# Bug Seeding: A Possible Jump-start to Stream Recovery

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# Bug Seeding: A Possible Jump-start to Stream Recovery

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Cover photo: A stonefly, *Pteronarcys princeps*, found in Gold Creek a year after seeding. Photo credit: Kate Macneale

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# EXECUTIVE SUMMARY

The “bug seeding” project aimed to jump-start the ecological recovery of several historically degraded King County streams by seeding them with a diverse community of macroinvertebrates – or “stream bugs” – from healthy streams. This work was funded by the U.S. Environmental Protection Agency as a Near Term Action to support the Puget Sound Partnership’s recovery targets for streams. This project focused on the Partnership’s Freshwater Quality vital sign and the Benthic Index of Biotic Integrity (B-IBI) indicator. Typically, healthy streams support a diverse macroinvertebrate community, including many unique types (or taxa) of sensitive mayfly, stonefly, and caddisfly larvae, as well as a suite of other insect larvae, snails, worms, crayfish, and clams. B-IBI indicator scores are largely based on the number of unique sensitive taxa at a site, and when conditions degrade and they disappear, B-IBI scores decline. Taxa can be impacted by excess fine sediment, scouring flows, contaminants, and high temperatures—all of which increase as forest land is converted to urban development. Sensitive taxa are those that disappear first when healthy forests are replaced by cities, roads, agricultural, and industry.

In the summer of 2018, a team of King County biologists seeded—or translocated—a collection of macroinvertebrates from healthy streams to four streams where many sensitive macroinvertebrate taxa were no longer found. Despite restoration efforts or otherwise good existing habitat in the four basins, few sensitive taxa were present and B-IBI scores remained low. Biologists suspected that one cause of the low B-IBI scores may be that the streams were isolated with no nearby source of sensitive taxa. The lack of healthy macroinvertebrate communities in the urban basins surrounding these sites may have limited biological recovery of these streams, even when conditions were suitable for them to thrive. By reintroducing small populations of sensitive native taxa, King County hoped to accelerate the recovery of the stream macroinvertebrate community.

Thanks to an enthusiastic team, the translocation went as planned. King County staff moved approximately 46,000 macroinvertebrates from two healthy “donor” streams to each of the four “recipient” streams. The recipient streams included Taylor Creek in Seattle, Gold Creek near Woodinville, Miller Creek in the City of Normandy Park, and a tributary of Yarrow Creek in the City of Bellevue. Samples collected from the recipient streams prior to seeding confirmed there were few sensitive species present prior to seeding, and B-IBI scores were typically poor or very poor. Reference samples collected from donor streams indicated that on average, the translocation added 15 new mayfly taxa, 9 new stonefly taxa and 13 new caddisfly taxa to each recipient stream. While it was not expected that all of the new taxa would become established in the recipient streams, persistence of even a few new taxa a year after seeding would suggest the recipient streams could support a more diverse and sensitive suite of macroinvertebrates.

**The primary result of the project is that seeding streams appears to have been partially successful in increasing stream macroinvertebrate diversity. In all four recipient streams, we found at least one new taxon or at least one taxon that we are fairly confident is new one-year post seeding in 2019. In two of the four streams,**

**B-IBI scores increased in part because of those new taxa.** We conclude the project was only partially successful because many of the added taxa were not found in post-seeding samples. In addition, we are uncertain if the new taxa present in 2019 will continue to thrive in the recipient streams in the future.

Below is a brief summary of results by stream:

- Gold Creek: Three new or possibly new taxa were found, including a stonefly, caddisfly and a fly. Most surprising was the **37-point increase** in the B-IBI score a year after seeding.
- Taylor Creek: Three possibly new taxa were found, including a beetle, midge, and a caddisfly. The B-IBI score increased **16 points** a year after seeding.
- Yarrow Creek tributary: One new stonefly was found a year after seeding. The B-IBI score **did not improve**.
- Miller Creek: Four new, or possibly new, taxa were found, including a mayfly, midge, crane fly and stonefly. However, the B-IBI score **did not improve**.

Several more years of post-seeding data will be needed to determine if new taxa persist in these streams. However, the initial results suggest **bug seeding, when done carefully and in appropriate locations, can help restore diverse stream macroinvertebrate communities.** Bug seeding can also be used to evaluate if restoration is necessary, or if a stream can support a more diverse macroinvertebrate community without restoration actions. If a stream has already been restored, bug seeding can be used to assess if the actions were effective or sufficient to support a more diverse community.

Tracking the success and failure of bug seeding experiments will also help refine our understanding and use of the B-IBI indicator. Seeding can help determine if isolation and a lack of nearby colonists are affecting B-IBI scores, and thus help us interpret the many factors that influence scores. By tracking which seeded taxa persist and those that do not, we can better understand the sensitivities of individual taxa and the biological potential of streams. We can use this information to develop better restoration strategies and improve the metrics used to measure effectiveness.

Bug seeding is relatively easy and inexpensive compared to habitat restoration and stormwater retrofits. The budget to complete this project (prepare the Quality Assurance Project Plan, seed four streams, monitor one-year post-seeding, and write the report) was approximately $100,000. **We want to stress**, however, that although it may be relatively easy to do, **bug seeding should only be done by professional biologists after careful consideration**. Scientific collection permits are needed to collect and move bugs, and projects must minimize the risk of translocating pathogens and non-native species to donor and recipient sites. In addition, **there must be a compelling reason to think recipient stream communities are limited primarily by a lack of colonists** and would benefit from the addition of sensitive taxa. **If other stressors are limiting the establishment of sensitive taxa, those stressors must be alleviated or eliminated before seeding.**

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# 1.0 INTRODUCTION

## 1.1 Study rationale and objectives

Many streams that flow into Puget Sound have been impacted by various stressors for decades, if not longer. The diverse community of aquatic macroinvertebrates native to regional streams respond to these stressors and thus are good indicators of stream health. The lack of sensitive taxa, especially some species of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), indicate conditions are likely degraded. If stressors are reduced and conditions improve, recovery of macroinvertebrate communities may be rapid (within a year) if there is a local source community. However, for streams without a nearby source of potential colonizers, recovery of the benthic community may be slow and/or limited (Parkyn and Smith 2011, Tonkin et al. 2014, Tonkin et al. 2017, Van Looy et al. 2019).

The ecological processes associated with colonization and recovery are relevant for the region because the presence of sensitive taxa is used to characterize the health and condition of streams. The multi-metric Benthic Index of Biotic Integrity (B-IBI) is a standardized scoring system that characterizes stream condition and health based on the composition and relative abundance of the benthic macroinvertebrates present. The overall B-IBI score for a site is highly dependent on several taxa richness measures (i.e., number of unique taxa present at a site). Although sensitive taxa are ubiquitous in streams that are in excellent condition, many of these taxa have limited dispersal capabilities. Some taxa can travel up to several kilometers, but most do not disperse more than a few hundred meters from their natal stream (Macneale et al. 2005, Sundermann et al. 2011).

The strong correlation between B-IBI scores and extent of urban development in the contributing basin suggests multiple stressors, at the basin-scale, are most important in explaining taxonomic richness at a site (Walsh et al. 2005). However, in some streams B-IBI scores are lower than expected given the land use in the basin and available habitat (Paul et al. 2009). There may be multiple explanations for lower-than-expected scores, but in some cases, it may be due in part to the limited local pool of sensitive taxa. The chance that sensitive taxa – that had been extirpated from a stream years ago - could recolonize a reach depends on how far those sensitive taxa can disperse and where they are coming from (e.g, Tonkin et al. 2014). Proximity to source populations within a stream network is a key factor explaining which taxa are able to colonize and how quickly communities recover after disturbance or restoration (Kitto et al. 2015, Tonkin et al. 2014, Tonkin et al. 2017).

If stream conditions (e.g., habitat, streamflow, water quality) have improved and are better than the B-IBI score indicates, the stream may have the capacity to support a greater number of sensitive taxa. To test this in restored streams that have not recovered and to jump-start recovery in newly restored streams, reintroductions have been proposed and are beginning to be implemented (e.g., Dumeier et al. 2018, Dumeier et al. 2020, Haase and Pillotto 2019, Jourdan et al. 2018, Morley et al. 2018, Witt 2017).

This project involved translocating (seeding, reintroducing) macroinvertebrate taxa collected from streams with sensitive taxa into four recipient streams that are isolated and had lower than expected B-IBI scores based on land use in their contributing basins. If seeded taxa were able to establish and persist in the recipient sites, taxa richness and potentially B-IBI scores may increase. If seeded taxa were unable to establish or persist, we would conclude that B-IBI scores accurately reflect current stream conditions and dispersal limitation does not explain or is not the only factor explaining low B-IBI scores.

The immediate goal of this project was to increase taxa richness and improve B-IBI scores in four target basins through macroinvertebrate seeding. A broader goal was to improve our understanding of how macroinvertebrate seeding may be used to accelerate the recovery of stream communities and improve B-IBI scores.

The project objectives include:

- Survey macroinvertebrates to establish baseline conditions, quantify taxa richness and calculate B-IBI scores in four recipient streams prior to seeding.
- Transplant sensitive taxa from two streams in the Cedar River basin (donor sites) to four recipient streams that have very poor or poor B-IBI scores and lack sensitive taxa.
- Survey recipient streams one-year post-seeding to determine if seeded taxa became established.
- Compare pre- and post-seeding taxa richness and B-IBI scores to determine if richness and B-IBI scores increased.
- Provide recommendations regarding where and when macroinvertebrate seeding is appropriate.

## 1.2 Study area

The study focuses on six streams in the Puget Lowland Ecoregion (Table 1, Figure 1). Macroinvertebrates were collected from two streams within the Cedar River watershed (donor sites) and were then placed in four recipient streams (Table 1, Figure 1). The two donor sites were within the protected portion of the Cedar River watershed, managed by the City of Seattle. All study sites are within two adjacent water resource inventory areas (WRIAs 8 and 9). The local climate conditions and native vegetation are similar across the ecoregion, and it is assumed that the study streams historically supported a similar macroinvertebrate assemblage.

**Table 1. Study site locations.**

| Site Type | Creek | Location | Coordinates | Basin (WRIA) |
|---|---|---|---|---|
| Donor | Cedar River | Unincorporated King County, near Hobart | 47.385199, -121.956818 | Cedar River/Lake Sammamish Basin (8) |
| | Webster Creek | Unincorporated King County, near Hobart | 47.427700, -121.915450 | Cedar River/Lake Sammamish Basin (8) |
| Recipient | Gold Creek | Unincorporated King County, near Woodinville | 47.742702, -122.141764 | Cedar River/Lake Sammamish Basin (8) |
| | Taylor Creek | City of Seattle | 47.507869, -122.247582 | Cedar River/Lake Sammamish Basin (8) |
| | Yarrow Creek tributary | City of Bellevue | 47.641796, -122.204353 | Cedar River/Lake Sammamish Basin (8) |
| | Miller Creek | City of Normandy Park | 47.447902, -122.348134 | Puget Sound (Duwamish-Green) Basin (9) |

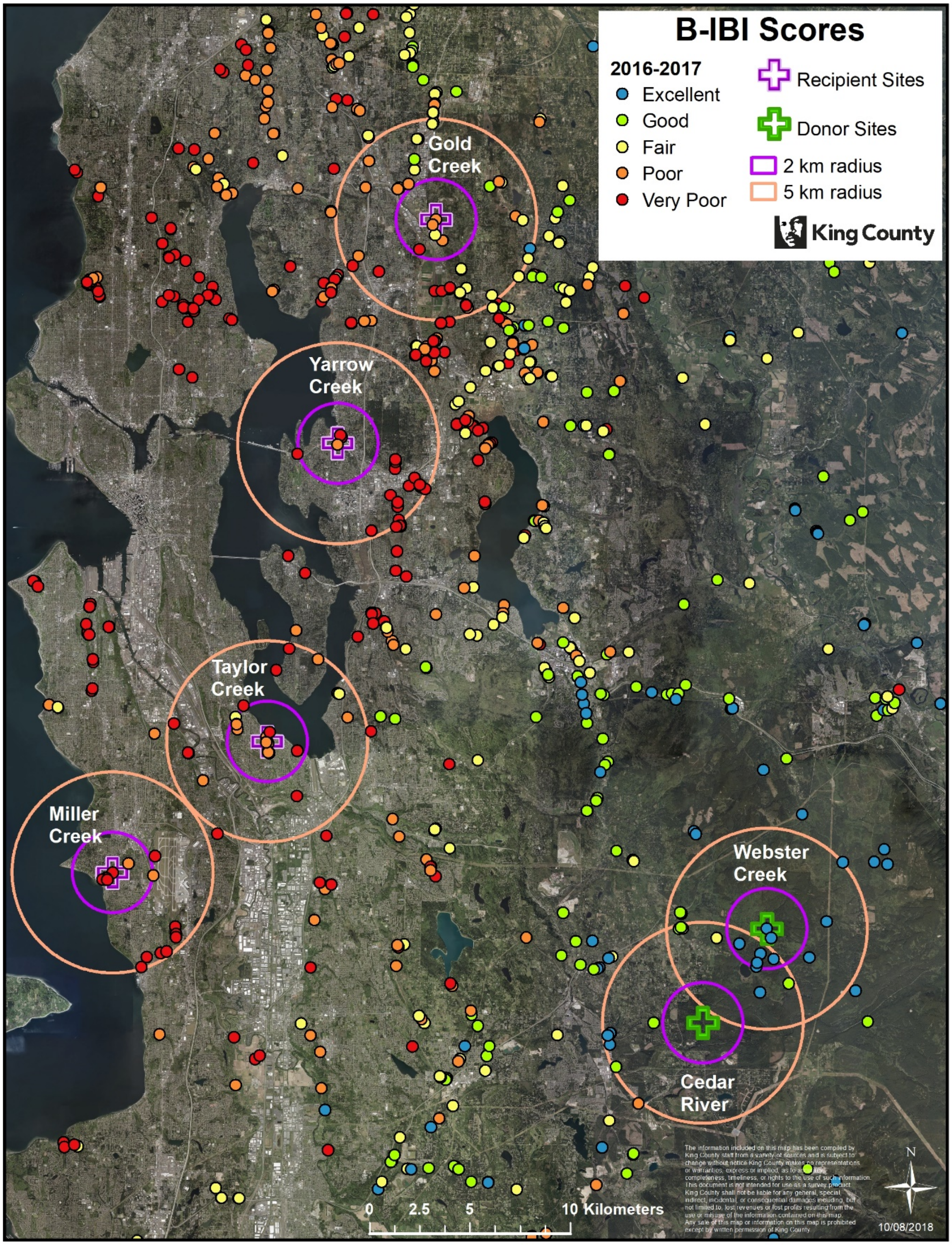


**Figure 1. Study sites and other B-IBI sites throughout the region. B-IBI sites are categorized (very poor to excellent) based on their average score from samples collected in 2016 and 2017.**

Recipient streams were selected in part because their distance from potential sources of colonists was generally greater than 5 km (Figure 1), and their B-IBI scores were lower than expected given the urban development in their basin (Figure 2). We selected sites that typically scored far below their estimated "biological potential" (Figure 2). Paul and others (2009) described "biological potential" as the upper limit of possible scores given the constraints of urban development in the basin and the stressors that are associated with urban development (Walsh et al. 2005). They defined this as the 90th quantile regression line (Figure 2), and they proposed that sites far below this line likely have greater potential for recovery compared to sites that are at or above the line.

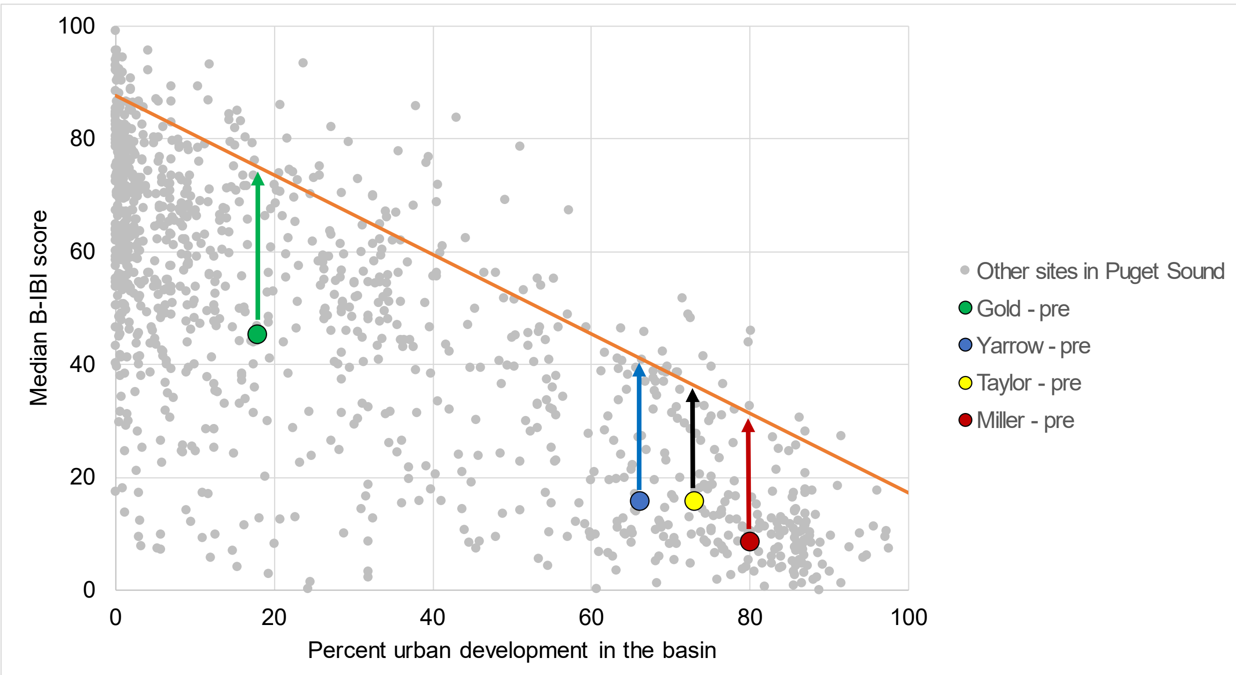


**Figure 2. Median B-IBI scores at sites across Puget Sound, and mean scores at recipient sites pre-seeding (2012–2018). The orange line represents the 90th quantile regression based on Puget Sound sites (grey dots). The arrows represent the difference between the pre-seeding score and 90th quantile line.**

Each of the recipient sites had previously had some stormwater controls implemented, local habitat conditions had been restored, or the condition of the watershed indicated in-stream conditions were better than what the current B-IBI scores indicated. In the case of Yarrow Creek tributary, the City of Bellevue in 2011 reduced a source of fine sediment upstream by controlling some erosive banks, and in 2015 they removed a culvert to increase fish passage and restored in-stream habitat within the study reach. In Taylor Creek, the City of Seattle has worked for over a decade to reduce stormwater inputs, restore in-stream habitat, and plant native riparian vegetation. Likewise, a variety of stormwater controls have been implemented in the Miller Creek basin over the last twenty years, including wetland restoration and the constructions of stormwater ponds to intercept runoff from SETAC airport. In Gold Creek, there were no restoration or stormwater control actions implemented upstream of the site, but the extent of forest cover in the basin suggested the stream may be able to support more sensitive taxa.

In summary, we selected recipient sites that met these five criteria:

- They lack many sensitive taxa and B-IBI scores are consistently very poor, poor, or fair.
- They are hydrologically disconnected or far from sources of sensitive taxa.
- Instream and/or stormwater management actions in the basin have been implemented to improve stream conditions, and yet B-IBI scores are still well below the expected biological potential.
- The cities or agencies involved in managing the recipient creek were willing to have Cedar River macroinvertebrates translocated to the site.
- The recipient sites were within the same larger watershed (WRIA 8) or an adjacent watershed (WRIA 9), as the donor sites (WRIA 8). This was important for ensuring translocated taxa were likely within their historic range.

Donor sites were selected because they support an abundance of sensitive taxa and represent some of the best stream habitat and water quality in the region (see Section 2.0). Sites in the protected portion of the Cedar River watershed are typically characterized as excellent (B-IBI>80) and have exceptionally high species diversity. There are also no known invasive species or pathogens present that could be inadvertently introduced to the recipient streams (personal communication, Linda Rhodes and Sarah Morley of the Northwest Fisheries Science Center).

# 2.0 SEEDING METHODS

## 2.1 Basket deployment

Colonization baskets were deployed on 7/16/2018, in Webster Creek and the main stem of the Cedar River. Baskets measured 15” × 12” × 4” (L×W×D), and each was filled with cobble, gravel and woody debris from the site and nestled within the benthos in a fast-flowing part of the stream. A nine-person crew deployed 73 baskets in each donor stream within about a six-hour time frame (Figure 3). The baskets were deployed for over six weeks and remained submerged for the duration.

**Figure 3. Staff deploying colonization baskets in Webster Creek on July 16, 2018.**

## 2.2 Basket retrieval and transport

Staff carefully retrieved baskets to ensure the macroinvertebrates associated with them survived the collection and transport process. To retrieve a basket, a D-net (500-µm mesh) was placed directly downstream of the basket to collect any dislodged individuals. The basket was then lifted and immediately placed into a large bin that contained a gallon bag of ice covered with thick paper towels (Figure 4). The substrate beneath the basket placement area was gently disturbed to wash additional macroinvertebrates from that area into the D-net. The D-net contents were then placed in the same bin.

**Figure 4. Staff retrieving a colonization basket from Webster Creek on September 4, 2018.**

On the first retrieval day (8/28/2018), a nine-person crew collected 17 baskets from each donor site and transported them to Gold Creek. All rocks, detritus and macroinvertebrates in the bins were carefully distributed among riffles in Gold Creek. Staff noted that most macroinvertebrates were alive and active. Staff found tailed frogs and small sculpin in a few bins which were returned (alive) to Webster Creek the following day. Staff repeated the basket retrieval and transport process for Taylor Creek on 9/4/2018, Yarrow Creek tributary on 9/5/2018, and Miller Creek on 9/7/2018. Seventeen baskets from each of the donor sites were moved to each of the recipient sites. To minimize the risk of unintentionally transporting organisms from recipient sites back to donor sites, all sampling gear, including nets, waders, and boots, were thoroughly cleaned, and then frozen overnight after each field day.

On the first retrieval day, staff also collected five randomly selected reference baskets from each donor stream to quantify the number of each macroinvertebrate taxon per basket. Individual reference baskets were processed separately, and macroinvertebrates were shipped to the taxonomic lab for identification and enumeration. Finally, staff weighed the washed rocks from three of the reference baskets, and estimated each basket contained approximately 28 lbs. of rocks.

Additional details regarding the study rationale, study sites, methods, and quality control and quality assurance plans are described in the Quality Assurance Project Plan (QAPP; King County 2018) developed for the project. In the QAPP, we listed Walker Creek as one recipient creek, but that site was changed to Miller Creek because stream conditions and access were better in Miller Creek.

# 3.0 ASSESSING DIVERSITY AT RECIPIENT SITES PRE- AND POST-SEEDING

This section describes two important steps: 1) the process used to assess which taxa were present at recipient or nearby sites *before* new taxa were added, and 2) the process used to assess if taxa present a year after seeding (in 2019) were new to the stream. These are critical steps, because determining which taxa had successfully established in the recipient streams requires confidence in knowing which taxa were added and which were already present. In addition, we describe how B-IBI scores are calculated and examine how new taxa may or may not affect B-IBI scores.

## 3.1 Establishing which taxa were present in the recipient streams before seeding

Using macroinvertebrate data downloaded from the Puget Sound Stream Benthos database (https://benthos.kingcounty.gov/), we compiled a list of all unique taxa present in each recipient stream prior to seeding. To ensure the list was as complete as possible, we considered data from all samples collected from the recipient site and any sites within the same subbasin (e.g., sites on all tributaries of Taylor Creek were included). For some streams, multiple sites along the stream have been sampled for many years and the number of unique taxa found in the stream is high (e.g., Miller Creek, Table 2). For other sites, the number of sites and sampling frequency is lower (Table 2). To characterize Miller Creek, taxa lists for sites in the Walker Creek basin were also included because portions of those streams are less than 1 km from each other. A list of sites reviewed as part of this process is included in Appendix A.

**Table 2. Number of sites, years of record, and number of samples reviewed to identify unique taxa associated with each stream prior to seeding.**

| Variable | Gold Creek | Taylor Creek | Yarrow Tributary | Miller Creek |
|---|---|---|---|---|
| Number of sites sampled in stream or subbasin | 2 | 9 | 3 | 8 |
| Years of record | 2002 - 2018 | 1994 - 2018 | 2001, 2013, 2016, 2018 | 2003 - 2018 |
| Number of samples reviewed to generate pre-seeding taxa list | 26 | 77 | 4 | 92 |
| Total number of unique taxa found in stream or subbasin | 150 | 149 | 72 | 176 |

The pre-seeding taxa lists included data from samples collected at each site within a week prior to seeding. We used these samples to confirm pre-seeding conditions and community composition immediately before new taxa were added. The samples were collected in late August or early September to coincide with the timing of past sampling events. Staff collected benthic samples using the standard King County method (King County 2020). At each site, staff use a Surber sampler (500-µm mesh) to collect 8, 1 $ft^2$ samples across multiple riffles, which are composited and preserved with 95%, denatured ethyl alcohol.

## 3.2 Determining which taxa were added and which taxa persisted

Reference basket macroinvertebrate data were used to estimate the number and types of taxa added to the recipient streams. The taxonomic lab, Rhithron Associates Inc., identified and counted all individuals in each of the ten reference baskets (Rhithron Associates 2017 and 2018). These data were then compared to the unique taxa list compiled for each recipient stream.

For taxa found in the reference baskets, we established a decision framework to determine whether taxa found in recipient streams post-seeding were new or possibly new to the site (Figure 5). Table 3 includes the number of new or possibly new ("inconclusive but suggestive" and "possibly suggestive") taxa added to each recipient stream. A complete list of taxa, the average number of individuals per basket, and whether they are considered new to a site are listed in Appendix B.

Some taxa, including midge larvae (flies in the Chironomidae family), worms, and mites, were ignored and assumed to be "not informative" because we could not ensure they were present in the recipient streams prior to seeding. Taxa in these groups were not identified to a finer taxonomic resolution in samples collected before 2012, and in years since, there were often unidentified individuals (e.g., left at the family level for Chironomidae) in samples that make it difficult to assess if taxa present in 2019 were new.

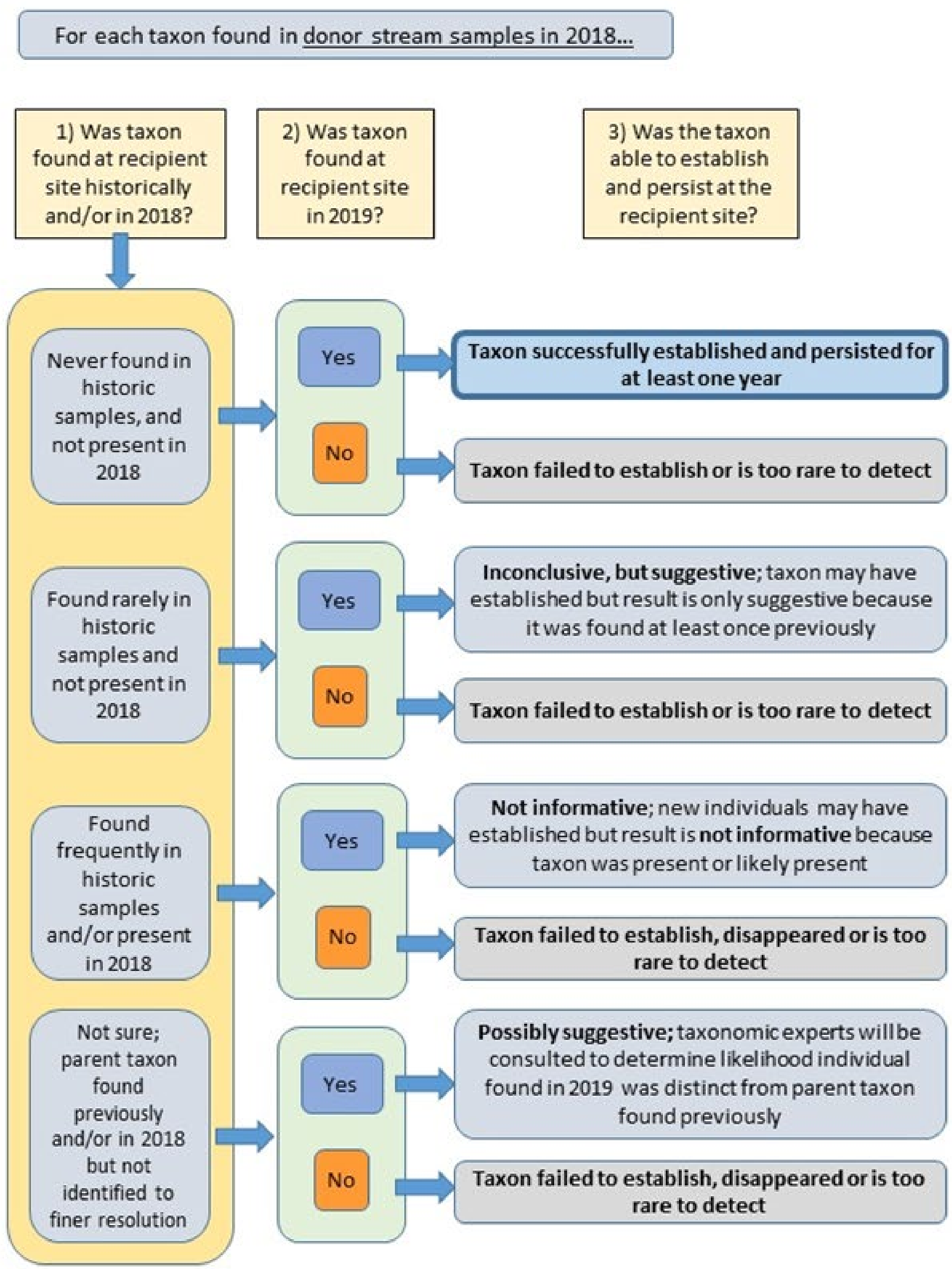


**Figure 5. Decision framework used to determine if taxa found in recipient streams post-seeding were new, or possibly new to a site.**

**Table 3. Number of taxa added to each recipient stream that would be considered new, possibly new, or not new if found in 2019, based on framework outlined in Figure 5.**

| Decision | Gold Creek | Taylor Creek | Yarrow Tributary | Miller Creek |
|---|---|---|---|---|
| New taxon: successfully established for one year | 47 | 56 | 80 | 39 |
| Possibly new: inconclusive but suggestive | 16 | 11 | 0 | 11 |
| Possibly new: possibly suggestive | 10 | 16 | 7 | 24 |
| Not informative (not new) | 112 | 102 | 98 | 111 |

## 3.3 Determining if new taxa will affect B-IBI scores

B-IBI scores represent the sum of ten metric scores, and seven of the ten metrics are based on counts of unique taxa (i.e., taxa richness). To determine if new taxa in a sample might influence B-IBI scores, we reviewed the B-IBI metrics and examined how the addition of one or more taxa may affect the metric and overall scores. Understanding the degree to which specific taxa impact B-IBI scores is important because we want to know how many new taxa at a site would be needed to improve B-IBI scores.

Due to the limited number of samples (single post-seeding sample per site) we could not conduct statistical testing, but we assumed differences of at least 15 points between pre and post-seeding B-B-IBI scores may suggest scores had changed more than would be expected by chance. The average standard deviation (SD) between 2018 and 2019 B-IBI scores from other King County sites is 7.2 points (based on 133 sites). Based on this measure of variability score improvements of more than 15 points (>2 SD) may represent significant differences between pre and post-seeding samples.

Each B-IBI metric can have a value of 0 to 10, which is calculated by a linear equation specific to that metric. For the seven richness-based metrics, we calculated how addition of a new taxa would change the score. For example, for each new unique taxa present in a sample, the taxa richness metric score would increase by 0.3 points. For some taxa that are counted in more than one metric, the influence of one new taxa can be greater. For example, the presence of one new stonefly taxon, *Pteronarcys princeps,* could increase the stonefly richness metric by 1.4 points and the long-lived taxa richness metric by 1.3 points, as well as the taxa richness metric by 0.3. Thus, the presence of *Pteronarcys princeps* in a sample could increase the B-IBI score by 3 points. (Note: There are upper limits for each of the ten metrics. For example, if 56 or more taxa are present in a sample, the taxa richness metric score would be 10 and presence of new taxa would not increase the score further.) The presence of new taxa can also influence scores for three other metrics (percent dominant, percent predator, and percent tolerant), but the contribution of an individual taxon will vary depending on sample composition.

On average, the presence of one new taxon would increase a B-IBI score by ~1.3 points, with some taxa adding as few as 0.3 points and others up to 5 points. Therefore, to improve the B-IBI score by 15 or more points, we estimate approximately 11 or 12 new taxa would need to be present.

More information about the scoring system and how metrics are calculated is available on the PSSB web site (https://benthos.kingcounty.gov/BIBI-Scoring-Types.aspx).

# 4.0 RESULTS AFTER ONE YEAR POST-SEEDING

There were clear signs of initial success one year after seeding. Although most taxa added from donor sites were not found in recipient sites, at least one new or possibly new taxon was found in each recipient stream in 2019, one year after seeding. In addition, B-IBI scores increased appreciably in Gold and Taylor Creeks, due in part to the presence of new taxa. 2019 B-IBI scores in Gold and Taylor creeks were much closer to their biological potential (as defined by the 90th quantile regression, Paul et al. 2009; Figure 6). In contrast, scores in Yarrow tributary and Miller Creek decreased slightly (Figure 6) despite the presence of at least one new taxon in those sites. Scores at these sites remained well below their biological potential (Figure 6). Additional results for each stream are provided in the sections below.

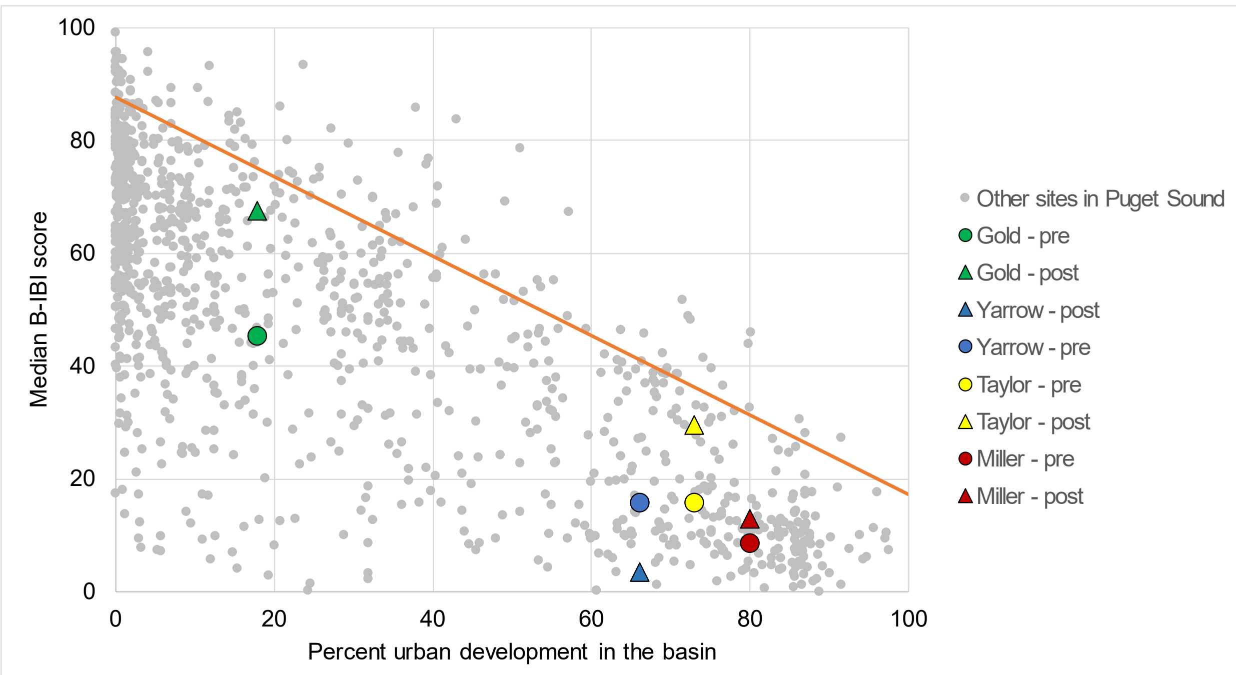


**Figure 6. Median B-IBI scores at sites across Puget Sound, and scores at recipient sites, pre (2012-2018) and post (2019) seeding. The orange line represents the 90th quantile regression based on Puget Sound sites (grey dots).**

## 4.1 Gold Creek

The results from Gold Creek are the most intriguing. The post-seeding Gold Creek B-IBI score (67.6) was 22 points higher than the average pre-seeding score (45.3; Figure 6 and 7) and nearly 37 points higher than the 2018 score immediately before seeding (30.8). The B-IBI score improved in part because of the seeding; we found several new or possibly new taxa in 2019. However, the B-IBI score also increased because we found several other taxa in the 2019 sample that had previously been rare. These taxa were in the donor baskets, and it is possible seeding enhanced these populations. Alternatively, the presence of these rare taxa in 2019 could be due to natural variability. To put this score increase in context, of all King County sites sampled in both 2018 and 2019 ($n_{sites}$=133), the observed increase at the Gold Creek site was the greatest.

We should note that Gold Creek results were not affected by subsampling. Rhithron counted and identified 544 individuals in the initial subsample and identified an additional 659 individuals when they processed the remainder of the sample. No new, or possibly new, taxa were present in the whole count that were not also present in the subsample. The scores discussed below are based on the initial subsample, with scores generated by PSSB based on a 500-count subsample of the data.

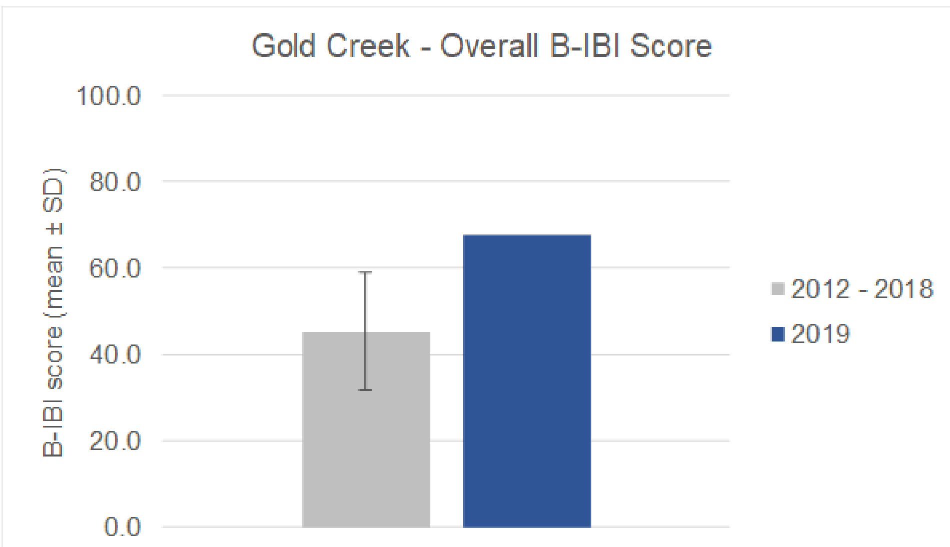


**Figure 7. B-IBI scores for Gold Creek samples, collected pre-seeding from 2012 – 2018 (n=7) and one year post-seeding in 2019 (n=1).**

Based on the decision criteria (Figure 5), we consider one taxon "new" and two more "inconclusive, but suggestive." The new taxon is a long-lived stonefly, *Pteronarcys princeps* (Plecoptera, Pteronarcyidae) that had not been found in Gold Creek prior to 2019. Two individuals were present in the sample, and both were estimated to be 3 years old (based on size; Townsend and Pritchard, 1998). Thus, they had survived a year in Gold Creek but had not originated there.

We found two additional taxa in the Gold Creek sample that may have been successful transplants. These include a caddisfly, *Wormaldia* (Trichoptera, Philopotamidae), that had been collected only once before in 2011, and a predaceous fly, *Glutops* (Diptera, Pelecorhynchidae), that was collected once in 2006.

The presence of these new taxa, in addition to the rare taxa, and the increased post seeding B-IBI score, indicate Gold Creek is able to support a much more diverse community than previous samples had indicated. These results suggest that a lack of colonists may explain why taxa richness in Gold Creek has been lower than expected. In addition, the presence of many rare taxa in the 2019 sample may also indicate that conditions are improving and populations already in the system may thrive and become more common if conditions remain suitable.

Seven of the 10 B-IBI metric scores for Gold Creek were higher in post-seeding (2019) samples compared to pre-seeding sample scores (collected 2012 – 2018); most scores were higher by several points (Figure 8). A brief description of how the pre- and post-seeding scores compare for each metric is presented below.

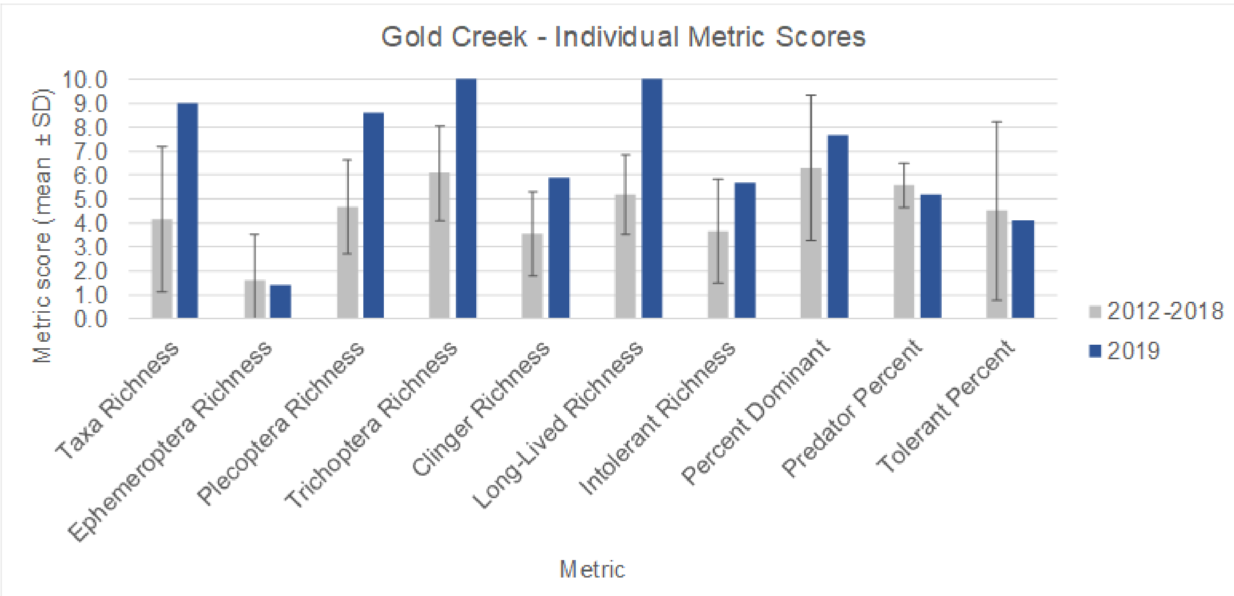


**Figure 8. Metric scores forGold Creek samples, pre-seeding (2012-2018, n=7) and post-seeding (2019; n=1).**

<u>Taxa Richness</u> – Overall taxa richness was substantially higher in 2019 (53 taxa) compared to the previous 2012–2018 average (39.1 taxa). This difference represents a nearly 5-point increase in the metric score (Figure 8). However, the presence of three new or possibly new taxa only partly explains the increase; their presence increased the taxa richness score by approximately 1 point. The presence of many other taxa, found in 2019 but only rarely in previous samples, is the primary reason for the increase in the taxa richness metric score.

<u>Ephemeroptera (mayfly) Richness</u> – No new mayflies were found in Gold Creek in 2019 and mayfly richness remained low at two taxa (Ephemeroptera Richness score of 1.4; Figure 8).

<u>Plecoptera (stonefly) Richness</u> – As mentioned above, one new stonefly taxon, *Pteronarcys princeps*, was found in Gold Creek. This helps explain in part the increase in taxa richness post-seeding (7 vs. 4.3 taxa), but we also collected other relatively uncommon stonefly taxa in 2019 as well. Overall the Plecoptera richness metric score increased nearly 4 points in

2019 compared to previous years (Figure 8), 1.4 of which can be attributed to the presence of *Pteronarcys princeps*.

Trichoptera (caddisfly) Richness – Overall caddisfly richness in 2019 was higher than average between 2012 and 2018 (11 vs. 5.9 taxa). Other than *Wormaldia*, all other taxa had been found at least once since 2012, though some had been found only once or twice. The Trichoptera Richness score in 2019 was10, but because a score of 10 can be achieved with 9 or more Trichoptera taxa, *Wormaldia* did not necessarily contribute to the increased metric score.

Clinger Richness – Clinger richness was higher in 2019 (17 taxa) than in previous years (13 taxa). The increase was in part due to the presence of *Wormaldia* and several other taxa rarely present before 2019 (e.g., *Narpus concolor*, *Cryptochia*, and *Neophylax splendens*). The presence of those four taxa explain the metric score increase from an average of 3.5 to 5.9 in 2019 (Figure 8).

Long-lived Taxa Richness – The presence of several new or previously rare taxa increased the long-lived richness in 2019 to 11, compared to the previous average of 6.1. Samples with ten or more long-lived taxa receive a score of 10 for this metric. The new and previously rare taxa include *Pteronarcys princeps*, *Glutops*, *Narpus concolor* (found once since 2012), and *Cryptochia* (not seen since 2011).

Intolerant Taxa Richness – Four intolerant taxa were found in 2019, which is higher than the previous average of 2.6. Three of the four taxa are typically found in Gold Creek samples (*Yoraperla*, *Hesperoperla pacifica*, *Ironodes*), but one, *Neophylax splendens*, had been found in only 2 of the 25 historic samples. The presence of *Neophylax splendens* increased the metric score by 1.4 points.

Percent Dominant – In 2019, the percent dominant score was slightly higher than the previous average, although it is unlikely due to seeding. The three most abundant taxa in 2019 have been dominant in previous Gold Creek samples.

Percent Predator – Seeding did not appear to change the relative abundance of predators in Gold Creek (Figure 8). The possible new fly, *Glutops*, is a predator; however, because this metric is based on the overall relative percent predators, the presence of this one individual did not affect the metric score.

Percent Tolerant – The percent tolerant score was slightly lower in 2019 compared to the previous average, indicating seeding did not alter the relative abundance of especially tolerant taxa.

## 4.2 Taylor Creek

The 2019 Taylor Creek B-IBI score was 16.1 points higher compared to 2018 (29.6 vs 13.5), and13.7 points higher compared to the average pre-seeding samples (15.9) (Figures 6 and 9). However, it is unclear how much of that improvement was due to seeding. In 2019, there were three taxa found that were possibly new to Taylor Creek. These new taxa contributed to the increased score but did not explain it entirely.

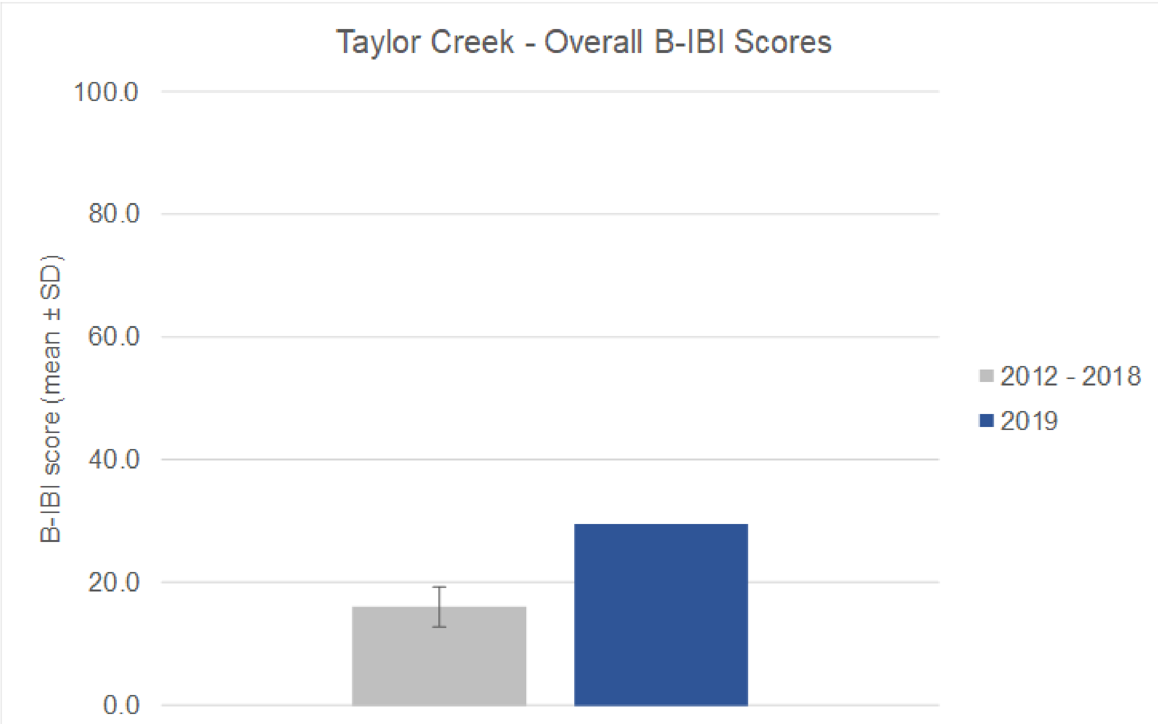


**Figure 9. The B-IBI scores for Taylor Creek samples, collected pre-seeding from 2012 – 2018 (n=7) and one year post-seeding in 2019 (n =1).**

One possibly new taxon was a long-lived beetle, *Zaitzevia* (Coleoptera, Elmidae), that is a clinger. In 77 previous samples, two beetle larvae were identified only to family (Elmidae), thus it is unclear if they were *Zaitzevia* or another more common taxon, *Lara*. However, given how common *Lara* is, we suspect the unidentified individuals were *Lara*, and the *Zaitzevia* collected in 2019 is a new taxon.

Although we did not account for most midges in this analysis, an intriguing midge larva was found in Taylor Creek. The midge, *Krenopelopia* (Diptera, Chironomidae), appears to be new to Taylor, although it is unclear if it was added by seeding. This taxon has never been found in Taylor Creek, but was not found in the reference seeding baskets. This midge was found in Webster Creek in 2016, indicating that it could have been present in the donor baskets, but not enumerated in the subset of baskets we analyzed.

A third possible new taxon, a caddisfly, *Glossosoma* (Trichoptera, Glossosomatidae), was found when the whole sample was processed, but was not present in the initial 500-count sample. This taxon was present in 5 of the 77 previous samples. Thus, it is possible the *Glossosoma* found in 2019 were not from seeding, but rather originated from a small population that existed in Taylor Creek. Because the one *Glossosoma* was found in the whole sample, and not the subsample used to calculate the B-IBI, it does not affect the B-IBI score or the metrics discussed below.

Other than *Glossosoma*, no other new or possibly new taxa were found in the whole sample that were not also found in the 500-count sample.

The post-seeding B-IBI score and the presence of some new taxa suggest Taylor Creek may be able to support a more diverse community than previous B-IBI scores suggest. Eight of the 10 B-IBI metric scores for Taylor Creek were higher post-seeding (2019) compared to pre-seeding samples (collected 2012–2018), though it is unclear how much can be attributed to seeding versus natural variability (Figure 10). A brief description of how the pre- and post-seeding scores compare for each metric is given below.

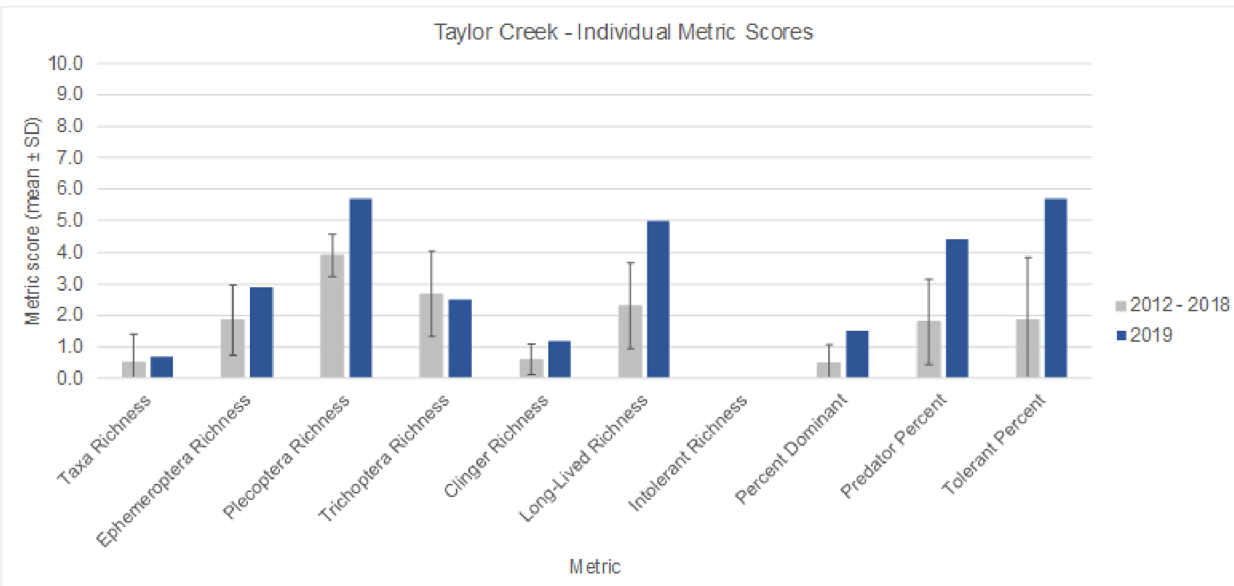


**Figure 10. Metric scores for Taylor Creek samples, pre-seeding (2012-2018, n=7) and post-seeding (2019) (n=1).**

<u>Taxa Richness</u> – The total count of unique taxa did not increase substantially post-seeding (29 post vs. 27.7 pre), despite the presence of *Zaitzevia* and *Krenopelopia*. The post-seeding taxa richness and metric score are well within the variation observed in pre-seeding samples (Figure 10).

<u>Ephemeroptera (mayfly) Richness</u> – No new or rare mayflies were found in post-seeding samples. Although mayfly richness in 2019 (3 taxa) was slightly higher than the average before seeding (2.3 taxa), the three mayfly taxa found in 2019 have been found regularly in previous samples.

<u>Plecoptera (stonefly) Richness</u> – No new or rare stoneflies were found in post-seeding samples. The post-seeding metric score is higher than the pre-seeding score (Figure 10), but all taxa have been routinely found in previous samples though not always in the same year.

Trichoptera (caddisfly) Richness – No new or rare caddisflies were found in post-seeding samples. The three caddisfly taxa found in 2019 were common in pre-seeding samples.

Clinger Richness – The clinger richness score increased by 0.6 points due to the presence of a new beetle, *Zaitzevia*.

Long-lived Taxa Richness – Long-lived taxa richness increased to 6 taxa, from a pre-seeding average of 3.9 taxa and resulted in a 2.3-point increase in the metric score (Figure 10). Some of this increase – 1.3 points – is due to the presence of *Zaitzevia*.

Intolerant Richness – The seeding had no effect on intolerant taxa richness; no intolerant taxa were present before or after seeding.

Percent Dominant – The percent dominant score increased slightly in 2019, but there is no evidence seeding contributed to the increase. The three dominant taxa in 2019 were abundant in pre-seeding samples.

Percent Predator – Percent predators in 2019 was much higher than the previous average (Figure 10), but it is unclear if this was due to seeding. The new midge, *Krenopelopia* is a predator, but because we only found one individual, its presence is not likely to affect this metric score. The increased score was most likely due to the unusually high number of *Sweltsa* stoneflies. In previous Taylor Creek samples, on average only 1.7 *Sweltsa* were present per sample. In contrast, 42 *Sweltsa* were present in the 2019 500-count sample. *Sweltsa* were among the taxa added to Taylor Creek, but because they had been found in recent samples, we do not know if the increase was due to seeding or natural variation in the Taylor Creek population.

Percent Tolerant – The percent tolerant score was also higher in 2019, but it is unclear if seeding affected the score.

## 4.3 Yarrow Creek Tributary

There was one sign of success in Yarrow Creek tributary: we found a new stonefly species (*Pteronarcys princeps*) in the 2019 post-seeding sample. This stonefly species was not found in the initial subsample (n=587 individuals) but was found when the whole sample was processed (2140 additional individuals). Based on its large size, we know that it did not originate in Yarrow Creek, but had survived a year in the stream. If this stonefly population is able to persist and reproduce, it could eventually influence the B-IBI score. However, because it was not found in the initial subsample, it was not considered when calculating the 2019 B-IBI score.

No other new or possibly new taxa were found in the subsample or whole sample. The B-IBI score and most taxa richness measures were lower after seeding than before (Figures 11 and 12), likely due to natural variation. Because seeding did not influence taxa richness and the B-IBI score, we do not discuss individual metrics in any additional detail.

Although finding one new stonefly is encouraging, the post-seeding B-IBI score suggests conditions in Yarrow Creek tributary remain very poor. The lack of nearby colonists is likely only one of several factors limiting recovery in this stream.

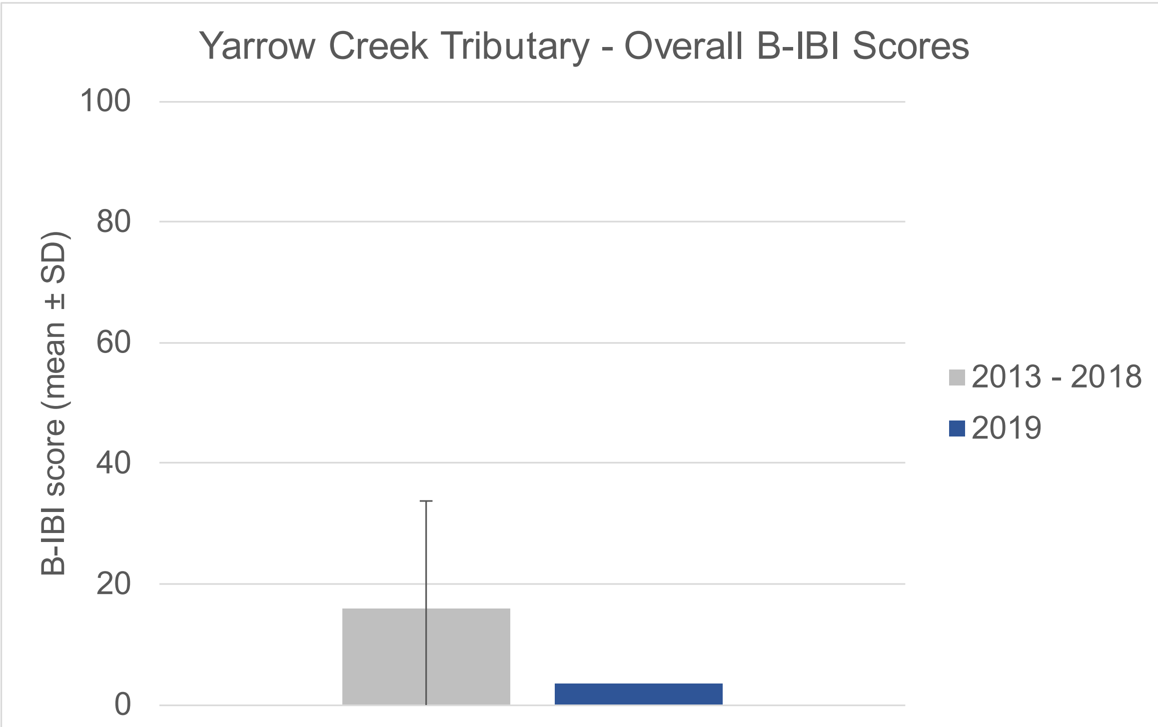


**Figure 11. The B-IBI scores for Yarrow Creek tributary samples, collected pre-seeding from 2013–2018 (n=3) and one year post-seeding in 2019 (n=1).**

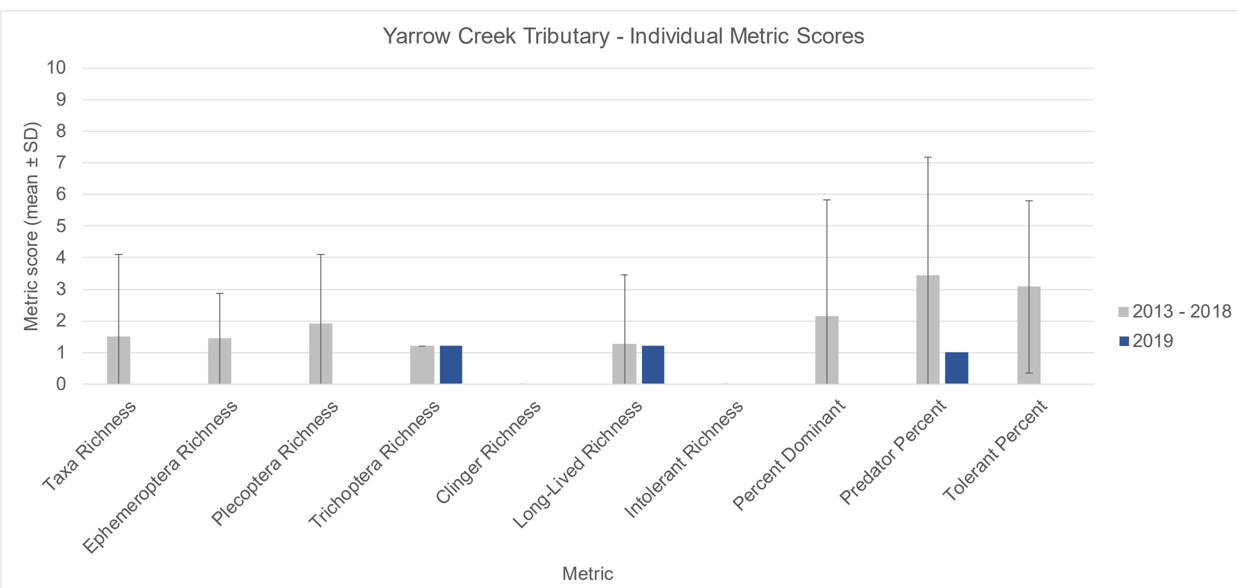


**Figure 12. Metric scores for Yarrow Creek tributary samples, pre-seeding (2013-2018, n=3) and post-seeding (2019; n=1).**

## 4.4 Miller Creek

One new and a few possibly new taxa were found in Miller Creek post-seeding, but these taxa did not substantially increase the B-IBI score (Figures 6 and 13). The one new taxon, a mayfly, *Diphetor hageni* (Ephemeroptera, Baetidae) was not found in the initial subsample (n=544 individuals) but was found when the whole sample was processed (3274 additional individuals). Because it was not found in the initial subsample, it was not considered when calculating the B-IBI score.

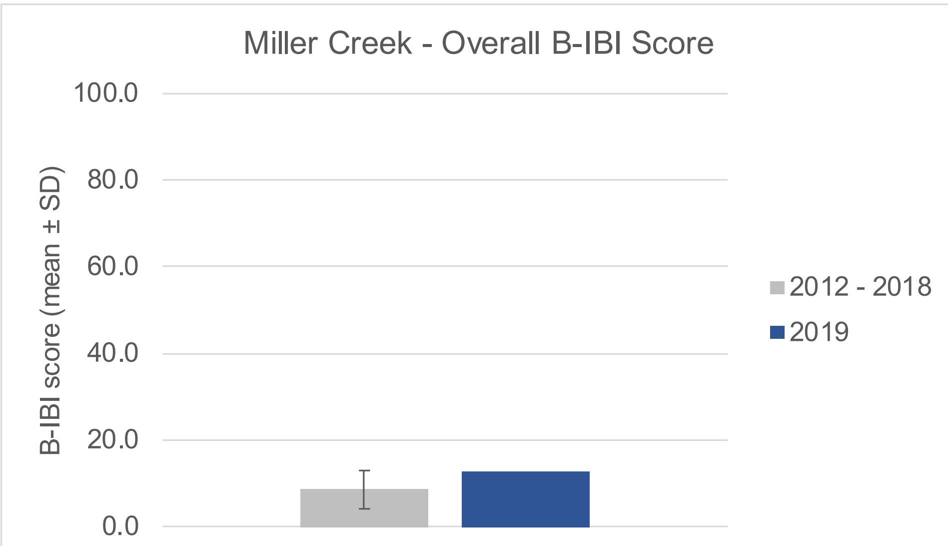


**Figure 13. The B-IBI scores for Miller Creek samples, collected pre-seeding from 2012-2018 (n=7) and one year post-seeding in 2019 (n=1).**

Several additional taxa were found in 2019 that we suspect had not been present before or had been rare. One likely new taxon is the fly midge, *Potthastia Gaedii group* (Diptera, Chironomidae). This midge had not been found in samples from 2012-2018; however, we cannot be sure if it was there previously (we started identifying Chironomidae to genus or species in 2012). Other rare taxa found in 2019 include a stonefly in the Leuctridae family, which had only been found in 3 of 91 samples from Miller and nearby Walker creeks. Likewise, we found a rare crane fly, *Antocha monticola* (Diptera, Tipulidae) in 2019 that had only been found in 2 of 91 previous samples.

Although it is encouraging to find these potentially new and rare taxa, they did not have a large effect on 2019 metric scores (Figure 14). Their presence increased taxa richness somewhat (33 taxa in 2019 vs. 25 in 2018), and presence of the crane fly, *Antocha monticola*, increased the clinger score by 0.5 points. The Trichoptera Richness score was not likely affected by seeding; all caddisfly taxa found in 2019 had been found in previous samples.

The presence of the new and rare taxa found in 2019 suggest Miller Creek may be able to support greater taxa richness than it has in the past. However, the very poor B-IBI score and the fact these new taxa did not increase the metric scores suggests a lack of colonists is likely only one of many factors currently limiting recovery in Miller Creek. Despite efforts to control stormwater, a recent study indicates water quality remains degraded in Miller Creek (Peter et al. 2020), and this may limit the establishment of sensitive taxa (e.g., McIntyre et al. 2015).

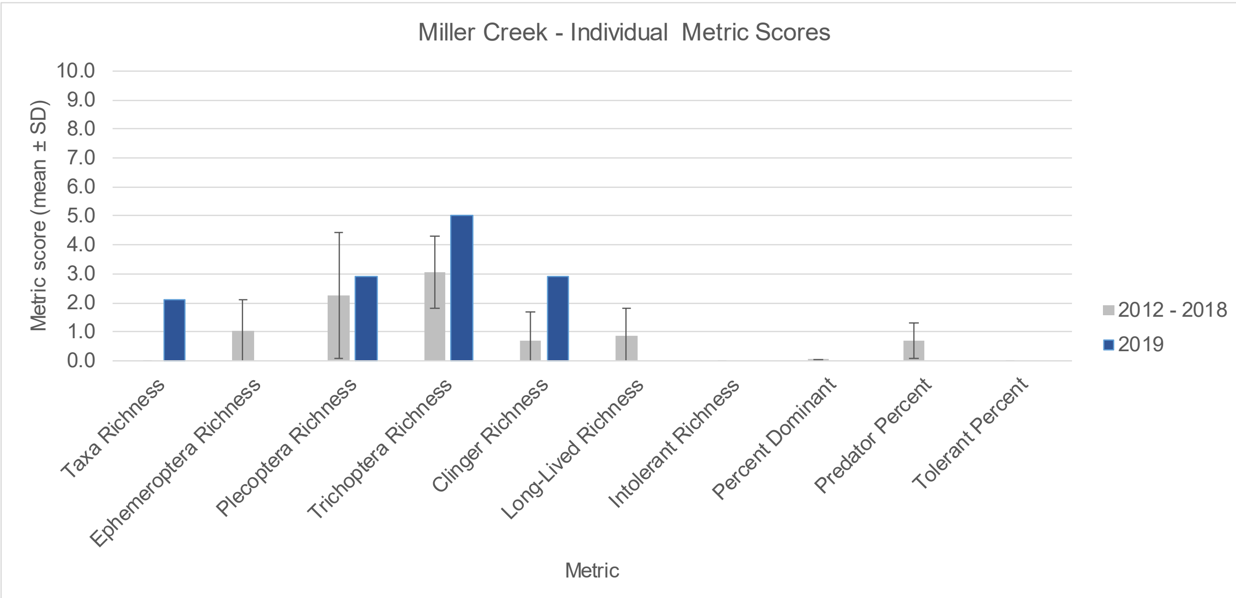


**Figure 14. Metric scores for Miller Creek samples, pre-seeding (2012-2018, n=7) and post-seeding (2019; n=1).**

# 5.0 CONCLUSIONS AND FUTURE RECOMMENDATIONS

The key conclusion from this study is that small, isolated streams that are disconnected from a source of colonists may benefit from bug seeding. Initial results suggest bug seeding was successful in reintroducing several macroinvertebrate taxa, thereby jump-starting the recovery of macroinvertebrate communities in some underperforming streams. Although several more years of data will be needed to determine if the new taxa persist, their survival and persistence for one-year post-seeding illustrates that stream conditions may be suitable for long-term success. These finding offers hope, even for some highly urbanized streams (Figure 6).

The key recommendation from this study is that bug seeding is a relatively easy and inexpensive action that is worth trying, if site conditions are appropriate. Bug seeding, like any species reintroduction, should be done with caution (see Jourdan et al. 2018). Care must be taken to ensure invasive species and diseases are not spread. There must also be a compelling reason to think that the target stream could support a more diverse macroinvertebrate community and the lack of nearby colonists is a limiting factor. However, if done carefully and in an appropriate stream, bug seeding may help accelerate recovery.

Results of this study also revealed that bug seeding will not necessarily restore diverse communities. Most of the added taxa were not found a year after seeding. B-IBI scores improved more than 15 points in two streams, but that outcome was likely only partially due to seeding. Seeding may have enhanced populations of taxa that had been present but were rare, but increased scores may also be due to natural, year to year variability. In streams where few new taxa persisted and scores remained low, current conditions – and not a lack of colonists – may ultimately be limiting recovery. Restoring conditions and natural processes in highly urbanized basins is especially difficult (e.g., Roy et al. 2014, Fanelli et al. 2019). Even if conditions were improved from highly degraded to moderately degraded, they may still be inadequate to support more sensitive taxa.

Bug seeding is therefore an effective tool, regardless of the outcome. If seeded taxa persist, recovery is jump-started, and streams may be able to reach their biological potential. If seeded taxa do not persist, we are more confident that dispersal of colonists is not the primary cause of low B-IBIB scores, and additional restoration actions are needed before we should expect recovery. Some taxa seeded to the four recipient streams persisted while others did not. By tracking which taxa persist, we can better understand the sensitivities of individual taxa and the conditions that support or prevent them from thriving.

In a restoration context, seeding can be used at various stages to inform management decisions regarding stream restoration. Initially, if B-IBI scores are low and indicate restoration is needed, a stressor identification analysis should be done to identify what conditions are impaired and in need of restoration. If that analysis indicates stressors are not present, and it is unclear what restoration actions are needed, bug seeding may be a cost-effective option to try before further investigation is initiated. Seeding can be used to test whether the stream—as is—has the capacity to support a more diverse community. If a stream is restored, bug seeding can be used to initiate rapid recovery as soon as habitat conditions are suitable (after disturbances due to construction have dissipated). Alternatively, managers may wish to wait and see if natural recovery occurs after restoration, and then only seed if no increase in B-IBI scores is observed after several years. As discussed above, these strategies apply only if a stream is reasonably isolated from a source of colonists. If diverse communities persist upstream or nearby (within 1 or 2 km), natural colonization is likely sufficient for recovery.

In addition to recommending bug seeding as a possible recovery tool, while being realistic about limitations, we recommend the following if considering a bug seeding project:

- Carefully select recipient streams; they should be isolated and support fewer taxa than expected based on their biological potential.
- Collect a sufficient number of pre-seeding samples (ideally multiple samples over several years) to ensure you can determine which taxa were present in the stream before seeding and which were added.
- Identify a source, or a healthy donor stream, that is ecologically similar to the recipient stream.
- Collect and transport macroinvertebrates in a safe and careful way, to ensure a high survival rate.
- Be extremely careful not to introduce any invasive species or pathogens to either the donor or recipient streams.
- After seeding, monitor the macroinvertebrate populations and B-IBI scores annually for at least five years to determine if new taxa have persisted.

Stream restoration is typically an expensive and laborious process, often focused on improving in-stream habitat conditions but rarely leading to biological recovery (Palmer et al. 2010). As stream ecologists work to understand what limits recovery and explore better restoration methods, bug seeding has been proposed and is starting to be applied in some situations (e.g., Dumeier et al. 2020, Morley et al. 2018, Witt 2017). We must track the success and failure of these projects to better understand if and when dispersal may be limiting recovery, or when other factors may be limiting. This information will improve how we restore streams and measure restoration effectiveness. It will also improve our understanding and use of the B-IBI indicator. If bug seeding confirms that connectivity and proximity of source populations affect taxa richness—and therefore B-IBI scores—this information will help us explain some of the variability in B-IBI scores not explained simply by conditions in the contributing catchment. Thus, additional seeding projects could help stream communities recover and improve the tool we use to monitor them.

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# Appendix A: Site Codes

To generate a list of all known taxa found pre-seeding at each site, we reviewed all available data from each recipient site. We also included data from additional sites on the same creeks, and for Miller Creek we included sites on nearby Walker Creek. All available data from each of the sites listed below were downloaded from the Puget Sound Stream Benthos (PSSB) database and reviewed to generate a complete taxa list for each recipient site.

**Table 4. PSSB site codes for sites included in review of taxonomic diversity in each recipient stream prior to seeding.**

| Location | Gold Creek | Taylor Creek | Yarrow Creek Tributary | Miller Creek |
|---|---|---|---|---|
| Recipient site | YarrowWestTribBelRM0.2 | 08WES1340 | 08SAM2865 | Miller_SWSSD |
| Other sites on same stream or on a nearby stream | A499 Yarrow<br>YarrowEastTribBelRM0.3 | TA01<br>TA02<br>TA03<br>TAEF6250<br>TAMA_MOUTH<br>TAMA7468<br>TAWF4847<br>WAM06600-065043 | E1118 | Miller_Cove<br>Miller_PortS<br>Miller13thAv<br>MillerCove2<br>Walker_PortS<br>WalkerPreserve<br>WalkerSwim |

# Appendix B: Taxa Added to Recipient Streams and Determination of Status

The following table includes the complete list of taxa identified in reference baskets collected from the two donor streams, Webster Creek and the Cedar River. The table includes the average number of each taxon found in the five baskets from each donor stream, and then whether each would be new, possibly suggestive (PS), inconclusive but suggestive (IS), or not informative (NI) if found post-seeding in each of the recipient streams. The decision framework is explained in Figure 5 in the main report. All midge larvae (Diptera: Chironomidae) are listed as NI because we did not have sufficient pre-seeding data to determine whether specific midge taxa were present prior to seeding. An asterisk (*) indicates taxon was identified as non-unique in the reference basket samples.

| Order | Family | Genus | Taxa in seeding baskets | Average number in Cedar baskets | Average number in Webster baskets | Estimated number added to each recipient stream | Gold | Taylor | Yarrow | Miller |
|---|---|---|---|---|---|---|---|---|---|---|
| Amphipoda | Crangonyctidae | Crangonyx | Crangonyx | 0.2 | 0 | 3 | NI | NI | NI | NI |
| Basommatophora | Physidae | Physella | Physella | 0 | 0.4 | 7 | New | New | NI | New |
| Basommatophora | Planorbidae | Menetus | Menetus | 0 | 0.2 | 3 | IS | IS | New | New |
| Branchiobdellida | | | Branchiobdellida | 0 | 0.6 | 10 | New | New | PS | New |
| Coleoptera | Amphizoidae | Amphizoa | Amphizoa | 0.2 | 0 | 3 | New | New | New | New |
| Coleoptera | Dytiscidae | Oreodytes | Oreodytes | 0.6 | 0.6 | 20 | New | New | PS | PS |
| Coleoptera | Elmidae | Cleptelmis | Cleptelmis addenda | 0.2 | 0.6 | 14 | IS | NI | New | NI |
| Coleoptera | Elmidae | Heterlimnius | Heterlimnius corpulentus | 2 | 40.8 | 728 | NI | PS | New | NI |
| Coleoptera | Elmidae | Lara | Lara | 0.6 | 0 | 10 | NI | NI | NI | NI |
| Coleoptera | Elmidae | Narpus | Narpus concolor | 0.2 | 0.8 | 17 | NI | NI | New | NI |
| Coleoptera | Elmidae | Optioservus | Optioservus | 0 | 15.6 | 265 | NI | NI | NI | NI |
| Coleoptera | Elmidae | Zaitzevia | Zaitzevia | 0.2 | 5.4 | 95 | New | PS | New | NI |
| Coleoptera | Elmidae | | Elmidae | 0.2 | 2 | 37 | NI | NI | PS | NI |
| Decapoda | Astacidae | Pacifastacus | Pacifastacus leniusculus | 0.2 | 0 | 3 | New | New | New | NI |
| Diptera | Athericidae | Atherix | Atherix | 0 | 0.2 | 3 | New | New | New | New |
| Diptera | Ceratopogonidae | | Ceratopogonidae* | 0.2 | 0 | 3.4 | NI | NI | NI | NI |
| Diptera | Ceratopogonidae | | Ceratopogoninae | 2 | 1.4 | 58 | NI | NI | New | NI |
| Diptera | Ceratopogonidae | | Forcipomyiinae | 1 | 0 | 17 | New | NI | NI | PS |
| Diptera | Chironomidae | Bilyjomyia | Bilyjomyia algens | 0.2 | 0 | 3 | NI | NI | NI | NI |
| Diptera | Chironomidae | Boreochlus | Boreochlus | 0.2 | 0 | 3 | NI | NI | NI | NI |
| Diptera | Chironomidae | Brillia | Brillia | 7.8 | 5.4 | 224 | NI | NI | NI | NI |
| Diptera | Chironomidae | Brundiniella | Brundiniella eumorpha | 2 | 0 | 34 | NI | NI | NI | NI |
| Diptera | Chironomidae | Chaetocladius | Chaetocladius | 0 | 0.2 | 3 | NI | NI | NI | NI |
| Diptera | Chironomidae | | Chironomini* | 0 | 1.4 | 23.8 | NI | NI | NI | NI |
| Diptera | Chironomidae | Conchapelopia | Conchapelopia | 0 | 0.2 | 3 | NI | NI | NI | NI |
| Diptera | Chironomidae | Corynoneura | Corynoneura | 1.2 | 3.8 | 85 | NI | NI | NI | NI |
| Diptera | Chironomidae | Cricotopus | Cricotopus* | 0 | 2.8 | 47.6 | NI | NI | NI | NI |
| Diptera | Chironomidae | Cricotopus | Cricotopus (Cricotopus) | 0 | 38.6 | 656 | NI | NI | NI | NI |
| Diptera | Chironomidae | Cricotopus | Cricotopus (Isocladius) | 0 | 0.2 | 3 | NI | NI | NI | NI |
| Diptera | Chironomidae | Cricotopus | Cricotopus bicinctus | 0 | 9.8 | 167 | NI | NI | NI | NI |
| Diptera | Chironomidae | | Diamesinae* | 0.2 | 0 | 3.4 | NI | NI | NI | NI |
| Diptera | Chironomidae | Eukiefferiella | Eukiefferiella | 1.2 | 248.4 | 4243 | NI | NI | NI | NI |
| Diptera | Chironomidae | Micropsectra | Micropsectra | 32.6 | 18.4 | 867 | NI | NI | NI | NI |
| Diptera | Chironomidae | Microtendipes | Microtendipes | 0.6 | 0 | 10 | NI | NI | NI | NI |
| Diptera | Chironomidae | Nanocladius | Nanocladius | 0 | 0.2 | 3 | NI | NI | NI | NI |
| Diptera | Chironomidae | NA | Orthocladiinae* | 0 | 79.2 | 1346.4 | NI | NI | NI | NI |
| Diptera | Chironomidae | Orthocladius | Orthocladius | 0 | 373.4 | 6348 | NI | NI | NI | NI |
| Diptera | Chironomidae | Orthocladius | Orthocladius lignicola | 0.2 | 0.2 | 7 | NI | NI | NI | NI |
| Diptera | Chironomidae | Pagastia | Pagastia | 0 | 15.8 | 269 | NI | NI | NI | NI |
| Diptera | Chironomidae | Parakiefferiella | Parakiefferiella | 0 | 0.6 | 10 | NI | NI | NI | NI |
| Diptera | Chironomidae | Parametriocnemus | Parametriocnemus | 11.8 | 0.4 | 207 | NI | NI | NI | NI |
| Diptera | Chironomidae | Paratendipes | Paratendipes | 0.2 | 0 | 3 | NI | NI | NI | NI |
| Diptera | Chironomidae | Parorthocladius | Parorthocladius | 0.2 | 0 | 3 | NI | NI | NI | NI |
| Diptera | Chironomidae | Polypedilum | Polypedilum | 0.2 | 61 | 1040 | NI | NI | NI | NI |
| Diptera | Chironomidae | Potthastia | Potthastia Gaedii Group | 0 | 10.4 | 177 | NI | NI | NI | NI |
| Diptera | Chironomidae | Pseudodiamesa | Pseudodiamesa | 1.8 | 0 | 31 | NI | NI | NI | NI |
| Diptera | Chironomidae | Psilometriocnemus | Psilometriocnemus | 1.2 | 0 | 20 | NI | NI | NI | NI |
| Diptera | Chironomidae | Rheocricotopus | Rheocricotopus | 0.2 | 2.4 | 44 | NI | NI | NI | NI |
| Diptera | Chironomidae | Rheotanytarsus | Rheotanytarsus | 0 | 108 | 1836 | NI | NI | NI | NI |

| Order | Family | Genus | Taxa in seeding baskets | Average number in Cedar baskets | Average number in Webster baskets | Estimated number added to each recipient stream | Gold | Taylor | Yarrow | Miller |
|---|---|---|---|---|---|---|---|---|---|---|
| Diptera | Chironomidae | Stempellinella | Stempellinella | 0.4 | 8 | 143 | NI | NI | NI | NI |
| Diptera | Chironomidae | Sublettea | Sublettea coffmani | 0 | 40 | 680 | NI | NI | NI | NI |
| Diptera | Chironomidae | Synorthocladius | Synorthocladius | 0.8 | 85 | 1459 | NI | NI | NI | NI |
| Diptera | Chironomidae | NA | Tanytarsini* | 0 | 5.6 | 95.2 | NI | NI | NI | NI |
| Diptera | Chironomidae | Tanytarsus | Tanytarsus | 0 | 0.8 | 14 | NI | NI | NI | NI |
| Diptera | Chironomidae | Thienemanniella | Thienemanniella | 0.2 | 61.8 | 1054 | NI | NI | NI | NI |
| Diptera | Chironomidae | Tvetenia | Tvetenia* | 0.2 | 0 | 3.4 | NI | NI | NI | NI |
| Diptera | Chironomidae | Tvetenia | Tvetenia Bavarica Group | 1.6 | 17.4 | 323 | NI | NI | NI | NI |
| Diptera | Chironomidae | Zavrelimyia | Zavrelimyia | 3.2 | 1 | 71 | NI | NI | NI | NI |
| Diptera | Chironomidae | | Thienemannimyia complex | 0 | 55.8 | 949 | NI | NI | NI | NI |
| Diptera | Dixidae | | Dixidae* | 0.2 | 0 | 3.4 | NI | NI | NI | NI |
| Diptera | Dixidae | Dixa | Dixa | 5.6 | 0 | 95 | NI | NI | NI | NI |
| Diptera | Dixidae | Dixella | Dixella | 0.2 | 0 | 3 | NI | New | New | PS |
| Diptera | Empididae | | Empididae* | 0 | 0.4 | 6.8 | NI | NI | NI | NI |
| Diptera | Empididae | Clinocera | Clinocera | 0 | 0.2 | 3 | NI | New | NI | PS |
| Diptera | Empididae | Neoplasta | Neoplasta | 0 | 2.6 | 44 | NI | NI | NI | NI |
| Diptera | Empididae | Oreogeton | Oreogeton | 0.2 | 0 | 3 | IS | New | New | PS |
| Diptera | Empididae | Roederiodes | Roederiodes | 0 | 0.6 | 10 | IS | New | New | PS |
| Diptera | Pelecorhynchidae | Glutops | Glutops | 0.6 | 0 | 10 | IS | New | New | NI |
| Diptera | Simuliidae | Simulium | Simulium | 6.2 | 36.4 | 724 | NI | NI | NI | NI |
| Diptera | Tabanidae | | Tabanidae | 0 | 0.2 | 3 | New | IS | New | NI |
| Diptera | Tipulidae | Antocha | Antocha monticola | 0 | 76.4 | 1299 | IS | IS | PS | IS |
| Diptera | Tipulidae | Dicranota | Dicranota | 1.8 | 0.2 | 34 | NI | NI | NI | NI |
| Diptera | Tipulidae | Hexatoma | Hexatoma | 2.8 | 0.2 | 51 | IS | IS | PS | IS |
| Diptera | Tipulidae | Limnophila | Limnophila | 0.6 | 0 | 10 | IS | IS | PS | IS |
| Ephemeroptera | Ameletidae | Ameletus | Ameletus | 2.4 | 0.4 | 48 | New | New | New | New |
| Ephemeroptera | Baetidae | Acentrella | Acentrella turbida | 0 | 45.4 | 772 | New | New | New | New |
| Ephemeroptera | Baetidae | | Baetidae* | 0.8 | 0 | 13.6 | NI | NI | NI | NI |
| Ephemeroptera | Baetidae | | Baetis* | 0.4 | 0 | 6.8 | NI | NI | NI | NI |
| Ephemeroptera | Baetidae | Baetis | Baetis flavistriga complex | 0 | 2 | 34 | New | NI | New | PS |
| Ephemeroptera | Baetidae | Baetis | Baetis piscatoris complex | 4 | 0 | 68 | New | NI | New | PS |
| Ephemeroptera | Baetidae | Baetis | Baetis tricaudatus complex | 18 | 96.4 | 1945 | NI | NI | NI | NI |
| Ephemeroptera | Baetidae | Diphetor | Diphetor hageni | 10.2 | 6 | 275 | PS | New | New | New |
| Ephemeroptera | Ephemerellidae | Attenella | Attenella | 0 | 0.2 | 3 | New | New | New | New |
| Ephemeroptera | Ephemerellidae | Attenella | Attenella delantala | 0.4 | 3.4 | 65 | New | New | New | New |
| Ephemeroptera | Ephemerellidae | Attenella | Attenella margarita | 0 | 0.2 | 3 | New | New | New | New |
| Ephemeroptera | Ephemerellidae | Drunella | Drunella | 3.2 | 9.4 | 214 | New | New | New | IS |
| Ephemeroptera | Ephemerellidae | Drunella | Drunella coloradensis | 0.2 | 0 | 3 | New | New | New | New |
| Ephemeroptera | Ephemerellidae | Drunella | Drunella doddsii | 6.6 | 7 | 231 | New | New | New | IS |
| Ephemeroptera | Ephemerellidae | Drunella | Drunella grandis | 0 | 1.4 | 24 | New | New | New | New |
| Ephemeroptera | Ephemerellidae | | Ephemerellidae* | 0 | 1 | 17.0 | New | New | New | IS |
| Ephemeroptera | Ephemerellidae | Ephemerella | Ephemerella | 0.4 | 0.4 | 14 | New | New | New | New |
| Ephemeroptera | Ephemerellidae | Ephemerella | Ephemerella aurivillii | 0 | 0.2 | 3 | New | New | New | New |
| Ephemeroptera | Ephemerellidae | Serratella | Serratella micheneri | 0 | 0.2 | 3 | New | New | New | New |
| Ephemeroptera | Ephemerellidae | Serratella | Serratella tibialis | 1.8 | 2.8 | 78 | New | New | New | New |
| Ephemeroptera | Ephemerellidae | Timpanoga | Timpanoga hecuba | 0 | 0.4 | 7 | New | New | New | New |
| Ephemeroptera | Heptageniidae | Cinygma | Cinygma | 3.2 | 0 | 54 | NI | NI | NI | NI |
| Ephemeroptera | Heptageniidae | Cinygmula | Cinygmula | 8.6 | 0.2 | 150 | New | PS | New | NI |
| Ephemeroptera | Heptageniidae | Ecdyonurus | Ecdyonurus criddlei | 0 | 11.8 | 201 | New | PS | New | PS |
| Ephemeroptera | Heptageniidae | Epeorus | Epeorus | 0.2 | 0 | 3 | New | PS | New | IS |
| Ephemeroptera | Heptageniidae | Ironodes | Ironodes | 7.6 | 0 | 129 | NI | PS | New | PS |
| Ephemeroptera | Heptageniidae | Rhithrogena | Rhithrogena | 9.2 | 19.6 | 490 | IS | PS | New | IS |
| Ephemeroptera | Leptophlebiidae | | Leptophlebiidae | 4.4 | 1.4 | 99 | IS | NI | NI | NI |
| Haplotaxida | Enchytraeidae | Fridericia | Fridericia | 0.2 | 0.8 | 17 | NI | NI | NI | NI |
| Haplotaxida | Enchytraeidae | Mesenchytraeus | Mesenchytraeus | 6 | 1.6 | 129 | NI | NI | NI | NI |
| Haplotaxida | Enchytraeidae | | Enchytraeidae | 0 | 1.2 | 20 | NI | NI | NI | NI |
| Haplotaxida | Naididae | Nais | Nais | 0 | 7.6 | 129 | New | NI | NI | NI |
| Haplotaxida | Naididae | Pristina | Pristina | 0 | 0.2 | 3 | NI | PS | PS | NI |
| Haplotaxida | Naididae | | Tubificinae | 0.2 | 0 | 3 | NI | NI | NI | NI |
| Lepidoptera | Crambidae | | Crambidae | 0.2 | 0 | 3 | New | New | New | IS |
| Lumbriculida | Lumbriculidae | | Lumbriculidae | 0.8 | 0 | 14 | NI | NI | NI | NI |
| Plecoptera | Capniidae | | Capniidae | 0 | 1.2 | 20 | New | New | New | New |
| Plecoptera | Chloroperlidae | | Chloroperlidae* | 0.4 | 0 | 6.8 | NI | NI | NI | NI |
| Plecoptera | Chloroperlidae | Paraperla | Paraperla | 0.6 | 0 | 10 | New | PS | New | PS |
| Plecoptera | Chloroperlidae | Sweltsa | Sweltsa | 5.8 | 1 | 116 | NI | NI | NI | NI |
| Plecoptera | Chloroperlidae | | Suwalliini | 0 | 21 | 357 | New | PS | New | NI |
| Plecoptera | Leuctridae | Despaxia | Despaxia augusta | 6.8 | 0 | 116 | PS | NI | New | PS |
| Plecoptera | Leuctridae | Moselia | Moselia infuscata | 1.4 | 0 | 24 | PS | PS | New | PS |
| Plecoptera | Leuctridae | | Leuctridae | 2.4 | 0 | 41 | PS | NI | New | PS |
| Plecoptera | Nemouridae | Malenka | Malenka | 0.6 | 0.2 | 14 | NI | NI | NI | NI |
| Plecoptera | Nemouridae | | Nemouridae* | 0.6 | 0.2 | 13.6 | NI | NI | NI | NI |
| Plecoptera | Nemouridae | Visoka | Visoka cataractae | 5.2 | 0 | 88 | IS | New | New | PS |
| Plecoptera | Nemouridae | Zapada | Zapada cinctipes | 22 | 2.8 | 422 | NI | NI | NI | NI |
| Plecoptera | Nemouridae | Zapada | Zapada frigida | 0.2 | 0 | 3 | IS | New | New | PS |
| Plecoptera | Nemouridae | Zapada | Zapada Oregonensis Group | 29.8 | 0 | 507 | NI | NI | New | NI |
| Plecoptera | Peltoperlidae | Yoraperla | Yoraperla | 2 | 0 | 34 | NI | New | New | New |

| Order | Family | Genus | Taxa in seeding baskets | Average number in Cedar baskets | Average number in Webster baskets | Estimated number added to each recipient stream | Gold | Taylor | Yarrow | Miller |
|---|---|---|---|---|---|---|---|---|---|---|
| Plecoptera | Perlidae | Calineuria | Calineuria californica | 3.2 | 1.8 | 85 | New | New | New | IS |
| Plecoptera | Perlidae | Claassenia | Claassenia sabulosa | 0 | 0.4 | 7 | New | New | New | New |
| Plecoptera | Perlidae | Doroneuria | Doroneuria | 3.6 | 0.6 | 71 | New | New | New | New |
| Plecoptera | Perlidae | Hesperoperla | Hesperoperla pacifica | 0.4 | 0.2 | 10 | NI | New | New | New |
| Plecoptera | Perlidae | | Perlidae | 13.4 | 5 | 313 | NI | New | New | PS |
| Plecoptera | Perlodidae | Isoperla | Isoperla | 0.2 | 8.4 | 146 | PS | IS | New | PS |
| Plecoptera | Perlodidae | Skwala | Skwala | 0 | 5 | 85 | NI | New | NI | PS |
| Plecoptera | Perlodidae | | Perlodidae | 0 | 3.4 | 58 | NI | NI | NI | NI |
| Plecoptera | Pteronarcyidae | Pteronarcys | Pteronarcys californica | 0 | 0.4 | 7 | New | New | New | New |
| Plecoptera | Pteronarcyidae | Pteronarcys | Pteronarcys princeps | 1 | 0 | 17 | New | New | New | New |
| Sarcoptiformes | | | Oribatida | 1.4 | 0 | 24 | NI | NI | NI | NI |
| Trichoptera | Apataniidae | Apatania | Apatania | 0.2 | 1.2 | 24 | New | New | New | IS |
| Trichoptera | Apataniidae | Pedomoecus | Pedomoecus sierra | 0 | 0.2 | 3 | New | New | New | New |
| Trichoptera | Brachycentridae | Brachycentrus | Brachycentrus | 0 | 1.2 | 20 | New | New | New | New |
| Trichoptera | Brachycentridae | Micrasema | Micrasema | 17.6 | 1.4 | 323 | NI | New | New | New |
| Trichoptera | Brachycentridae | | Brachycentridae | 0 | 1 | 17 | NI | New | New | New |
| Trichoptera | Calamoceratidae | Heteroplectron | Heteroplectron californicum | 0.2 | 0.2 | 7 | New | New | New | New |
| Trichoptera | Glossosomatidae | Anagapetus | Anagapetus | 3.6 | 0 | 61 | New | PS | New | New |
| Trichoptera | Glossosomatidae | Glossosoma | Glossosoma | 18.4 | 109.4 | 2173 | NI | IS | NI | NI |
| Trichoptera | Glossosomatidae | | Glossosomatidae* | 1.6 | 8.8 | 176.8 | NI | IS | NI | NI |
| Trichoptera | Hydropsychidae | Arctopsyche | Arctopsyche | 0 | 15.8 | 269 | New | PS | New | PS |
| Trichoptera | Hydropsychidae | | Arctopsychinae* | 0 | 66.4 | 1128.8 | NI | NI | NI | NI |
| Trichoptera | Hydropsychidae | Hydropsyche | Hydropsyche | 13.2 | 305.8 | 5423 | NI | NI | NI | NI |
| Trichoptera | Hydropsychidae | | Hydropsychidae* | 7.6 | 16.2 | 404.6 | NI | NI | NI | NI |
| Trichoptera | Hydropsychidae | Parapsyche | Parapsyche | 2.4 | 0 | 41 | NI | NI | NI | NI |
| Trichoptera | Lepidostomatidae | Lepidostoma | Lepidostoma | 9.8 | 6.2 | 272 | NI | IS | NI | NI |
| Trichoptera | Limnephilidae | Allocosmoecus | Allocosmoecus partitus | 0 | 0.2 | 3 | PS | New | New | PS |
| Trichoptera | Limnephilidae | Dicosmoecus | Dicosmoecus gilvipes | 0 | 2 | 34 | PS | New | New | NI |
| Trichoptera | Limnephilidae | Psychoglypha | Psychoglypha | 0 | 1 | 17 | PS | New | New | NI |
| Trichoptera | Limnephilidae | | Limnephilidae | 1.4 | 0.8 | 37 | NI | New | New | NI |
| Trichoptera | Philopotamidae | Wormaldia | Wormaldia | 0.2 | 2 | 37 | IS | NI | New | NI |
| Trichoptera | Polycentropodidae | | Polycentropodidae | 0.6 | 0 | 10 | PS | NI | New | New |
| Trichoptera | Psychomyiidae | Psychomyia | Psychomyia | 0 | 0.6 | 10 | New | New | New | New |
| Trichoptera | Rhyacophilidae | Rhyacophila | Rhyacophila | 3.8 | 1.4 | 88 | NI | NI | NI | NI |
| Trichoptera | Rhyacophilidae | Rhyacophila | Rhyacophila atrata complex | 0.2 | 0.4 | 10 | NI | PS | New | PS |
| Trichoptera | Rhyacophilidae | Rhyacophila | Rhyacophila Betteni Group | 3.8 | 0 | 65 | NI | NI | NI | NI |
| Trichoptera | Rhyacophilidae | Rhyacophila | Rhyacophila Brunnea/Vemna Group | 10.6 | 3 | 231 | NI | NI | NI | NI |
| Trichoptera | Rhyacophilidae | Rhyacophila | Rhyacophila Coloradensis Group | 0 | 4 | 68 | PS | PS | New | PS |
| Trichoptera | Rhyacophilidae | Rhyacophila | Rhyacophila narvae | 1 | 3.6 | 78 | NI | PS | New | PS |
| Trichoptera | Thremmatidae | | Thremmatidae | 1 | 0 | 17 | New | New | New | New |
| Trichoptera | Uenoidae | Neophylax | Neophylax rickeri | 0 | 11.6 | 197 | IS | New | New | New |
| Trichoptera | Uenoidae | Neothremma | Neothremma | 0.4 | 0 | 7 | IS | New | New | New |
| Trichoptera | Uenoidae | Oligophlebodes | Oligophlebodes | 1.2 | 0 | 20 | IS | New | New | New |
| Trichoptera | Uenoidae | | Uenoidae | 0.2 | 0 | 3 | NI | New | New | New |
| Tricladida | Planariidae | Polycelis | Polycelis | 11.2 | 4 | 258 | NI | IS | NI | NI |
| Trombidiformes | | | Acari* | 0 | 0.2 | 3.4 | NI | NI | NI | NI |
| Trombidiformes | Aturidae | Aturus | Aturus | 0 | 0.2 | 3 | NI | NI | NI | NI |
| Trombidiformes | Hygrobatidae | Atractides | Atractides | 0 | 6.8 | 116 | NI | NI | NI | NI |
| Trombidiformes | Lebertiidae | Estelloxus | Estelloxus | 0.2 | 0 | 3 | NI | NI | NI | NI |
| Trombidiformes | Lebertiidae | Lebertia | Lebertia | 0.4 | 6.4 | 116 | NI | NI | NI | NI |
| Trombidiformes | Mideopsidae | Xystonotus | Xystonotus | 0.2 | 0 | 3 | NI | NI | NI | NI |
| Trombidiformes | Protziidae | Protzia | Protzia | 0.2 | 11.4 | 197 | NI | NI | NI | NI |
| Trombidiformes | Sperchontidae | Sperchon | Sperchon | 0.2 | 20.2 | 347 | NI | NI | NI | NI |
| Trombidiformes | Sperchontidae | Sperchonopsis | Sperchonopsis | 1.6 | 0.4 | 34 | NI | NI | NI | NI |
| Trombidiformes | Torrenticolidae | Monatractides | Monatractides | 5.2 | 0.2 | 92 | NI | NI | NI | NI |
| Trombidiformes | Torrenticolidae | Torrenticola | Torrenticola | 1.8 | 3.8 | 95 | NI | NI | NI | NI |
| Veneroida | Pisidiidae | Pisidium | Pisidium | 0 | 1.4 | 24 | NI | NI | New | NI |
| Veneroida | Sphaeriidae | | Sphaeriidae | 0.2 | 4 | 71 | NI | NI | NI | NI |
| | | | Nemata | 0.4 | 2 | 41 | NI | NI | NI | NI |
| | | | Ostracoda | 2 | 0 | 34 | NI | IS | NI | New |
| Esimated total number added to each recipient stream | | | | | | 46699 | | | | |