



Impacts of Disturbance on Benthic Macroinvertebrates Across Central Yukon - Results Report

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Overview

Biomonitoring uses aquatic organisms to assess how disturbance affects freshwater ecosystems. Unlike water-quality measurements, aquatic organisms integrate environmental conditions over time, revealing impacts that single-point water samples can miss [1–3]. As a result, biomonitoring allows managers to directly link disturbance to ecological change, rather than inferring biological responses from water quality alone [2, 3]. Across Canada, benthic macroinvertebrates (BMI) or “water bugs” are widely used in biomonitoring programs because they are diverse, abundant, relatively long-lived, easy to collect, and they respond to different types of stress [3]. Together, these characteristics make BMI excellent indicators of change in freshwater ecosystems.

Although biomonitoring is an important tool, effective biomonitoring programs require many reference sites (undisturbed areas) that serve as benchmarks for identifying impairment [4]. Further, reference sites must remain comparable to exposed sites through time so that differences reflect disturbance rather than natural temporal change [5]. In central Yukon, freshwater ecosystems are influenced by multiple stressors, including wildfires, hydroelectric generation, and placer mining. To assess some of these impacts, a territory-wide BMI biomonitoring program was established in 2006 [6]. However, many reference sites, particularly in the Stewart River watershed, have only been sampled once since 2006. This limited temporal coverage raises concerns about whether BMI communities at reference sites remain representative of current environmental conditions. Additional uncertainty surrounds how reference sites were grouped and compared to test sites (those possibly affected by anthropogenic stressors) via the Yukon reference condition model, which underpins the territorial BMI monitoring program [7–9].

Objectives

This study was developed to improve freshwater ecosystem monitoring across central Yukon by addressing the following objectives:

1. Understanding whether historic reference sites remain appropriate benchmarks for contemporary biomonitoring programs.
2. Refine the Yukon reference condition model (based on the suitability of historic reference sites) to improve assessments of how cumulative stressors shape aquatic health.

Methods

In 2025, we visited 28 watercourses, mainly within the Stewart River Watershed and the Traditional Territory of the First Nation of Na-Cho Nyäk Dun (FNNND) (Figure 1). Sites were selected to cover a gradient of undisturbed to disturbed catchments using spatial data provided by GeoYukon (surface disturbance, linear disturbance, and fire disturbance layers). When possible, BMI were collected at stations used by other regional monitoring programs or priority areas identified by FNNND.

During visits to watercourses in 2025, we collected BMI from 6 undisturbed (reference) sites and 22 test sites exposed to placer mining, wildfire, hydroelectric development, or combinations of these stressors. Combined with sites previously visited in 2024, our dataset covers 58 watercourses within the Stewart River Watershed (12 reference sites and 44 test sites total).

At each site, benthic macroinvertebrates were sampled using [Canadian Aquatic Biomonitoring Network \(CABIN\)](#) kick-net protocols. After collection, BMI samples were preserved in the field and later identified under a microscope. We also characterized aquatic habitat conditions at each site and collected water quality samples. Water quality data provide supporting context for interpreting biological patterns and helps verify whether observed differences in BMI communities are associated with specific disturbance types. We first summarize water-quality patterns across site types before assessing temporal changes in BMI communities.

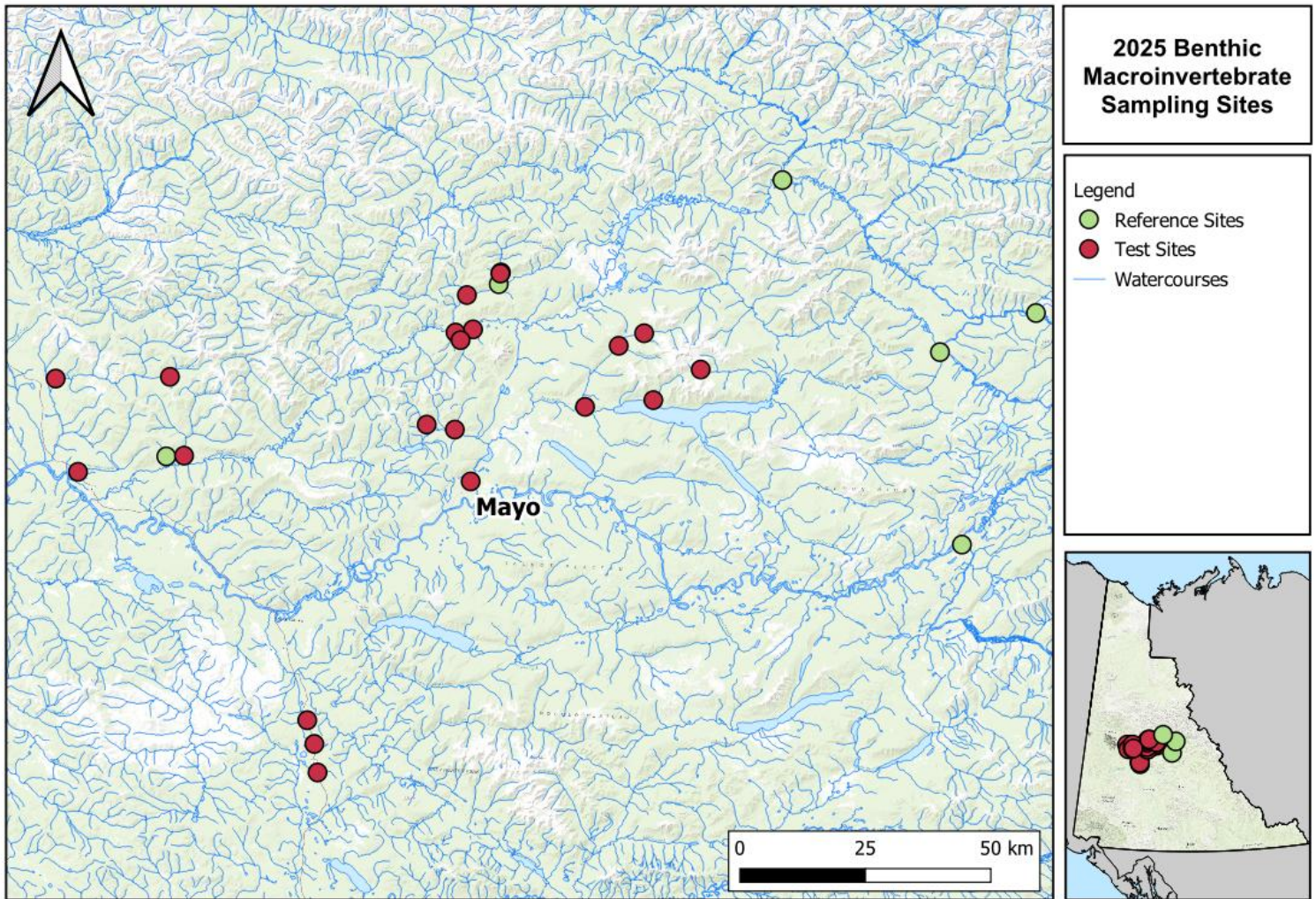


Figure 1. BMI sites visited across the 2025 season.

Results – Water Quality

Water chemistry differed between reference and exposed sites. Reference sites consistently had a different chemical signature than all exposure sites, while the different exposure types (fire exposed, placer exposed, and sites exposed to multiple stressors) were similar to each other. Overall, site type explained about 14% of the overall variation in water chemistry, meaning

disturbance had a measurable impact on water quality, though other environmental factors also contribute to variation across the study region.

To understand which water quality parameters were associated with site type, we examined water quality patterns in detail. We found reference sites were mainly associated with higher levels of dissolved minerals, including calcium and magnesium, conductivity, total dissolved solids, alkalinity, hardness, and sulfate. This pattern is seen in Figure 2 where arrows represent the direction and strength of water quality parameters that separate site type. Here, longer arrows equate to more influential water quality variables. Reference sites (green dots) cluster near the arrows representing dissolved minerals, indicating that water chemistry at these sites is structured largely by mineral content. A second pattern associated with placer and cumulative-effect sites is also seen in Figure 1. Placer exposed sites (purple dots), and to a lesser extent sites exposed to multiple stressors (“cumulative”, black dots), cluster near higher concentrations of sulfate, metals (e.g., lithium, antimony, cobalt, nickel, copper, lead, arsenic), and suspended material (higher turbidity).

Together, these results suggest that reference sites differ from exposed sites based on unique water quality signatures. From a biomonitoring perspective, the next question is whether these water quality differences translate into consistent differences in BMI communities. Understanding these water quality patterns provides essential context for interpreting BMI results and assessing whether disturbance-related changes in water quality are accompanied by biological responses.

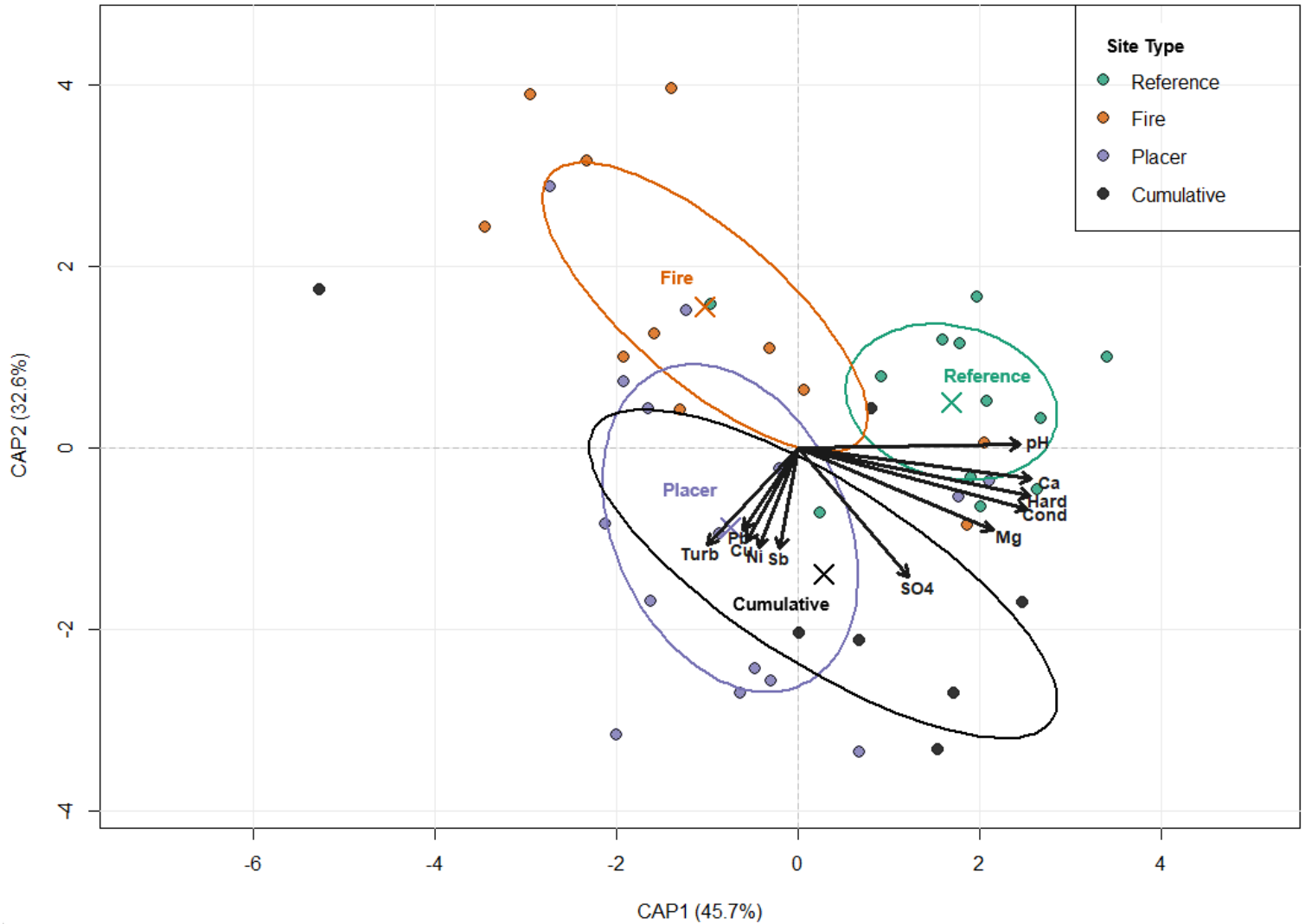


Figure 2. Canonical analysis of principal coordinates (CAP) plot showing the relationship between key water quality variables and types of sites BMI were collected from. Placer-exposed sites are shown as purple dots, sites exposed to multiple stressors (“cumulative”) as black dots, fire-exposed sites as orange dots, and reference sites as green dots. Coloured “X” markers indicate the centroid for each site type. Arrows represent different water quality variables (Turb = turbidity, Pb = lead (total), Cu = copper (total), Ni = nickel (total), Sb = antimony (total), SO4 = sulfate, Mg = magnesium (total), Cond = conductivity, Hard = hardness, Ca = calcium (total), and pH = pH units). Arrow length reflects the relative influence of each variable in separating site types.

Results – Benthic Macroinvertebrates

A core principle of biomonitoring is that reference sites reflect baseline conditions. If this assumption is not met, exposed sites cannot be compared against a reliable benchmark, undermining the ability to detect ecological change. Across central Yukon, many reference sites have been monitored over time; however, most have only been revisited once. This raises an

important question: have communities at reference sites remained stable, or have they shifted over time in ways that limit their value as a baseline? Therefore, before addressing management questions such as how disturbance is influencing aquatic ecosystems, we first need to evaluate whether our reference-site network is still representative of current conditions.

To quantify how much communities changed between historic and current surveys, we used Bray–Curtis dissimilarity (BC), which summarizes differences in BMI family-level abundance. Smaller BC values indicate more similar communities, while larger values indicate greater change. Figure 3 illustrates differences in BC between historic (_H) and current (_C) surveys at paired sites, with the length of the connecting line representing the amount of change over time. Test sites – those that are exposed to one or more stressor – showed consistently larger historic-to-current BC values than reference sites. Patterns in BMI summary metrics and site-specific community turnover also supported these multivariate results. Test sites showed larger changes in abundance and greater community turnover through time, while reference sites fluctuated but did not show consistent directional change. Together, these preliminary results indicate that historic reference sites are relatively stable and continue to host BMI communities that are comparable to those at current reference sites.

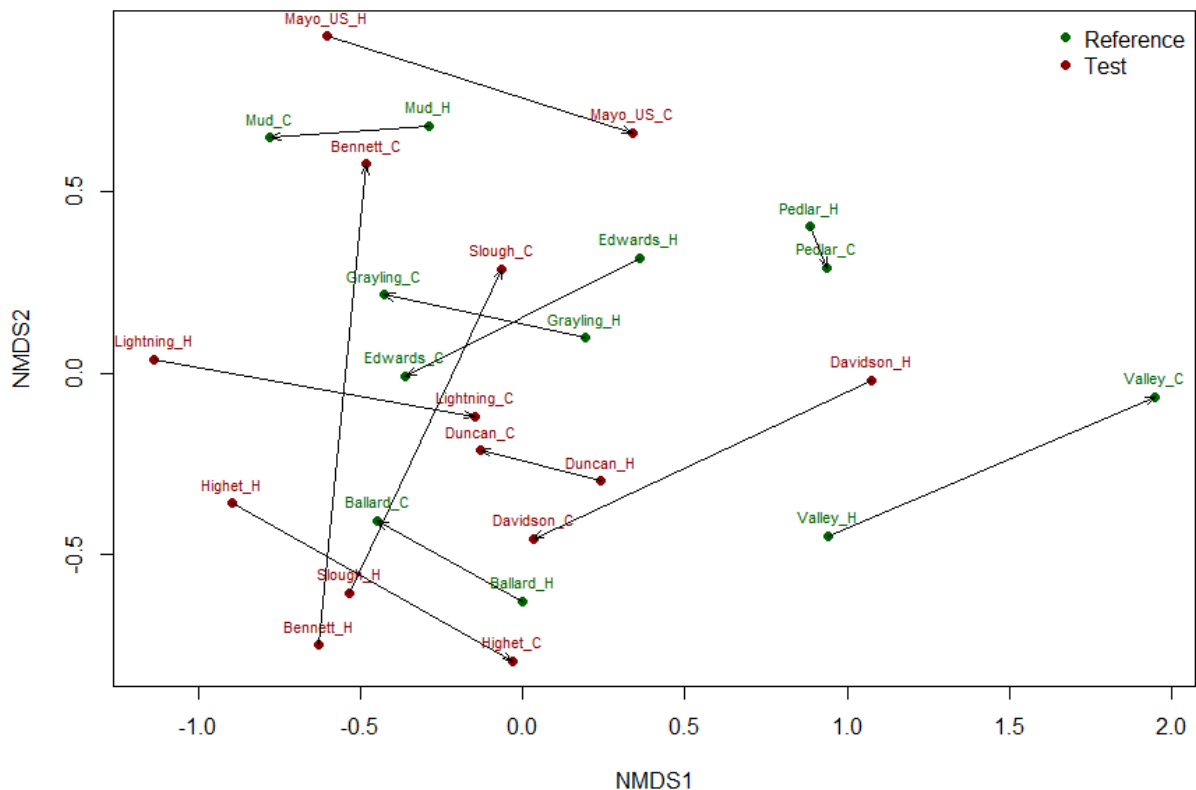


Figure 3. Two-dimensional NMDS of benthic macroinvertebrate communities (stress = 0.18) for historic (_H) and current (_C) surveys based on Bray–Curtis dissimilarity. Lines connect paired

surveys at the same site (longer lines = greater dissimilarity). Reference sites are shown in green and test sites in red.

Although test site communities changed more over time than reference sites, our main objective is to determine whether historic reference samples are similar enough to current reference samples to be pooled for reference condition modelling. To address this, we created a benchmark that represents typical community differences among current reference sites. For each current reference site, we identified the minimum BC dissimilarity to any other current reference site, then took the median of these nearest-neighbour distances (0.600) as a screening benchmark. We then compared each historic–current reference pair against this benchmark.

If a historic–current reference pair has a BC value below the benchmark, the change observed through time is not greater than the natural variation observed among current reference sites. If a reference pair exceeds the benchmark, it can be flagged as potentially unstable and interpreted with caution. Using this approach, five of six reference pairs in the study had BC values below the current reference benchmark. Valley was the only reference site pair above the benchmark (BC = 0.664), indicating greater temporal change than seen across current reference communities. This supports pooling most historic reference samples with current reference samples, while treating Valley as a borderline site. Interestingly, Valley was one of the only reference sites that received less short-term precipitation under current conditions than in the past, possibly contributing to the differences in BMI communities over time.

It is important to note that current reference sites are quite variable, with some nearest-neighbour BC values exceeding 0.70. This suggests substantial natural variability in BMI communities within the Stewart River Watershed. For this reason, the median nearest-neighbour benchmark is intended as a screening tool rather than a strict pass/fail threshold, particularly given the small number of reference sites. Even so, the fact that most reference pairs fall below the benchmark, while test pairs tend to exceed it, supports cautious pooling of historic and current reference samples for reference condition modelling. BMI data collected in 2025 that is still being processed will help further investigate this pattern, which is essential before refining the Yukon reference condition model (objective 2).

Communication

In 2025, a variety of communication and outreach activities were conducted to share project objectives and preliminary results with a range of audiences. Updates were primarily disseminated through formal presentations, supplemented by a brief research video produced as part of the WCS Canada Weston Family Boreal Research Fellowship funding requirements. This video will be publicly available on [WCS Canada's YouTube channel](#). The Yukon Fish and Wildlife Enhancement Trust was acknowledged as a funding partner in all presentations, written materials, and videos.

Key communication activities include:

**University of Saskatchewan School of Environment and Sustainability Symposium
Presentation (August 2025)**

- Following fieldwork, Wes presented preliminary project findings to peers, alumni, and faculty at the University of Saskatchewan.

The Wildlife Society Conference Presentation (October 2025)

- Wes presented initial findings at the Wildlife Society Conference in Edmonton, Alberta, as part of a symposium focused on cumulative effects in northern regions. Following the presentation, Wes participated in a panel discussion engaging attendees on cumulative effects studies in northern ecosystems.

The Canadian River Institute Days Presentation (November 2025)

- Wes presented preliminary project results to peers and faculty at the Canadian River Institute Days event.

Yukon Biodiversity Forum (upcoming – March 2026)

- To engage directly with Yukoners and local researchers, Wes will present project findings at the Yukon Biodiversity Forum.

Society of Canadian Aquatic Sciences (SCAS) Conference (upcoming – May 2026)

- Wes will present preliminary results, including 2025 BMI data, at the SCAS Conference in Winnipeg. This session will provide an opportunity to receive feedback from freshwater scientists and peers conducting similar research in northern ecosystems.

Next Steps and Implications

Water quality and BMI data together offer preliminary evidence that disturbance is influencing aquatic ecosystems across central Yukon, and that historic reference sites may still serve as suitable benchmarks for current biomonitoring programs. Building on these findings, we will revisit the Yukon reference condition model and address past shortfalls related to how the model was developed [7–9]. We will also explore whether traits related to how BMI eat, move, breathe, and reproduce can complement the model, as trait-based approaches have helped identify the mechanisms linking disturbance to community responses in other studies [10–12].

Overall, this study is important because it will help strengthen regional land use planning across the territory. Land use plans are designed to balance development with the protection of environmental, cultural, and social values within an area [13]. However, these plans are only effective if we understand how ecosystems respond to development. Currently, land use planning in the Yukon tends to focus on the links between development and terrestrial ecosystems, with less attention given to freshwater ecosystems [14]. Although the most recent Draft Dawson Regional Land Use Plan acknowledges the value of BMI as indicators of aquatic condition, it references a historic BMI monitoring program that has since been discontinued [8, 14]. This study will address these gaps by improving the Yukon reference condition model, providing managers with an effective tool to determine whether multiple stressors are pushing BMI communities beyond expected reference conditions. This is particularly important given recent increases in placer mining [15] and projections of increasing wildfire severity across the territory [16].

Project Partners and Funders

Support from our project partners and funders was essential to this study. We are grateful to the many organizations and individuals who helped refine our objectives, assisted with fieldwork, provided equipment, reviewed preliminary results, and supported the communication of findings.



Photos



Photo 1. Caddisfly larva collected from a river in central Yukon examined under a microscope.



Photo 2: Wes Moir collecting benthic macroinvertebrates from the Mayo River using a kick net.



Photo 3: Clara Reid completing a habitat survey.



Photo 4: Wes Moir processing benthic macroinvertebrate samples in the field. Photo credit: Mary-Jo Michell

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