Appendix 14. Biological Community Assessments and Calculations of Metrics

Biological Community Assessments and Calculations of Metrics

How Water Quality is Measured: Abiotic and Biotic (Biological Community) Assessments

The VT Water Quality Standards are a set of regulations that classify each waterbody, establish uses (such as swimming and fishing) that must be protected, and set standard criteria for chemical, physical and biological attributes of state waters that must be attained. The federal Clean Water Act (CWA) regulations do not generally protect man-made water-bodies unless they are connected to other bodies or water, but the state law covers small farm ponds under surface water as a water of the state.

When water quality is assessed, water samples, typically tested for abiotic factors such as temperature, dissolved oxygen, pH, and nutrient, bacteria, and turbidity levels, give us information about a single point in time. We can determine, at that moment the sample was taken, the water quality in the system. This information is valuable, especially in understanding whether or not it is safe to swim and recreate in the rivers and streams assessed. After collecting samples over years, or above and below potential problem areas in the watershed, trends begin to emerge. Understanding a longer-term history of the water quality and overall watershed health also requires the assessment of the biota (living organisms) in the rivers and streams. These assessments are called Biological Community Assessments. Macroinvertebrates (aquatic insects such as dragonflies, damselflies, mayflies, stoneflies, and caddisflies) are one such *bioindicator,* living organisms which can tell us about health of the rivers and streams to support life. Macroinvertebrates are key indicators of water quality and aquatic habitat conditions because their life histories often contain both aquatic and terrestrial stages, and because of their limited mobility in their aquatic forms. Their limited mobility in this phase of their life cycle generally confines insects to one area of a river or stream; therefore, their presence is usually indicative of the water quality and habitat conditions where they are found. Alternatively, fish are more mobile and may only be passing through an area when they are sampled, so not necessarily residing there. As such, fish communities may also provide information about the larger watershed, not just about the reaches of rivers and streams where they are found. More information about using organisms for assessment is included below.

The Vermont Water Quality Standards (effective date December 30, 2011) provide the authority and basis to use communities of aquatic insects (macroinvertebrates) and fish to measure the quality of Vermont's rivers and streams. The Water Quality Standards also empower the Secretary of the Vermont Agency of Natural Resources to authorize the use of these numerical biological indices, which measure different aspects of biological communities such as the number of individuals within a species, the number of species, and the tolerance to pollution of the species present, to determine whether the biological communities indicate that the stream is fully supporting its "aquatic life use" classification (e.g., Class A(1), A(2), or B). The responsibility of monitoring the aquatic communities and relating the data to the water quality standards falls on the Watershed Management Division of the Vermont Department of Environmental Conservation (DEC). DEC Biologists use a set of established methods and statistical analyses to assess the condition of biological communities across the state. These consistent methods provide an indication of the quality of the water as well as the condition of the aquatic habitat for all plants and animals that live in these environments. An outline of how these metrics and indices are calculated is below. For a full description of methods and analyses, see the 2003 Report from the DEC.

Biological assessment (or "bioassesssment") of aquatic habitats is an effective indicator of water quality and habitat condition because species differ in their tolerance for different "stressors" that degrade aquatic habitat. Species can be sensitive, somewhat sensitive, or tolerant to a variety of stressors and pollutants in rivers and streams. The species found in a biological (especially those that tend to dominate over multiple assessments) can tell you whether the quality of the water being assessed is excellent, very good, good, fair or poor. For example,

- Many species of stoneflies (order Plecoptera) are very sensitive to levels of dissolved oxygen and will not be found in streams where dissolved oxygen is not present in adequate levels. (Very high temperatures, stagnated water or chemical pollutants may affect oxygen levels in surface waters).

- Some species of mayflies (order Ephemeroptera) are sensitive to acidic waters and will not be found in streams with acid impairment. (Mayflies are one group of macroinvertebrates very important to fish, and many people who fly fish try to time their fishing during hatches [mass emergence] of these insects.)

- Midges (Order Diptera, family Chironomidae) are a very common fly that exists in many types of aquatic habitats. Several species of midge are tolerant to organic pollution such as nutrient enrichment. (The presence of large numbers of midges suggests that there may be nutrient issues in the watershed.)

- Native brook trout and other salmonid fish, characterized by their tendency to swim upstream in fresh water to spawn, are generally sensitive to changes in water temperature. In order for a river or stream to have suitable habitat for brook trout, the water must not be too warm (the upper limit for suitable water temperature for brook trout is usually 65-72°F) for extended periods of time. (A vegetated riparian (riverside) buffer, such as the silver maple trees shading some areas of the Missisquoi River, helps to keep the water temperature at a level which can sustain trout populations.)

- Presence of largemouth bass and yellow perch indicate warm water temperatures for a significant portion of the year. (These species are found more frequently in lakes, ponds, and slower-flowing sections of rivers and streams).

Using numerical values related to the presence of various species found in a stream, biologists calculate "metrics" which provide numerical scores of the quality of the water and habitat. This is how scientists are more easily able to compare one water body to another, or compare the present water quality of a water body to historical records. For some metrics, species are assigned a tolerance value from 0 to 10 based on their level of tolerance to pollution. A score of 0 means that the species is generally intolerant of any pollution, and a score of 10 indicates that the species is very tolerant of pollution and its presence is likely indicative of severely degraded habitats. Low tolerance scores for the entire stream community can be a general indicator of low levels of aquatic pollution. For other metrics, the method of feeding (or "functional feeding group") is used to calculate scores for the sample. For example, the percentage of species in a macroinvertebrate community that graze the surface of rocks in the stream bottom for algae ("scrapers") will generally decrease as a stream becomes more polluted. Conversely, the proportion of scavengers and generalist feeders will often increase in as water quality declines. To properly evaluate a stream community several metrics are used for each stream sample so that a variety of characteristics about the river and habitat may be measured. Though this type of sampling takes time, it provides a more complete picture of the health of the water body than abiotic sampling alone could produce.

Macroinvertebrate Community Assessments

Macroinvertebrates (aquatic insects) are most often juvenile life stages of insects such as mayflies, stoneflies, caddisflies, dragonflies and other insects that spend the first portion of their lives in streams before they emerge from the water as the winged adults which are often seen near waterways. Macroinvertebrates are especially useful as indicators of water quality, because they spend most of their lives (as eggs, larvae and adults) in or near the water where they're found. This means that their presence in a water body provides long-term information about the quality of the river or stream, as opposed to a chemical analysis which is more of a 'snapshot' sample that reflects present conditions on the day of sampling.

The Vermont Department of Environmental Conservation (DEC) assesses the water quality of Vermont's surface water typically on a 5-year rotating basis. When sampling a stream or river reach, DEC scientists use eight separate measurements, called metrics, to score and evaluate the macroinvertebrate community. Each metric (such as pollution tolerance, biological diversity, and feeding preference) independently measures a different aspect of the community structure, and therefore a different aspect of water quality and habitat condition. The various metrics are calculated to assess interactions between the macroinvertebrate communities and their waterway such as:

- The pollution tolerance of the resident macroinvertebrates - this evaluates the level of organic and/or inorganic pollution present in the stream
- The taxonomic structure of the macroinvertebrate community - this evaluates the biological diversity (number of different species) within the community
- The composition of various feeding guilds present within the macroinvertebrate community – understanding the number of individuals with a particular feeding type (grazers, scavengers, predators…) allows scientists to evaluate the prevalence of different trophic (feeding) levels in the habitat and help evaluate the amount of pollution and the health of the macroinvertebrate community

For each measurement, threshold scores have been set to determine whether or not the community meets the standard for this measurement. These values are based on data from reference streams (high quality streams similar to the one studied), which are in minimally disturbed watersheds where the macroinvertebrate community exists in close-to-natural condition. Since stream-dwelling animals will vary with stream type, thresholds have been established for three types of streams that are common in Vermont: Small High Gradient, Medium High-Gradient and Warm-Water High Gradient. Metrics for slow-gradient streams are in development at the time of publication of this Management Plan.

A stream site will receive a pass or fail grade for each of the eight macroinvertebrate metrics based on the standards set for each stream type. If the score for a metric exceeds the threshold score, it will "pass"; if the metric score does not meet the minimum score for that stream type, it will "fail" for that particular metric. Whether or not a stream reach is determined to *Support Aquatic Life Use* (meet water quality standards) or *Not Support Aquatic Life Use* (fails to meet water quality standards) depends on how many metrics are determined to pass:

- Aquatic Life Use is *supported* when five or more metrics pass and none fail
- Aquatic Life Use is *not supported* when one or more metrics fail

- If a community is not found to meet either of the above criteria, the DEC will make an *indeterminate* designation for the stream and it will require further assessment

Fish Community Assessments

Fish metrics are calculated similarly to macroinvertebrate metrics, and represent various aspects of the structure of fish communities and their interactions with their environment. Information on native species abundance, tolerance of resident fish species to different stressors , diversity and density of fish species and the presence of differing trophic (feeding) levels are all included in the metrics for fish community evaluation. The Vermont DEC compiles fish metrics into an Index of Biotic Integrity (IBI), which provides a single score that is the combination of all fish metrics. When the IBI is compiled, each fish metric will receive a standard score of 1, 3 or 5 which is based on the data generated in the field survey conducted by state scientists. These calculations are outlined in the tables and examples below. The VT DEC uses two fish IBIs: one for cold water fisheries (CWIBI) and one for mixed water fisheries (MWIBI). For the purposes of applying an IBI, all *wadeable* streams in Vermont located at elevations of over 500 feet will be designated as cold water; this applies to streams in the Study area. Many of the streams in the Study area are above 500 feet and thus considered cold water fisheries (excluding Enosburg Falls which is below 400 feet). All streams below 500 feet are classified as warmwater streams unless naturally-reproducing coldwater species are present. The indices are not designed for slow- flowing, sand-bottomed streams or large non-wadeable rivers.

Calculations for the two indices are summarized in below. For a thorough description of the IBIs, their calculation and utilization in determining aquatic life use standards, please refer to the original VT DEC document.

Cold-Waters Index of Biotic Integrity (CWIBI)

Table A14.1. The CWIBI for fish is calculated as follows:

CWIBI - For cold water streams naturally supporting from two to four native fish species	**Score for Metric**		
Metric	**5**	**3**	**1**
1. Number of intolerant species (one exotic trout species may be substituted for brook trout)	2	1	0
2. Proportion of individuals as coldwater stenotherms (survive in limited temperature range)	> 75%	50-75%	< 50%
3. Proportion of individuals as generalist feeders	< 5%	5-9%	> 9%
4. Proportion of individuals as top carnivores	> 35%	25-35%	< 25%
5. Brook trout density (#s/100m^2-1 pass)	> 4.0	2.0-4.0	< 2.0
6. Brook trout age class structure (young-of-the-year = < 100mm, adult=>100mm); [yoy = Young of Year]	yoy and adults present	yoy only	yoy absent

Example: If a fish survey on a reach on the Missisquoi River yields:

1. 1 intolerant species (score of 5)
2. 78% of the fish are coldwater fish species (score of 5)
3. <5% of which are generalist feeders (score of 5)
4. 30% are top carnivores (score of 3)
5. Brook trout density is 3 (score of 3)
6. YOY and adults are present in the stream (score of 5)

The total score is 26. If you multiply this by 1.5 (see Table 14.3), the CWIBI = 39 which indicates *Very Good* water quality.

CWIBI Conditions for Use:

1. Only fishes over 25mm (about 1 inch) in length should be considered
2. Only naturally reproducing salmonids are to be considered
3. Only species represented by more than a single individual will be entered into metrics 1 and 6
4. Since the number of metrics differ between IBIs, the CWIBI scores are multiplied by 1.5 so that cold water sites scores are comparable with mixed-water site scores (MWIBI).

Mixed-Waters Index of Biotic Integrity (MWIBI)

Fish Community Assessments

Rich Langdon from the ANR notes that the IBIs apply only to wadeable waters, approximately a water level at knee height. Only portions of the Missisquoi River small enough in which to wade are assessable using the IBIs. All of the Trout River and much of the upper Missisquoi River from the headwaters to Troy/North Troy are wadeable. Determining which to use requires initial sampling of the native fish species present (2-4 species is the CWIBI and >4 MWIBI. The lower reaches of the Trout River are assessable using the MWIBI, and the upper reaches using the CWIBI.

The calculation of the MWIBI is more intricate, as it represents a greater diversity of species, habitats and water conditions than the CWIBI. There are more metrics (nine instead of six), and any metrics have two separate thresholds based on elevation or size of the watershed. The metrics in the MWIBI are parsed into three main categories:

- Species richness and composition: evaluates the number of native species, number of species intolerant and tolerant of pollution, and the number of species that indicate a well-functioning fish community
- Trophic Composition: examines the structure of the community from the perspective of the various feeding guilds present in the resident fish species
- Fish Abundance and Condition: measures 1) the total number of fish caught in the sample, and 2) the occurrence of abnormalities in individual fish, which may be indicative of toxins in the water body

Table A14.2. The scoring for the MWIBI for fish is calculated as follows:

For mixed-water streams naturally supporting more than four native species				Score for Metric		
Metric Category	***Metric***	***Site Elevation Criteria***		**5**	**3**	**1**
Species Richness and Composition	1. Total number of native fish species	n/a		*Follows maximum species richness lines*		
	2. Number and identity of native, intolerant species (*A non-native trout may be substituted for brook trout when absent*)	>400 ft		>1	1	0
		<400 ft		>0	--	0
	3. Number and identity of native benthic insectivores (bottom dwelling insect eaters)	<400 ft., Site drainage <25 km^2		>0	--	0
		All other sites		>1	1	0
	4. Proportion of individuals of white suckers and creek chubs (more tolerant species)	n/a		<11%	11-30%	>30%
Trophic Composition	5. Proportion of individuals as generalist Feeders	>500 ft		<20%	20-45%	>45%
		<500 ft		<30%	30-60%	>60%
	6. Proportion of individuals as water column and benthic insectivores (score a "1" if blacknose dace is >60% of total assemblage or 100% of insectivores)	>500 ft		>65%	30-65%	>30%
		<500 ft		>55%	20-55%	>20%
	7. Proportion of individuals as top carnivores (*Non-native trout included)*	Cold water assemblage		>15%	5-15%	<5%
		Warm water assemblage, site drainage >25 km^2.		>10%	3-10%	>3%
		Warm water assemblage, site drainage <25 km^2		0	-	-
Fish Abundance And Condition	8. Proportion of individuals with Deformities: fin erosion, lesions or tumors	n/a		>1%	1-4%	>4%
	9. Abundance in Sample (100m^2 sampling area) (*non-native species included*)	Site Elevation <500 ft		>20	10-20	<10*
		Site Elevation <500 ft	Alk. >9 mg/L	>10	7-10	<7*
			Alk. >9 mg/L	>6	3-6	<3*

*If these scores are obtained, the site is automatically scored "Poor".

MWIBI Conditions for Use:

1. For wadeable streams only
2. Site should naturally support at least five native species
3. Only individuals more than 25mm (about 1 inch) total length are to be entered into the score
4. Only species with more than one individual captured are entered into the score
5. Stocked fish are not considered in determinations

Since the number of metrics differ between IBIs, the CWIBI scores are converted so that cold water sites scores are comparable with mixed-water site scores (Table A14.3 below).

Table A14.3. An example site calculation for converting the CWIBI. Multiplying the CWIBI scores by 1.5 makes them compatible with MWIBI scores so that sites across habitat types may be compared. The factor of 1.5 is accounted for by the different number of metrics in each IBI; there 6 in CWIBI and 9 in MWIBI.

Metric	**Actual Data from Field Survey**	**Metric Score**	**Converted Metric Score**
1. Number of intolerant species	1	3	4.5
2. Proportion of individuals as coldwater stenotherms (survive in limited temperature range)	80%	5	7.5
3. Proportion of individuals as generalist feeders	10%	1	1.5
4. Proportion of individuals as top carnivores	37%	5	7.5
5. Brook trout density (#s/100m^2-1 pass)	4	5	7.5
6. Brook trout age class structure (young-of-the-year = < 100mm, adult=>100mm)	yoy only	3	4.5
Total Site Score		22	**33**
Community Ranking		***Good***	

Table A14.4. Fish Community Ranking and the comparable IBI scores:

CWIBI Score	**MWIBI Score**	**Fish Community Ranking**
42-45	41-45	*Excellent*
36	37	*Very Good*
33	33	*Good*
27	27	*Fair*
<27	<27	*Poor*

As with the macroinvertebrate metrics, the fish IBIs are used to assign an overall water quality ranking to a stream reach (see the Table below). The rankings are based on the overall IBI score, and are presented below. **Sites that have been identified as *Very Good* and *Excellent* have been selected for Water Quality ORVs in this Management Plan.**

Using Fish Indices to Determine Support of Water Quality Standards

All possible scores for Coldwater and Mixed-water Indices of Biotic Integrity and the corresponding water quality classification contained in the Vermont Water Quality Standards are presented in the table below. If a site meets the required score for its corresponding Water Quality Standard (e.g., A(1), B(2), etc.), then it supports its designated aquatic life use standard established under the Clean Water Act and Vermont Water Quality Standards. If the score fails to reach the corresponding standard for the water body, then that water body is in "non-support" of its designated water quality standard use and is placed on the 303d list.

The 303d List

Failing during the assessment of a Biotic Index is one way a water body is determined to be "impaired." In this instance, it is the aquatic life "use" that the waterbody fails to attain, thus it is added to the 303(d) list of impaired waters that is reported to and approved by the EPA annually. This list contains all waters identified as impaired in Vermont, and may be found in Appendix 17. For many of these impaired waters, depending on the impairment, TMDLs (Total Maximum Daily Loads) are established. TMDLs are the maximum levels of pollutants allowed into surface water in order to get the waterway back in compliance with water quality standards.

Scores in the table below range from 9 (very poor) to 45 (excellent).

Table A14.5. Table 8 from the 2004 report *Biocriteria for Fish and Macroinvertebrate Assemblages in Vermont Wadeable Streams and Rivers* by the Water Quality Division of the VT DEC found on their website (http://www.vtwaterquality.org/bass/docs/bs_wadeablestream2.pdf).

Water Quality Standards Classification Range	Range	Possible Scores	
		CWIBI	MWIBI
A-1	41-45	42, 45	41, 43, 45
Best professional judgment determines placement into A-1 or B1 designated use criteria	39	39	39
B-1	36-37	36	37
Best professional judgment determines placement into B1 or A2, B2-3 designated use criteria	35		35
A-2, B-2, B-3	33	33	33
Best professional judgment determines placement into Class B-2,3 or Non-Support	29-31	30	31, 29
Non-Support	<29	27, 24, 21, 18, 15, 12, 9	27, 25, 23, 21, 19, 17, 15, 13, 11, 9