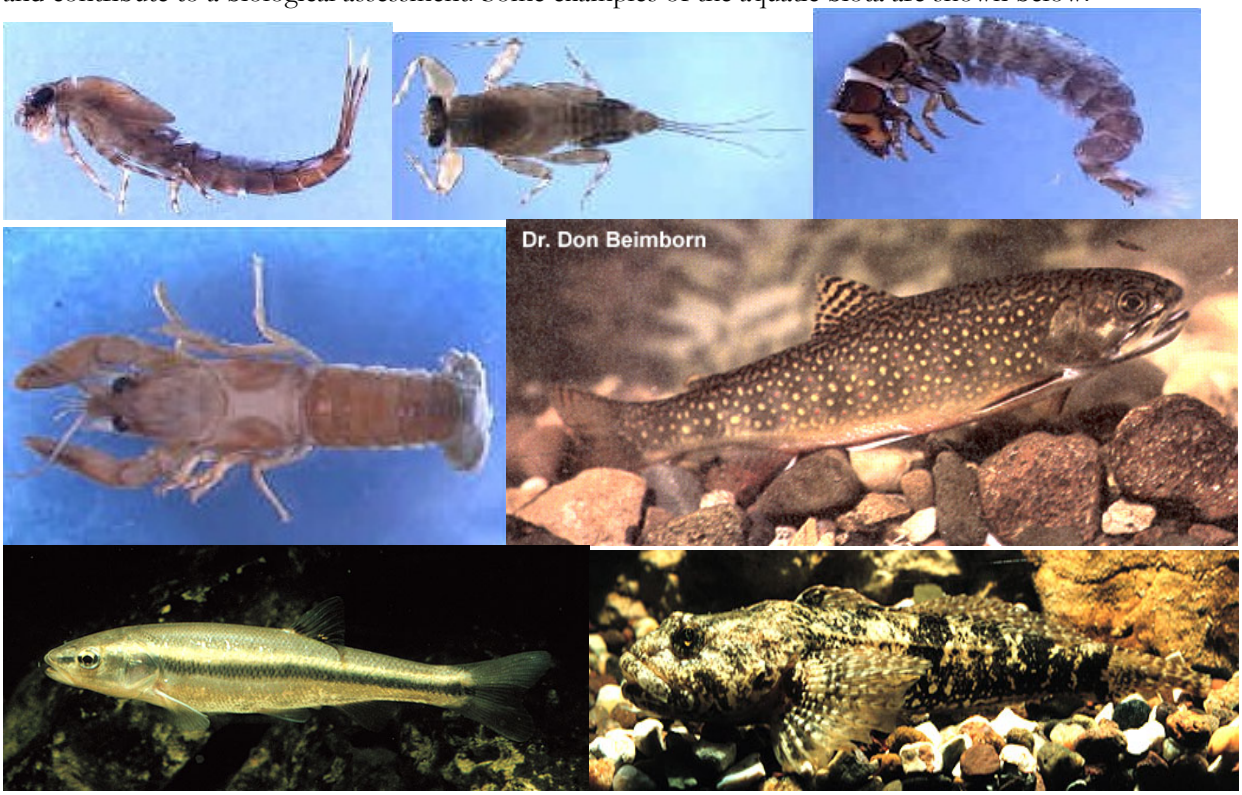
The Use of Biological Assessments by the Vermont Agency of Natural Resources to determine the Status of Streams and Rivers with Respect to the State Impaired Waters List Under Mandate by the Federal Clean Water Act

Introduction

In the 2001-2002 session, Act 109, passed by the Vermont legislature and signed by the governor, effective May 16, 2002, directed the Secretary of the Agency of Natural Resources to submit to the General Assembly a report that outlined the Agency's use of instream biological data in support of additions or deletions from the State's impaired waters list. The USEPA requires states to periodically submit lists of waters that do not meet applicable state water quality standards under authority of Section 303d of the Federal Clean Water Act (1972). In addition to the chemistry-based Vermont water quality criteria, the Agency has developed biological threshold criteria to determine compliance with the State Water Quality Standards (Chapter 3, revised and effective July 1, 2002). This brief report outlines the use of biological criteria and how evaluation of the aquatic biota is used in the placement of a river or river segment on the impaired waters list, and conversely supporting a water being removed from that list.

What are Aquatic Biota?

The biological information used to make river and stream assessments is derived from collections of macroinvertebrate and fish communities. For these purposes macroinvertebrates are defined as those organisms without backbones that are large enough to see with the naked eye and that the majority of their life in the river. Examples include: the larvae of aquatic insects such as caddisflies and mayflies; clams; aquatic worms; amphipods; and crayfish. All species in the fish community, both game and non-game, are collected and contribute to a biological assessment. Some examples of the aquatic biota are shown below.



How are the Aquatic Biota Sampled from a River?

Macroinvertebrates and fish communities are consistently sampled using standardized techniques. Macroinvertebrates are sampled by dislodging organisms from rocks, logs. Plants and other habitat structures and collecting the drifting insects into fine mesh nets. Fish are sampled with a backpack-mounted electroshocker that temporarily stuns fish, which are then collected with dip nets and placed into buckets of water for identification and eventual release**.** Fish are collected in 150-400 foot-long stream sections.

Why sample the Aquatic Biota?

The 1972 Federal Clean Water Act provided the rationale to measure the health of the aquatic biota in stipulating that steps should be taken "to restore the chemical, physical and *biological* integrity of the nation's waters. Until standardized sampling and analytical methods evolved in the mid 1980s, State and Federal Water Quality Standards were water chemistry-based (e.g. specific concentrations of toxins, nutrients and dissolved oxygen). While chemical-based criteria were easily established and understood, two major problems existed with their sole use in protecting our waters. First, although a single water chemistry sample indicates a clear compliance/non-compliance with a standard, it only represents a single point in time; a snapshot of conditions. Chemical variables in running waters vary (sometimes dramatically) by season, by day, and even hour to hour. Therefore, collecting enough data to fully represent stream conditions can be problematic and often unfeasible. Another drawback is that most chemical standards (which remain applicable even in the presence of biological assessment information) were developed to protect the aquatic biota and therefore existed as surrogate measures, with a presumption of aquatic life use support status rather than an assessment of the "real thing". During the 1980s and 1990s, sampling and analytical methods for aquatic biota evolved to the point that accurate measures of community health for both fish and macroinvertebrates could be consistently produced. These measures could then be used in the creation of usable biological criteria to be used in the determination of compliance with State Water Quality Standards.

The use of biological criteria have two primary advantages over the sole use of water chemistry-based criteria:

1. *The evaluation of communities of aquatic biota allows a <u>direct</u> assessment of the original resource that is being protected.*

2. *A single biological sample gives <u>a long-term</u> perspective of overall conditions - not just a snapshot.*

Both macroinvertebrate and fish communities reflect the condition of their environment in a relatively predictable fashion. The biological community from a healthy river, an example of which is pictured below, will have certain attributes related to its species composition and abundance that are characteristic and easily identified by biologists.

The health of fish and macroinvertebrate communities is a direct reflection of many environmental factors both human-induced and natural. Aquatic organisms respond to chemical pollutants from direct and indirect discharges, high loads of sediments, enrichment from excess fertilizers and increased water temperature from removal of streamside vegetation.

A raw bank created by the stripping away of trees and bushes along the stream bank contributes sediment into the stream during high waters. Note the sand bar forming in the foreground.

Excessive sediments from eroding stream banks and other sources can smother fish eggs and fill the spaces between rocks where macroinvertebrates live.

Petroleum products, stormwater, and sediments from urban development contribute to both physical and chemical degradation of aquatic habitat.

Runoff from unwisely planned agricultural activities such as barnyards can lead to excessive sedimentation and unhealthy water quality and habitat for fish and macroinvertebrates.

Agency biologists at the Vermont Department of Environmental Conservation (VTDEC) have developed a set of specific community characteristics, called *metrics* for both fish and macroinvertebrate communities that accurately measure community health, often referred to as the biological integrity of the community. Values of these metrics are sensitive to changes in environmental quality. Impaired sites will exhibit a certain characteristic range of metric values that differentiates them from unimpaired sites. By identifying these critical ranges of community metrics through statistical methods, the Agency was able to derive threshold criteria that correspond to each of the water management types contained in Class A and B WQS.

Example Metrics used by the VTDEC to measure the biological health of stream and rivers.

Macroinvertebrates	Fish
Number of individuals collected	Number of individuals collected
Number of species or types collected	Number of species collected
Proportion of community made up of intolerant forms	Number of intolerant species collected
Proportion of community made up of tolerant forms	Proportion of tolerant species collected
Average pollution tolerance of all species	Proportion of pollution tolerant and intolerant feeding types
Similarity of community species to the appropriate reference community	Proportion of trout or other carnivores
Similarity of community functions to the appropriate reference community	Proportion of diseased or abnormal fish from sample

What is meant by the term "Biological Health"?

How close to its reasonably attainable potential is the biological health of a disturbed stream? The Agency answers this question by comparing numeric biological criteria from disturbed streams with ranges of the same numeric criteria representing minimally disturbed conditions. An important principle in creating numeric biological criteria based on metrics is that of using a standard or *reference* ideal by which to compare sites. The biological reference condition is represented by Vermont waters that are least impacted by human activities. Reference rivers and streams are essentially the best (healthiest) waters in the state and support biologically healthy communities. Since the reference condition is defined by Vermont conditions, it therefore represents realistic and attainable potential. Successive departures from the reference condition are allowed in the WQS in the current water management type structure, as discussed later.

How are Biological Assessments made ?

Agency biologists selected data from nearly 100 reference sites statewide to develop expectations for metric values that are representative of the reference condition. Because the makeup of aquatic communities in reference rivers normally differs between types of streams, reference metric expectations were adjusted by river community type. A small coldwater stream draining the Green Mountains will support different species (and therefore slightly different community metric values) than will a lowland warmwater river in the Champlain Valley. As an example, there are at least four basic macroinvertebrate reference stream categories, each with a slightly different set of reference metric threshold criteria; they are:

1. Small High Gradient Streams

2. Medium Size High Gradient Streams

3. **Warmwater Streams and Rivers**

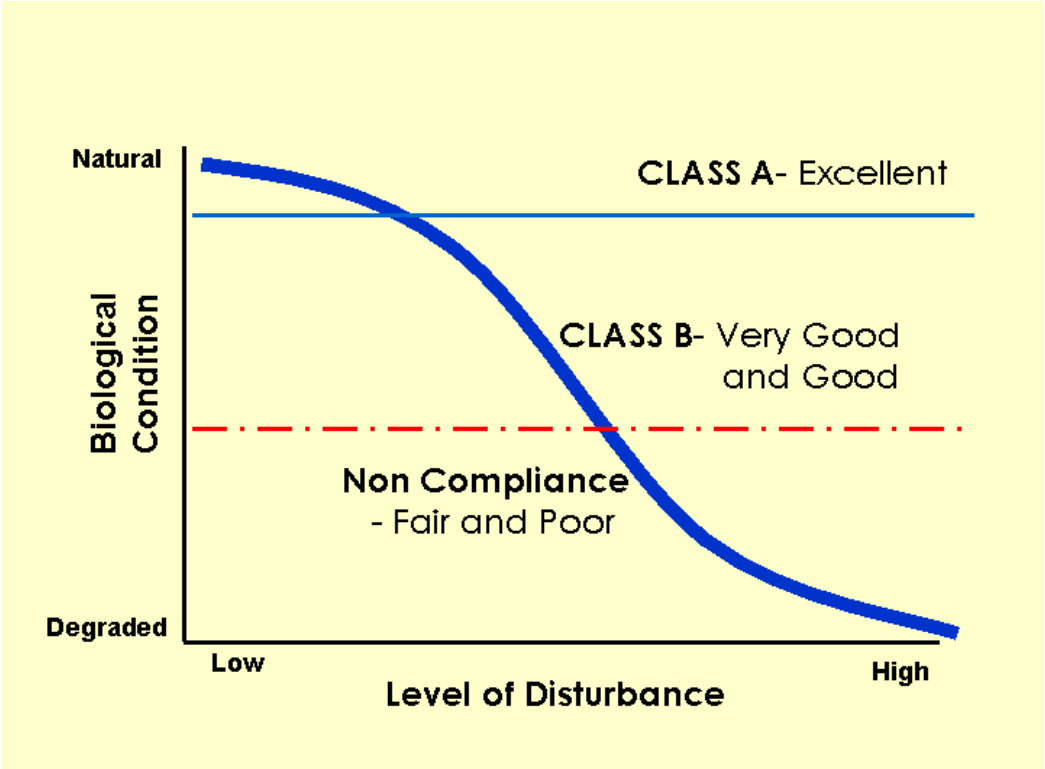
4. Slow Winders - *silt or sand bottom, low-gradient streams*

When a river site is sampled, the resultant fish or macroinvertebrate data (metric values) are compared to the expected values from the reference condition for that particular river type. The amount of deviation between the sampled site data and the range of reference metric values is then compared to the designated water management type threshold criteria for that river reach in determining compliance with the appropriate class standard. The following table shows the narrative biological criteria contained in the Vermont WQS. The numeric threshold criteria were devised to quantitatively define these narratives.

Narrative Biological Water Quality Standards for each Water Management Type for Vermont surface waters. Class B, type 1, and Type 2, 3 represent successively greater departures from the range of reference metric values and thereby the criteria can be regarded as less rigorous than that of Class A waters.

Class A Waters		**Class B Waters**	
Water Management *Type - 1* (Ecological)	Water Management *Type - 2* (Water Supply)	Water Management *Type - 1*	Class B and Water Management *Type -2 and 3*
Measures of biological integrity for fish and macroinvertebrate assemblages are *within the range of the natural condition.* [*Reference Condition*]	*Moderate change* from the reference condition for macroinvertebrate and fish assemblages.	*Minor change* from the reference condition for macroinvertebrate and fish assemblages.	*Moderate change* from the reference condition for macroinvertebrate and fish assemblages.

The following graph shows the relationship between the disturbance of the aquatic habitat and the resultant health of the aquatic biota. With increasing habitat degradation (from one or more impacts) the aquatic community (as depicted in changes in metric values) responds in a predictable fashion. As the graph line progresses on its downward leg, the level of departure from the reference condition increases. At fixed points along this slope threshold criteria are exceeded for type A-1 (excellent), Type B-1 (very good), and Type B-2,3 (good)- respectively. Sites rated are Fair or Poor are considered to be impaired.



The raw data collected from streamside is entered into a computer database program which calculates biological community metrics. The integrity of the macroinvertebrate community is characterized by eight metrics. Each one of these eight metrics was statistically shown to be sensitive to changes to shifts in community structure that result from physical or chemical degradation of the aquatic habitat. The fish community is described by a total of 12 metrics. The fish metrics are different from the macroinvertebrate metrics, but have also been shown to measure community response to environmental impact. The table on page 4 summarizes the types of biological metrics used by the Agency to assess biological health in streams and rivers. Note that the table lists general types so that a metric type may be represented by more than one actual metric.

How is the Determination of Compliance From Biological Information Made?

Biological metric values from a sampled stream or river site are compared to the appropriate threshold criteria for that particular water management type. Metric values must meet or exceed the minimum threshold criteria to meet the management objectives for that water management type. The final determination of compliance is made only after agency biologists have reviewed the results. A final 303(d) listing determination is based on a "weight-of-evidence" finding that combines biological assessment data with additional site information regarding the intensity, frequency, and duration of observed impacts.

In the absence of statistically-derived threshold criteria, best available data regarding biological condition and appropriate reference conditions are applied to develop "weight-of-evidence" findings relative to the degree of biological impact and 303(d) listing category.

There are **three general outcomes** or findings possible, resulting from a biological assessment
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Biological Assessment Finding	Explanation	Outcome
1. IMPAIRMENT	Biological assessment clearly indicates that **narrative criteria *are not met*** and that there is no evidence that factors other than **pollutant impact** are responsible for the determination. In this instance the data indicates **failure of several metrics** to meet threshold criteria by a **significant margin** or **over multiple years and/or locations**.	The designation of impairment **requires inclusion on the State 303(d) list.** An appropriate plan for attaining standards (eg. TMDL, watershed permit, water quality restoration plan) must be developed for each impaired waterbody.
2. UNDETERMINED STATUS WITH PROBABLE IMPAIRMENT OR NON-IMPAIRMENT.	Biological assessment indicates that no firm determination on whether or not the narrative criteria have been met can be made for reasons including but not limited to: inadequate data quality; unknown source of impairment; natural site limitations; closeness of metric values to threshold criteria, Most often this outcome is brought about by the site metrics barely passing or barely failing the threshold criteria.	Further biological assessment sampling needs to be made before a final determination can be made.
3. NON-IMPAIRMENT	Biological assessment data clearly indicates that narrative criteria are being met by a significant margin.	No further consideration Needed.

What are the Data Qualities needed to make a determination of Compliance?

The biological collection data is examined for quality (was the sample taken in accordance with accepted methods?, was it representative of actual stream conditions?). If the sample taken was adequate, the next step is to consider the extent of deviation from the threshold criteria-how many metric criteria were not met? How close to the criteria were the metric values?. Additional information about the site is also considered such as existing chemical, physical, and biological data.

It should be understood while firm, scientifically determined numeric threshold criteria exist that interpret the narrative criteria contained in the WQS, that final determinations of compliance are not made until the data has been thoroughly reviewed by trained biologists and evaluated using best professional judgement. Currently, before a site gets placed on the impaired waters list it must fail the biological assessment threshold criteria at least two years in a row (in some cases, sites exhibiting significant impairment may be listed after a single year's data). This is felt to be a necessary step since biological data is susceptible to natural variation and metric values that lie on the margin generate low confidence. The ultimate goal of the Agency's evaluation is to assure that the observed impairment is truly a result of disturbance rather than natural variation.

How Much of the River is Represented by a Single Biological Sample?

There is no single universal answer to this question. Biological data is representative of conditions and indicative of impact from upstream areas since waters flows down gradient. Factors affecting the extent of river represented by a sample include number and size of tributary streams emptying in to the river, effects of groundwater entering the river, and the location of potentially polluting discharges into the river. Ideally a river or stream should be sampled at many locations along its length to allow for an accurate accounting of the health of the aquatic biota. In some cases with sufficient longitudinal biological data, some streams sections can be identified as not meeting standards while others meet criteria. This allows the efficient pin-pointing of restorative efforts preventing the application of restoring activities in stream reaches where they are not needed. When designating the extent of an observed impairment, available chemical, physical, and biological data are used to estimate the extent of the impacts. Additional information that may be used in determining extent includes but is not limited to: land use; location and character of known discharges; geomorphic and riparian corridor condition.

How Old can assessment data be to provide a Realistic Evaluation of Current Condition?

The Agency starts by evaluating any data that is available for the preceding five years. All historical data points are evaluated for consistency with current methods and to what extent this information is likely to reflect current conditions. The most recent representative data are given greater credibility. In some instances, data available from the previous ten years, when available, are considered in order to provide additional input to assessments of impairment. In most cases, data older than ten years old are not considered.

How are waterbodies removed from the 303(d) list based on Biological Assessments?

The same methodologies described above are used for adding or subtracting waterbodies from the 303(d) list.

The following attachments provide examples of how individual waterbody assessments are made in order to determine impacts and provide more detail into the development and implementation of biological assessments by ANR.

Attachment 1: Lord' Brook – new 2002 listing – impaired

Attachment 2: Winooski River – new 2002 listing – no longer impaired

Attachment 3: A summary of the proposed State 2002 303(d) List and the number of waters represented in each section.

Attachment 4: Executive Summary – Wadeable Stream Biocriteria Development for Fish and Macroinvertebrate Assemblages in Vermont Streams and Rivers

Attachment 5: Procedures for Determining Aquatic Life Use Status in Selected Wadeable Streams

Attachment 1: Biological assessment summary fact sheet – Lord's Brook 2002

I. Current condition and status

1. Description of impaired water body

   - Lord's Brook, tributary to West Branch of the Ompompanoosuc River;
   - From mile 0.2 to mile 3.3, just below Elizabeth Mine south cut drainage;
   - Classified as Class B/Coldwater fish habitat water pursuant to the Vermont Water Quality Standards;
   - Segment is designated Small High Gradient wadeable macroinvertebrate stream type and as Cold Water Index of Biotic Integrity (CWIBI) wadeable fish community stream types for the purposes of biological community assessments;
   - Segment is located just below an area where copper mine drainage from the "south cut" of the Elizabeth Mine complex enters Lord's Brook.

2. Description of Data used to characterize impairment.

   - Macroinvertebrates – Three sites on Lord's Brook were assessed in 2000;
   - Fish - Three sites on Lord's Brook were assessed in 2000;
   - The same three sites were assessed for both fish and macroinvertebrates. Sites were located above, immediately below, and approximately 3 miles below the point where mine drainage from the "south cut" entered Lord's Brook;
   - Both the macroinvertebrate and fish communities were assessed as excellent immediately above and three miles below the drainage discharge.
   - Just below the point where the drainage enters Lord's Brook, the macroinvertebrate community was assessed as "fair" and the fish community "poor". Field observations indicated that visual impacts were evident and apparently very persistent. Water quality monitoring data also showed consistent exceedences of WQS's presumed to have adverse effects on biological communities.

3. Summary statement - overall "weight-of-evidence" summary of findings from 2 above:

   - Biological and chemical assessment data for Lord's Brook provide the basis for a designation of impairment. These data are of high quality. Impacts to the fish community are severe (extremely few fish present), and the field observation of habitat condition suggest that this condition is persistent over time.

4. Confidence: past, present, future:

- DEC has high confidence in the application of biological assessments to Lord's Brook at this site. DEC is confident that the reference conditions and evaluations applied to these assessments are appropriate.
- DEC is highly confident that an assessment of impairment of aquatic life use as measured by macroinvertebrate and fish condition, as well as water chemistry, is accurate and representative of current conditions at this site

5. Recommendations - recommended assessment needs:

- Based on the above assessment, the stream segment below the mine drainage discharge, between miles 0.2 and 3.3, or some portion thereof, should be proposed for addition to the 303(d) list.

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Attachment 2: Biological assessment summary fact sheet – Winooski River near Gallison Hill Road, East Montpelier 2002

I. Current condition and status

4. Description of impaired water body

    - Winooski River, Gallison Hill Road vicinity, Town of East Montpelier;
    - From the vicinity of Gallison Hill Road upstream for one mile;
    - Classified as Class B/Coldwater fish habitat water pursuant to the Vermont Water Quality Standards;
    - Segment is designated as most probably a Warm Water Moderate Gradient (WWMG) wadeable macroinvertebrate stream type (site is located in a transition between WWMG and MHG, with highest probability of being WWHG) and as Mixed Water Index of Biotic Integrity (MWIBI) wadeable fish community stream types for the purposes of biological community assessments;
    - Segment is located adjacent to Central Vermont Landfill.

5. Description of Data used to characterize impairment.

    - Macroinvertebrates – three (3) assessments at two adjacent sites;
    - Two sites were assessed in order to evaluate impact of landfill leachate on the biota of the Winooski River;
    - A 1992 macroinvertebrate assessment of "fair" provided the basis for the original listing of this site on the 303(d) list. Two additional macroinvertebrate assessments conducted in 1993 and 2000 have resulted in assessments of "good" and "very good" respectively.
    - Observations by field staff indicate that visual impacts from landfill leachate were not evident at this site; some evidence of moderate enrichment and fine siltation;

6. Summary statement - overall "weight-of-evidence" summary of findings from 2 above:

    - Biological assessment data for the Winooski River in the vicinity of the Central Vermont Landfill provide the basis for non-impairment designation. These data are of high quality and demonstrate a pattern of non-impairment over time (2 assessments over 7 years). The current data indicate that impairments previously identified in this river segment are no longer present.

7. Confidence: past, present, future:

    - DEC has high confidence in the application of biological assessments to the Winooski River at this site. DEC is confident that the reference conditions and WWMG macroinvertebrate evaluations applied to these assessments are appropriate for this stream reach.
    - DEC is highly confident that an assessment of non-impairment of aquatic life use as measured by macroinvertebrate condition is accurate and representative of current conditions at this site

8. Recommendations - recommended assessment needs:

    - Based on the above assessment, this site is no longer impaired and should be proposed for removal from the 303(d) list.

    - This stream reach should continue to be monitored as part of the Agency's 5-year rotational watershed monitoring program.