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Ministry of Environment

The Biological Integrity of Okanagan Streams:

Using Benthic Invertebrates to Monitor Stream Health

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Synopsis

The Okanagan's ecosystems are coming under increasing pressure with the population growth and associated development currently experienced in the region. We sought a method of assessing the health of the Okanagan's lowland streams, many of which are in or near urban areas.

We chose to use benthic invertebrates as indicators of stream health. In streams, benthic invertebrates are often the larvae of aquatic insects. Because they typically spend most of their life cycle in the stream, these invertebrates respond to conditions in and near the stream and integrate these effects over time.

After examining the benthic invertebrate community in several Okanagan streams, we selected five measures, or metrics, that describe the community:

- Total number of taxa
- Number of stonefly taxa
- Number of mayfly taxa
- Number of intolerant taxa
- Number of clinger taxa

These metrics were selected for their predictable and measurable response along a gradient of land use. The metrics were combined into a benthic index of biological integrity (B-IBI) following a method widely used in the Pacific Northwest.

We developed a version of the B-IBI specifically to assess Okanagan streams at low elevations in the valley bottom, and we then ranked the health of 31 stream sites using the index.

The Okanagan B-IBI scored 21 of the 31 stream sites (68%) as having fair, poor, or very poor condition. Only 5 scored as good and 5 as excellent. The lowest scores were recorded for urban streams such as BX Creek in Vernon, Mill Creek in Kelowna, and Eneas Creek in Summerland.

This information is useful for reporting the present ecological integrity of Okanagan streams and for tracking changes over time.

In this report, we describe the reasons for using a biological index, how the B-IBI was developed, how the B-IBI compares with other monitoring methods, and the current B-IBI results for Okanagan streams.

Contents

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Photo credits for front: Kick net sampling, Carrie Morita; Caddisfly, 10 mm from end of case to nose, Ralph Adams; Urban stream, Vic Jensen.

Introduction

What is biological integrity?
The biological integrity of a stream is how well the habitat can support biological communities, including algae, invertebrates, fish, and aquatic mammals and birds. For a stream to have high integrity, it must be unimpaired by human or other disturbances and must contain a diverse assemblage of naturally occurring plants and animals.

The organisms living in the stream reflect the impacts of activities in the stream's watershed or in upstream reaches. Impacts such as land clearing, agriculture, and urbanization cause changes in water temperature, water flow, chemical or metal content of water, and the amount of suspended material in water, among others. These impacts reduce a stream's biological integrity.

By measuring the biological communities present in a stream, it's possible to determine the condition or health of the stream. One easily measured biological community is the benthic invertebrate community.

Mayfly larva. Body length from nose to tip of abdomen is 7 mm. Photo credit: Ralph Adams

What are benthic invertebrates?
Benthic invertebrates are animals without backbones that live on the substrate at the bottom of streams, lakes, and the sea. The word benthic comes from the Greek word *benthos* meaning 'depths of the sea.' Many benthic invertebrates—especially in streams—are the larvae of aquatic insects, such as stoneflies, mayflies, and caddisflies. Other benthic invertebrates are snails, worms, and leeches.

The benthic invertebrates discussed here are mainly the aquatic insect larvae. Each individual can be grouped in several different ways:

1. **Type**: stoneflies (Plecoptera), mayflies (Ephemeroptera), caddisflies (Trichoptera), true flies including midges (Diptera), dragonflies and damselflies (Odonata).

2. **Feeding**: predators feed on other invertebrates, grazers feed on algae attached to rocks, shredders feed on leaves and other coarse materials.

3. **Behaviour**: clingers attach securely to rocks, climbers scale vegetation, burrowers dig into the sediment.

4. **Sensitivity**: tolerant insects can survive poor water quality and physical disturbance better than intolerant insects, which are known to decline in number as water gets warmer or more turbid.

Why monitor benthic invertebrates?
Impacts to streams can be measured in a variety of ways. Conventional stream monitoring generally relies on collecting water samples or sediment samples to measure contaminant concentrations. However, these methods provide only a snapshot of the stream condition at the time when the sample was taken. They don't integrate the effects over a longer time period, so they give less detailed information than biological measures.

On the other hand, benthic invertebrates live in streams and experience all the chemical and physical conditions that take place over days, weeks, and even months. They either thrive or suffer according to the quality of their stream environment, which depends largely on what happens in the surrounding watershed. Different groups of invertebrates respond to the stream environment by becoming abundant and others decline in number or disappear altogether. Therefore, the community of invertebrates—which ones are absent, which are present, how many are there—provides a cumulative, integrated picture of the condition of the stream environment.

Benthic invertebrates also provide a crucial link in a stream's food chain by being a food source for fish. Of course, fish, being part of the biological community, can also be monitored to get a picture of stream health. However, monitoring fish is more difficult than monitoring invertebrates, because fish are mobile on a daily basis, as well as seasonally. There also tend to be fewer fish—both in number of species and number of individuals—in streams. Lastly, a stream reach may not have any fish in it but will still influence downstream fish habitat. Here is where benthic invertebrates are so useful: they are easy to collect and are found throughout streams, as well as in most types of streams, regardless of their condition.

Why monitor benthic invertebrates in the Okanagan?
The Okanagan has seen a marked increase in population growth and development over the past 30 years. Since 1976, the population has doubled from 170,000 to 340,000 people. BC Statistics projects that it will increase to about 470,000 by 2031 (www.bcstats.gov.bc.ca). This growth has put pressure on stream habitats and watersheds.

Many of the Okanagan's rivers and streams have been dammed, dyked, straightened, dredged, or buried by culverts. Rivers and streams also receive urban stormwater runoff, septic tank and fertilizer seepage, and other contaminant inputs. Because of various land activities, the riparian habitat along the margins of streams has also been lost in many instances. Riparian vegetation performs many functions, which include shading the water, providing erosion control along the banks, and contributing energy to the stream ecosystem through leaf litter that is used by benthic organisms as food.

Okanagan streams with low and high impact from human activities. Photo credit: Vic Jensen

These land and water impacts affect water quality and quantity as well as other aspects of stream habitat. As the habitat changes, so too will the type and number of organisms that are capable of living in the altered stream ecosystem. Monitoring the biological response that these impacts have is key to understanding the effects and minimizing the damage done to Okanagan streams. By choosing to monitor benthic invertebrates, it's possible to directly assess a vital biological component of the stream ecosystem, a component that integrates the cumulative stresses on the ecosystem.

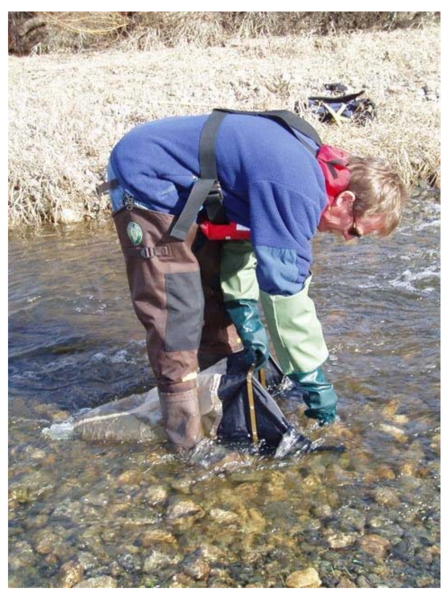
How are benthic invertebrates monitored?
Benthic invertebrates are easy to sample with a small amount of basic equipment. Nets are used to collect all the invertebrates present on the streambed in a defined area. Each sample is preserved and stored in a jar. Individuals in each sample are later counted and identified under a microscope by a trained taxonomist.

Once the data have been collected, one of several methods can be used to analyze the results. The method we've chosen to use in the Okanagan is called the benthic index of biological integrity, or B-IBI. This method is used widely in the United States and also in some other regions of BC and has been tested and refined in numerous stream ecosystems. B-IBI is called a multimetric analysis, because it uses a defined number of characteristics (metrics) that are found to respond predictably in the geographic area of interest.

How can the information be used?
Monitoring benthic invertebrates provides information about the present status of stream health and also allows stream conditions to be tracked over time. Streams in a particular area can be compared to assess how different impacts or different degrees of impact have affected them.

The information gained from monitoring benthic invertebrates, among other biological indicators, can be particularly helpful for evaluating and maintaining environmental values when urban and rural developments are planned and underway. For example, benthic invertebrate monitoring would be useful as an effectiveness indicator in integrated stormwater planning processes (www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/stormwater.html).

More guidelines on planning and undertaking developments in an environmentally sound manner can be found in the Ministry of Environment's publication called *Develop with Care: Environmental Guidelines for Urban and Rural Land Development in British Columbia*.



Collecting benthic invertebrates with a Surber net.
Photo credit:Carolyn Johns

The Okanagan Study

What were the objectives?

The benthic invertebrate monitoring study in the Okanagan had three objectives:

1. To develop a benthic index of biological integrity (B-IBI) to measure the health of Okanagan streams specifically
2. To test Okanagan streams in the valley bottom and apply the index to them
3. To compare the index with other methods of assessing stream health

How was the B-IBI developed?

We sampled 23 Okanagan streams, some at upper and lower locations, yielding 31 sampling sites. Samples were collected in the fall from 1999 through 2004, but not every site was sampled every year. The stream sites are shown on the map (page 8).

We selected 9 of the 31 stream sites to develop or calibrate the index. Five of these sites were considered "best available condition" and four were chosen to represent "worst available condition" according to an estimated level of human impact.

Human impact was estimated using an evaluation of the sampling site as well as data on three land uses in the watershed:

1. Potential agricultural activity in the watershed (using ALR boundaries)
2. Forest harvest activity in the watershed over a 20-year period (1970s to 1990s)
3. Percent urban area within 100 metres of the stream

At each of the stream sites, we sampled benthic invertebrates in riffle habitat. We used Surber samplers with fine-mesh nets and placed them on the stream bed. The stones, gravel, and finer sediments within a defined quadrat were gently rubbed and mixed to dislodge the invertebrates, which then flowed downstream into the Surber net.

We also took all the larger stones from the quadrat to inspect them and make sure that we'd collected all the attached invertebrates.

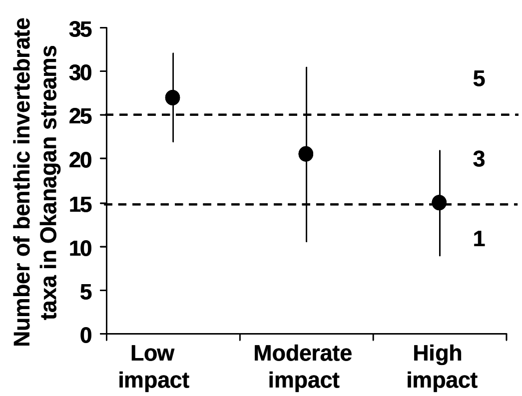
The invertebrate samples were preserved with a chemical fixative and were later examined using a microscope. The microscope analysis included counting and identifying the invertebrates. These data were sorted into different categories, or metrics, such as the total number of taxa, the total number of mayfly taxa, the total number of stonefly taxa, and so on.

What Are Taxa?

A taxon (singular of taxa) refers to a group used to identify and categorize an organism. A taxon can be at whatever level of identification is most practical for the study being undertaken. When working with a B-IBI, the invertebrates are often identified to Genus and Family and then summed at the Order level (e.g., mayfly, caddisfly, etc.).

Five metrics showed the strongest and most consistent response to the stress gradient from low impact (5) to high impact (1), as shown on the graph below. The five metrics were:

1. Total number of benthic invertebrate taxa
2. Number of plecoptera taxa (stoneflies)
3. Number of ephemeroptera taxa (mayflies)
4. Number of clinger taxa
5. Number of intolerant taxa



Following the work of others—notably James Karr and Ellen Chu who describe benthic indices in their book *Restoring Life in Running Waters*—we then used the five B-IBI metrics to score each site from 5 to 25 and determine the stream condition. This B-IBI score equates to a stream condition ranging from very poor to excellent, as shown in the table below.

B-IBI score	Stream condition
23–25	Excellent
19–22	Good
14–18	Fair
9–13	Poor
5–8	Very poor

The B-IBI continues to be refined as more data are collected, so new metrics may be added in future, and some of the current five metrics may be removed.

What is the condition of Okanagan streams?

Once the index had been developed from the low- and high-impact calibration groups, we applied it to all 23 Okanagan streams that we had sampled to determine stream condition at all sites, including the nine index calibration sites.

At the 31 sites tested, the B-IBI ranged from 5 to 25. From these scores, the stream condition was ranked as shown in the graph (above, at right): excellent for 5 sites, good for 5, fair for 12, poor for 6, and very poor for 3. The B-IBI scores and stream conditions for individual sites are shown in the table on page 9.

Most of the sites sampled during this study were ranked by the B-IBI as fair, poor, or very poor. This result indicates the heavy impact that human activities have had on valley bottom streams in the Okanagan.

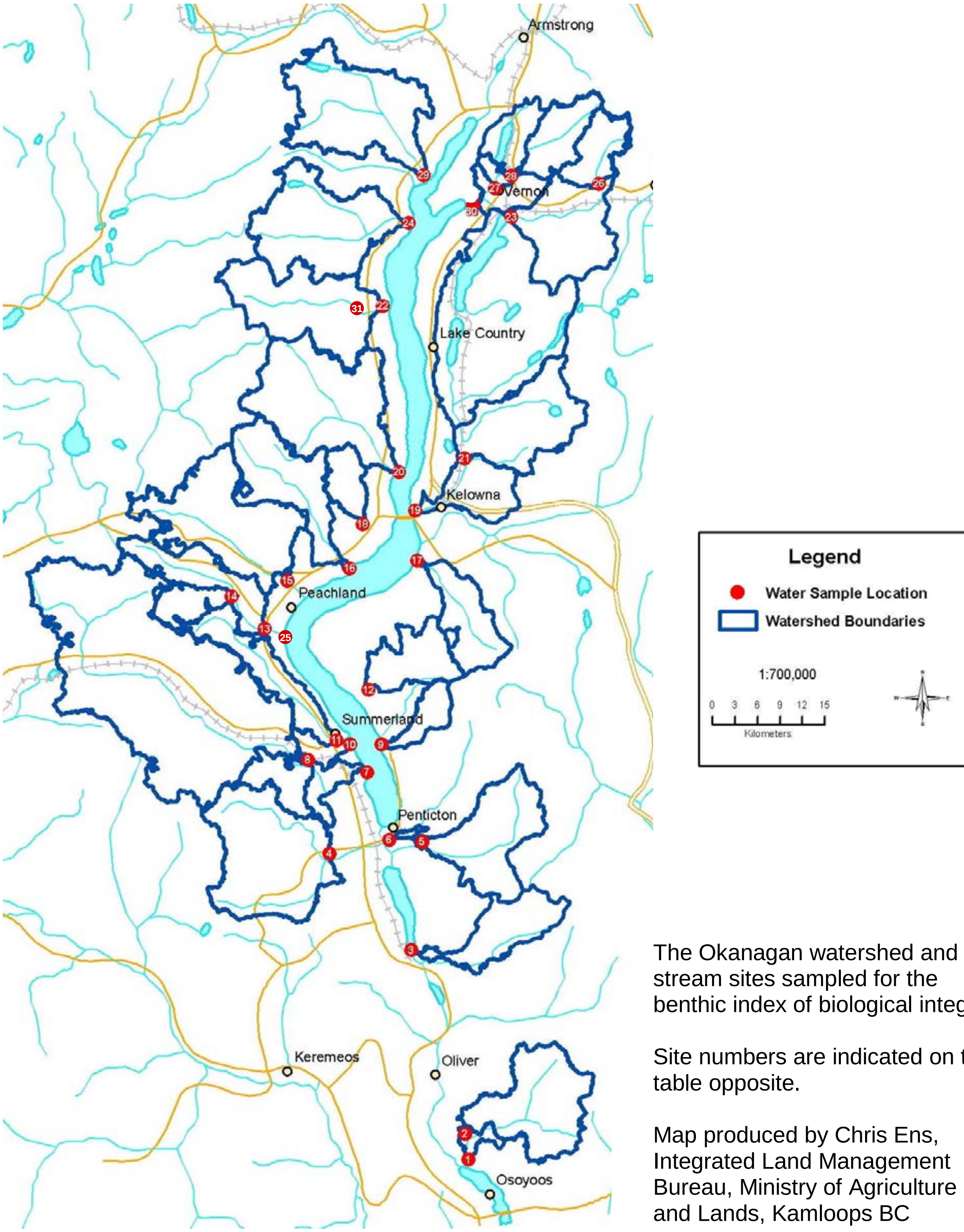
The three lowest scoring sites were BX Creek at 30th Avenue, Mill Creek near the mouth, and Eneas Creek near Rosedale Avenue. Each of these streams has extensive encroachment and loss of riparian vegetation. BX and Mill creeks, in particular, have been extensively altered by channelization and stormwater drainage. Both Mill Creek and Eneas Creek have detectable pesticides in their sediments.

Species of Special Note

Two damselfly species found at a few Okanagan sites are included on British Columbia's list of endangered species. *Argia vivida* is red-listed (at risk of becoming—or already is—threatened or endangered). *Argia emma* is blue-listed (of special concern because of its particular sensitivity to human activities or natural disturbances).

In the Okanagan, *Argia vivida* has been found in Max Lake near Penticton and Eneas Creek in Summerland, and an *Argia* species that is either *A. vivida* or *A. emma* has been found in BX Creek in Vernon.

Photo: *A. vivida* adult male © Neil Morgan



The Okanagan watershed and the stream sites sampled for the benthic index of biological integrity.

Site numbers are indicated on the table opposite.

Map produced by Chris Ens, Integrated Land Management Bureau, Ministry of Agriculture and Lands, Kamloops BC

Map #	Stream name	Site location	B-IBI score	Stream condition
29	Equesis	At Westside Road	25	Excellent
13	Peachland, upper	Downstream of PID intake	25	Excellent
31	Shorts, upper	At Westside Road	25	Excellent
5	Ellis, upper	At diversion	23	Excellent
24	Whiteman	At Westside Road	23	Excellent
12	Chute	At Glenfir Road	19	Good
23	Coldstream, lower	At Creekside Park	19	Good
26	Coldstream, upper	Upstream of municipal reservoir	19	Good
20	Lambly	Near mouth	19	Good
18	McDougall	At Shannon Lake Road	19	Good
17	Bellevue	At Lakeshore Road	17	Fair
28	BX, upper	Upstream of Pleasant Valley Road	17	Fair
14	Greata	Downstream of WSC station	17	Fair
1	Inkaneep, lower	Near mouth	17	Fair
2	Inkaneep, upper	Near Inkaneep	15	Fair
9	Naramata	At 8^{th} Street.	15	Fair
25	Peachland, lower	Near mouth	15	Fair
16	Powers	Near mouth	15	Fair
4	Shingle	Near mouth	15	Fair
22	Shorts, lower	Near mouth	15	Fair
15	Trepanier	At Highway 5C	15	Fair
8	Trout, upper	Above municipal intake	15	Fair
6	Ellis, lower	Near mouth	11	Poor
10	Prairie	Near mouth	11	Poor
30	Vernon	At 25th Avenue	11	Poor
21	Mill, upper	At Bulman Road	9	Poor
3	Shuttleworth	Near mouth	9	Poor
7	Trout, lower	Near mouth	9	Poor
11	Eneas	Downstream of Rosedale Avenue	7	Very poor
27	BX, lower	At 30th Avenue	5	Very poor
19	Mill, lower	Near mouth	5	Very poor

Is the B-IBI a useful tool for monitoring Okanagan streams?

Assessing the condition of a stream site can be hindered by multiple impacts occurring over space and time. This situation exists in the Okanagan where there is rarely a single impact to a stream at a single location (known as point source impacts). Instead, the main impacts to streams come from non-point sources at a landscape level and may include hydrologic changes, contaminant inputs, land use changes, and stream habitat alterations.

The B-IBI is a powerful tool to use in situations with multiple, non-point-source impacts, because biological communities—benthic invertebrates, in this case—integrate the effects of the many stresses over time.

Is the B-IBI the only way to collect and assess benthic invertebrate data?
No, there are other ways to assess stream health using benthic invertebrates. Environment Canada has recently developed a national biological monitoring program called the Canadian Aquatic Biomonitoring Network (CABIN) to promote standardized sampling and assessment. The CABIN system incorporates all available data on both benthic invertebrates and physical habitat features in a multivariate analysis. Because it uses a wider variety of data than the B-IBI, the CABIN system may be an even more powerful way of assessing a stream's health once calibrated for the Okanagan area.

The CABIN system uses a kick net instead of a Surber net to sample invertebrates in streams. Nevertheless, we analysed the Okanagan stream data with the CABIN system to determine how closely the results would match the B-IBI scores. Despite different collection methods the CABIN analysis for Okanagan sites gave stream condition scores very similar to the B-IBI scores in 81% of the cases.

To increase our confidence in comparing data collected by the different methods, in 2005, we collected benthic invertebrate samples on 10 streams using both a kick net and a Surber net. We then analysed the data from each collection method using the Okanagan B-IBI. For 7 of the 10 streams, the data collected by kick net and Surber net gave identical stream health scores. For the remaining three streams, the scores were similar and within one category.

Thus, while methods of benthic invertebrate collection and analysis may differ, the findings agree that many Okanagan streams, particularly urban ones, are degraded.

To date, we have used the B-IBI due to its wide application in the Pacific Northwest and its applicability to small spatial scales. As well, the CABIN system is currently at the development stage for many areas across Canada including the Okanagan. The CABIN system will continue to be refined. In the interim, the B-IBI provides a useful way to describe stream health.

Using a kick net to sample benthic invertebrates.
Photo credit: Carolyn Johns

How do biological measures compare with conventional monitoring?
Conventional monitoring of streams generally assesses water quality or sediment quality through chemical or physical measures. To determine how biological indicators, such as B-IBI and CABIN, compare with conventional indicators, we did some additional sampling on the Okanagan streams.

At many of the 31 stream sites, we sampled the water for nutrients, bacteria, and metals and the sediments for metals, PAHs, and pesticides.

What Are PAHs?

Polycyclic aromatic hydrocarbons, or PAHs, are a group of over 100 chemicals that result from combustion. The combustion may be natural (forest fires, volcanoes) or man-made (oil, gas, wood, and other fuels).

PAHs find their way into stormwater runoff and then into streams where they repel water and bind to organic sediments. PAHs are used as indicators of stream contamination from urban runoff.

We then calculated the Ministry of Environment's water quality index and the Canadian Council of Ministers of the Environment's (CCME) sediment quality index. We compared the results of these analyses with the B-IBI results. The table below shows the comparison for four Okanagan streams.

Stream	Water quality index	Sediment quality index	Condition from B-IBI score
Peachland	Good	Fair	Excellent
Trepanier	Good	Fair	Fair
Vernon	Fair	Excellent	Poor
Mill	Fair	Marginal	Very poor

While this comparison is limited, it suggests that water and sediment quality indices may overestimate the biological condition of a stream. One sediment contaminant that was much higher in urban streams and is linked to low benthic scores is PAH.

What are the advantages of using biological indicators?

Monitoring stream health with biological indicators differs in many ways from conventional monitoring with water or sediment samples. There are several advantages to using biological monitoring:

- Biological monitoring is more comprehensive in what it measures, because organisms—in this case benthic invertebrates—integrate multiple effects over time.
- Samples can be taken less frequently—every year or even every few years—and still provide valuable information on changes over time.
- Biological sampling done once per year may be more cost effective than repeated sampling of water and sediment for a range of contaminants.
- Once a biological index has been developed and calibrated for a region, it is quick and easy to apply to data.
- Biological monitoring is more effective at giving an early warning about the deteriorating condition of a stream.
- Benthic invertebrates should be the primary monitoring tool where aquatic life is the most sensitive resource.

Benthic invertebrates from an Okanagan stream. Dish is 9 cm diameter. Photo credit: Sue Salter

Summary

- Benthic invertebrates are excellent indicators of stream health, because they respond to conditions in and near the stream and integrate effects over time.
- The Okanagan benthic index of biological integrity (B-IBI) specifically assesses Okanagan streams at low elevations in the valley bottom.
- The Okanagan B-IBI scored 21 of the 31 stream sites (68%) as having fair, poor, or very poor condition. Only 5 scored as good and 5 as excellent.
- The lowest scores were recorded for urban streams such as BX Creek in Vernon, Mill Creek in Kelowna, and Eneas Creek in Summerland.
- Different collection methods, such as the Surber net and kick net, yield similar results for establishing stream condition.
- The lowest scores are likely associated with a variety of stressors such as riparian vegetation loss, channelization, stormwater inputs, and degraded water and sediment quality.
- Urban stormwater is a significant source of PAHs. Urban streams with high PAHs also have the lowest B-IBI scores.

Further Reading

Bennett, S.A. Evaluation of metrics and comparison of two sampling methods for use in the Okanagan B-IBI. Draft report, Jan. 31, 2007. Prepared by BioLogic Consulting, Terrace, for Ministry of Environment, Penticton.

Canadian Aquatic Biomonitoring Network, http://cabin.cciw.ca

Jensen, E.V. *Cumulative Effects Monitoring of Okanagan Streams using Benthic Invertebrates, 1999 to 2004*, B-IBI technical report. wlapwww.gov.bc.ca/sir/pp/envqual/waterqual/monitor_ok_benthic_06.pdf

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

Ministry of Environment, *Develop with Care: Environmental Guidelines for Urban and Rural Land Development in British Columbia,* www.env.gov.bc.ca/wld/documents/bmp/devwithcare2006/develop_with_care_intro.html

Salmon Web: Community-based monitoring for biological integrity of streams, www.cbr.washington.edu/salmonweb/

Stonefly, about 8 mm long.
Photo credit: Shauna Bennett

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