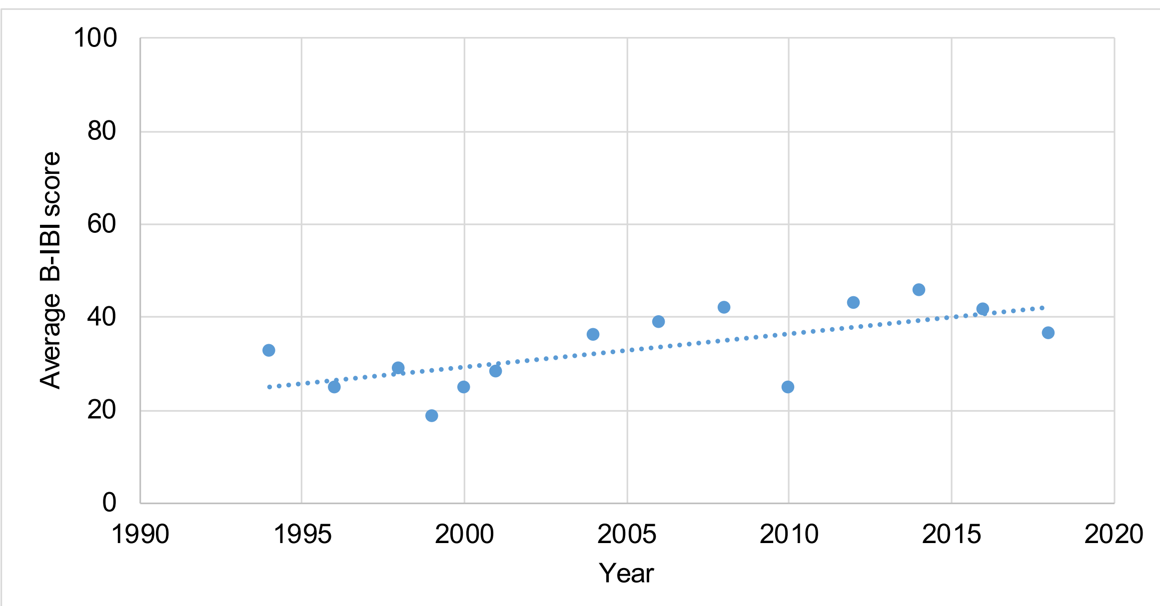

Figure 6. Improving trend in overall B-IBI scores in Fauntleroy Creek.

In contrast, six streams had positive trends for at least one component metric (Table 5). Increasing trends in the Long-Lived Richness score was the most common metric improving among streams, followed by improving trends in the Trichoptera Richness score. No trends were seen in any stream for Ephemeroptera or Intolerant Richness scores.

Table 5. Significant trends in overall B-IBI and component metric scores by stream. "+" indicates a positive trend, "-" indicates a negative trend. (*)= p < 0.05, (~) = p < 0.1.

Stream	Overall B-IBI	Taxa Richness	Ephemeroptera Richness	Plecoptera Richness	Trichoptera Richness	Clinger Richness	Long-Lived Richness	Intolerant Richness	Percent Dominant	Percent Predator	Percent Tolerant
Fauntleroy	+ (*)	+ (*)		+ (*)			+ (*)				
Longfellow					+ (*)		+ (*)			- (*)	- (~)
Mapes		- (~)									
Mohlendorph											
Pipers					+ (*)		+ (~)				- (*)
Puget											
Schmitz											
Taylor		+ (*)					+ (*)		+ (~)		- (~)
Thornton		+ (*)		+ (*)	+ (*)	+ (*)	+ (*)		+ (*)		- (*)
Venema					+ (*)	+ (*)	+ (*)				- (~)

3.2.2.2 Trends in Individual Taxa within Streams

All ten streams had taxa with significant trends. All ten B-IBI component metrics were potentially affected by the taxa trends, although a trend for only one intolerant taxa (*Cinygmula)* was significant in only in one stream (Fauntleroy Creek); however, it was a declining trend. There was an increasing trend in abundance for the intolerant taxon *Hesperoperla pacifica* at Fauntleroy Creek; however, because there was no corresponding trend in its presence/absence, this trend is unlikely to impact Intolerant Richness score there. Taxa trends for all streams are presented in Appendix E.

Within Fauntleroy Creek, trends for thirty-five taxa were significant ($p<0.05$) or near-significant ($p<0.1$) for taxa abundance or presence/absence. This number excludes taxa where trends are likely due to changes in naming convention or taxonomic level of effort. Twenty-one taxa had a clear positive influence on B-IBI score and metrics, while thirteen taxa had a clear negative influence. One positively trending tolerant taxon, *Menetus*, contributes to a declining Percent Tolerant score while also contributing to an improved Taxa Richness score. The positive trend in the Plecoptera Richness score seen within Fauntleroy Creek is driven in part by the increasing presence of *Zapada cinctipes, Pteronarcys princeps,* and *Zapada Oregonensis* Group. The latter two taxa also contribute to the positive trend observed for the Long-Lived Richness score, along with the taxa Lara and Pisidium. All B-IBI metrics, except Trichoptera Richness and Percent Tolerant, had at least one trending taxa that contributed to an improving metric score. Taxa contributing to declining metric scores were observed for all B-IBI metrics except Plecoptera Richness.

3.2.3 Trends at the Site Scale

3.2.3.1 Trends in Overall B-IBI and Metric Scores at Sites

Of the six sites with a sufficient length of record for trend analysis, only one site (NFCC, Thornton Creek) had a significant ($p<0.05$) improving trend in overall B-IBI score. No significant declines in overall B-IBI scores over time at any site were observed, though one site had a declining score for the percent tolerant metric, indicating a significant increase in the percentage of tolerant taxa (Table 6). Scores for at least one B-IBI metric had improved at five sites (Table 6).

Table 6. Significant trends in B-IBI and component metric scores by site. "+" indicates a positive trend, "-" indicates a negative trend. (*)= p < 0.05, (~) = p < 0.1.

Stream	Site	Overall B-IBI	Taxa Richness	Ephemeroptera Richness	Plecoptera Richness	Trichoptera Richness	Clinger Richness	Long-Lived Richness	Intolerant Richness	Percent Dominant	Percent Predator	Percent Tolerant
Pipers	PI01					+ (*)	+ (~)					- (*)
Thornton	KNKC				+ (~)			+ (~)				
	NFCC	+ (*)				+ (~)						
	NFCT											
	SFCC					+ (*)				+ (~)		
	SFCT					+ (*)						

3.2.3.2 Trends in Individual Taxa at Sites

All six sites had significant or near-significant trends in taxa presence or abundance. None of the trending taxa contributed to Ephemeroptera or intolerant taxa scores. Taxonomic trends for the all six sites are presented in Appendix F.

Within NFCC (Thornton), trends in taxa abundance or presence/absence for eleven taxa were significant ($p<0.05$) or near-significant ($p<0.1$). This number excludes taxa where trends are likely due to changes in naming convention or taxonomic level of effort. Six taxa had a clear positive influence on B-IBI score and metrics, though one of these was NZMS which contributes to the taxa richness score. Only two taxa had a clear negative influence on B-IBI. One tolerant taxon, *Pagastia*, is decreasing in abundance and detected presence/absence over time. This trend improves the Percent Tolerant score but causes some decline in Taxa Richness. All B-IBI metrics, except Intolerant Richness, had at least one trending taxa that contributed to an improving score. Taxa contributing to declining scores were observed in all B-IBI metrics except Plecoptera, Trichoptera and Intolerant richness. None of the trending taxa contributed to improving or declining Intolerant Richness scores.

3.3 New Zealand Mudsnail Distribution

New Zealand mudsnails are a freshwater invasive species that have no natural predators, parasites, or diseases to control their population size in North America. They can reproduce very quickly and have the potential to become a serious economic and ecological problem for the Puget Sound region. Of the streams sampled in the City of Seattle since 2009, NZMS have been observed in Thornton, Mapes , Pipers, Longfellow creeks and as of 2018, in Taylor Creek. They were first recorded in the Puget Sound region at one location (TMMA8751) in Thornton Creek in 2009 at very low abundances (6 snails, 1% of the sample), but have since expanded in distribution and abundance. They are now present in 15 of the 16 Thornton Creek sites (only TNMA7673 remains snail-free), as well as in four other streams. In 2017 and 2018, NZMS accounted for over half the number of organisms in samples from three Thornton Creek sites (Appendix G). To date, NZMS have not been observed in Fauntleroy, Mohlendorph, Ravenna, Schmitz, or Venema creeks, and have only been found in low densities (less than 1% of the sample) in Longfellow, Pipers and Taylor creeks. No NZMS were observed in Puget Creek during the 2018 sampling; this was the first sampling event at this location since 1999.

Increasing trends in NZMS were seen for both frequency of occurrence and abundance across the city. These finding indicate that since their initial introduction, NZMS have colonized additional stream basins and generally increased in abundance. However, the trend in abundance may be misleading. While numbers of NZMS have increased relative to baseline (zero NZMS prior to introduction), a curious pattern emerges on closer examination. Inspecting the abundance of NZMS within individual sites reveals that they often undergo either a “boom-bust” cycle of population growth or simply remain at low levels (Figure 7). Two adjacent sites in Thornton Creek (KNKT and KNKT-U) were in a "boom" phase as of 2018. One site, 95T, appears to be experiencing a second "boom-bust" cycle. What accounts for these patterns and their stability is unknown.

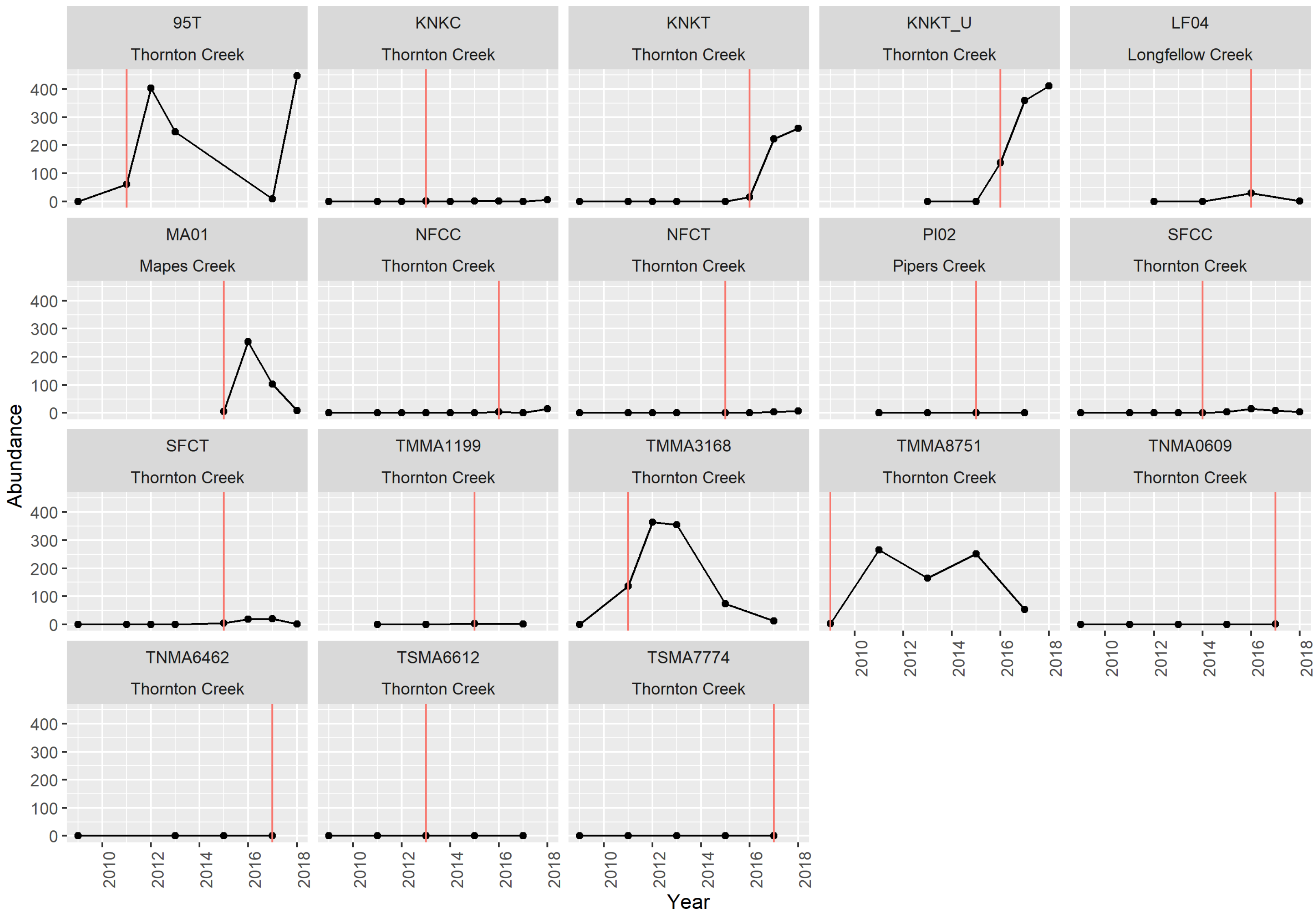

Figure 7. **Observed New Zealand mudsnail abundance at sites where they have been positively identified. Red vertical lines indicate first year of detection.**

4.0 DISCUSSION

Watershed health and biotic integrity are generally poor in Seattle streams as measured by the B-IBI. Fauntleroy Creek is in the best shape with one B-IBI score in the Fair category, followed by Venema and Mapes creeks. The seven other creeks generally scored in the very poor category. These results are not unexpected given the high intensity of urbanization in Seattle's watersheds. However, there is some cause for hope. The trends analysis suggests that while scores remain low, they are not significantly declining in any of the sampled locations. Indeed, within some streams and sites, B-IBI trends are on an upward trajectory, driven by the changing presence and abundance of multiple taxa. While trends in some taxa are encouraging, it should be noted that virtually none of these taxa are considered intolerant. The stonefly, *Hesperoperla pacifica,* found within Fauntleroy Creek, is the only positively trending intolerant taxon detected in any of the Seattle streams sampled. At the same time, half of the streams have declining scores for Percent Tolerant. These results indicate that water quality remains highly degraded within the streams. On the other hand, none of the positive B-IBI trends appear to be driven solely by increased Taxa Richness due to the introduction of NZMS or other tolerant taxa. Despite the degraded conditions, more native taxa are slowly establishing themselves within Seattle streams.

New Zealand mudsnails threaten the health and stability of aquatic ecosystems because they crowd out native species. They reproduce rapidly and have reached densities of over 400,000 snails per square meter in parts of the United States. They have not approached those densities in any of the City of Seattle study sites; however, it is still too early to predict how large of a problem they will become in the Puget Sound region. It is well understood that once established in a stream or a lake, it is impossible to remove them without harming native species. New Zealand mudsnails were most recently discovered in Taylor Creek in 2018, bringing the total number of monitored Seattle streams containing the snail to five. Taylor Creek is a tributary to the Lake Washington subbasin, which contains a number of other streams where NZMS have been observed (initial date of discovery): Kelsey Creek (2012) in Bellevue, McAleer Creek (2013) in Lake Forest Park and Shoreline, and May Creek (2014) in Newcastle and Renton. While the ability of NZMS to disperse via the lake is not known, the mode of introduction to Taylor Creek was most likely by people who had walked in a contaminated stream. This underscores the need to stay vigilant with decontamination procedures and education efforts to help prevent their spread[1].

[1] See the King County New Zealand mudsnail web site for more information on mudsnails and appropriate decontamination techniques: http://www.kingcounty.gov/environment/animalsAndPlants/biodiversity/threats/Invasives/Mudsnails.aspx

5.0 REFERENCES

Fore, L.S., K. Paulsen, and K. O'Laughlin. 2001. Assessing the performance of volunteers in monitoring streams. Freshwater Biology 46: 109 123.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6:21–27.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running waters: A method and its rationale. Illinois Natural History Survey, Special Publication 5.

Karr, J.R. 1998. Rivers as sentinels: using the biology of rivers to guide landscape management. Pages 502 528. In Naiman, R. J. and R. E. Bilby (editors). River Ecology and Management: Lessons from the Pacific Coastal Ecosystem. Springer, New York, NY.

Karr, J.R. and E.W. Chu. 1999. Restoring Life in Running Waters: Better Biological Monitoring. Island Press, Washington, D.C.

King County. 2014. Recalibration of the Puget Lowland Benthic Index of Biotic Integrity (B-IBI). Prepared by Jo Wilhelm (King County Water and Land Resources Division [WLRD]), Leska Fore (Statistical Design), Deb Lester (WLRD) and Elene Dorfmeier (WLRD). Seattle, Washington.

Kleindl, W.J. 1995. A Benthic Index of Biotic Integrity for Puget Sound Lowland Streams, Washington, USA. M.S. Thesis, University of Washington, Seattle, Washington.

Morley, S.A. 2000. Effects of Urbanization on the Biological Integrity of Puget Sound Lowland Streams: Restoration with a Biological Focus. M.S. thesis, University of Washington. Seattle, Washington.

Morley, S.A., and J.R. Karr. 2002. Assessing and restoring the health of urban streams in the Puget Sound basin. Conservation Biology. 16:1498 1509.

Walsh, C.J. 2006. Biological indicators of stream health using macroinvertebrate assemblage composition: a comparison of sensitivity to an urban gradient. Marine and Freshwater Research 57:37 47.

Appendix A: B-IBI Component Metrics

B-IBI is composed of ten component metrics, each with an expected response to disturbance (Table A-1). More information about the B-IBI scoring system can be found on the Puget Sound Stream Benthos web site (pugetsoundstreambenthos.org).

Table A-1. Ten B-IBI metrics and their expected response to disturbance. Table adapted from Karr and Chu (1999).

Metric	Response to Disturbance
Taxa richness and composition	
Total number of taxa	Decrease
Number of Ephemeroptera (mayfly) taxa	Decrease
Number of Plecoptera (stonefly) taxa	Decrease
Number of Trichoptera (caddisfly) taxa	Decrease
Number of long-lived taxa	Decrease
Tolerance	
Number of intolerant taxa	Decrease
Percent of individuals in tolerant taxa	Increase
Feeding ecology and other habits	
Percent of individuals that are predators	Decrease
Number of clinger taxa	Decrease
Population attributes	
Percent dominance (3 taxa)	Increase

This page intentionally left blank.

Appendix B: B-IBI Condition Categories

B-IBI is divided into 5 biological condition categories (Table B-1).

Table B-1. Qualitative categories of biological condition. Modified from Karr (1981) and Karr et al. (1986) by Morley (2000) and updated with B-IBI 0-100 scoring. Closed brackets [ ] include endpoints; open brackets ( ) exclude endpoints.

Biological Condition Category	Description	B-IBI
Excellent	Comparable to least disturbed reference condition; overall high taxa diversity, particularly of Ephemeroptera (mayfly), Plecoptera (stonefly), Trichoptera (caddisfly), long-lived, clinger, and intolerant taxa. Relative abundance of predators high.	[80, 100]
Good	Slightly divergent from least disturbed condition; absence of some long-lived and intolerant taxa; slight decline in richness of Ephemeroptera, Plecoptera, and Trichoptera; proportion of tolerant individuals increases.	[60, 80)
Fair	Total taxa richness reduced – particularly intolerant, long-lived, Plecoptera, and clinger taxa; relative abundance of predators declines; proportion of tolerant individuals continues to increase.	[40, 60)
Poor	Overall taxa diversity depressed; proportion of predators greatly reduced as is long-lived taxa richness; few Plecoptera or intolerant taxa present; dominance by three most abundant taxa often very high.	[20, 40)
Very Poor	Overall taxa diversity very low and dominated by a few highly tolerant taxa; Ephemeroptera, Plecoptera, caddisfly, clinger, long-lived, and intolerant taxa largely absent; relative abundance of predators very low.	[0, 20)

This page intentionally left blank.

Appendices C through G

Appendix C: B-IBI Score and Metrics for Each Site Visit in 2017 and 2018

Appendix D: City-wide Taxonomic Trends

Appendix E: Taxonomic Trends by Stream

Appendix F: Taxonomic Trends by Site

Appendix G: New Zealand Mudsnail Distribution and Percent Composition by Site over Time

The above appendices may be found here:

https://your.kingcounty.gov/dnrp/library/2020/kcr2696-2017/kcr2696-2017-appendices.pdf