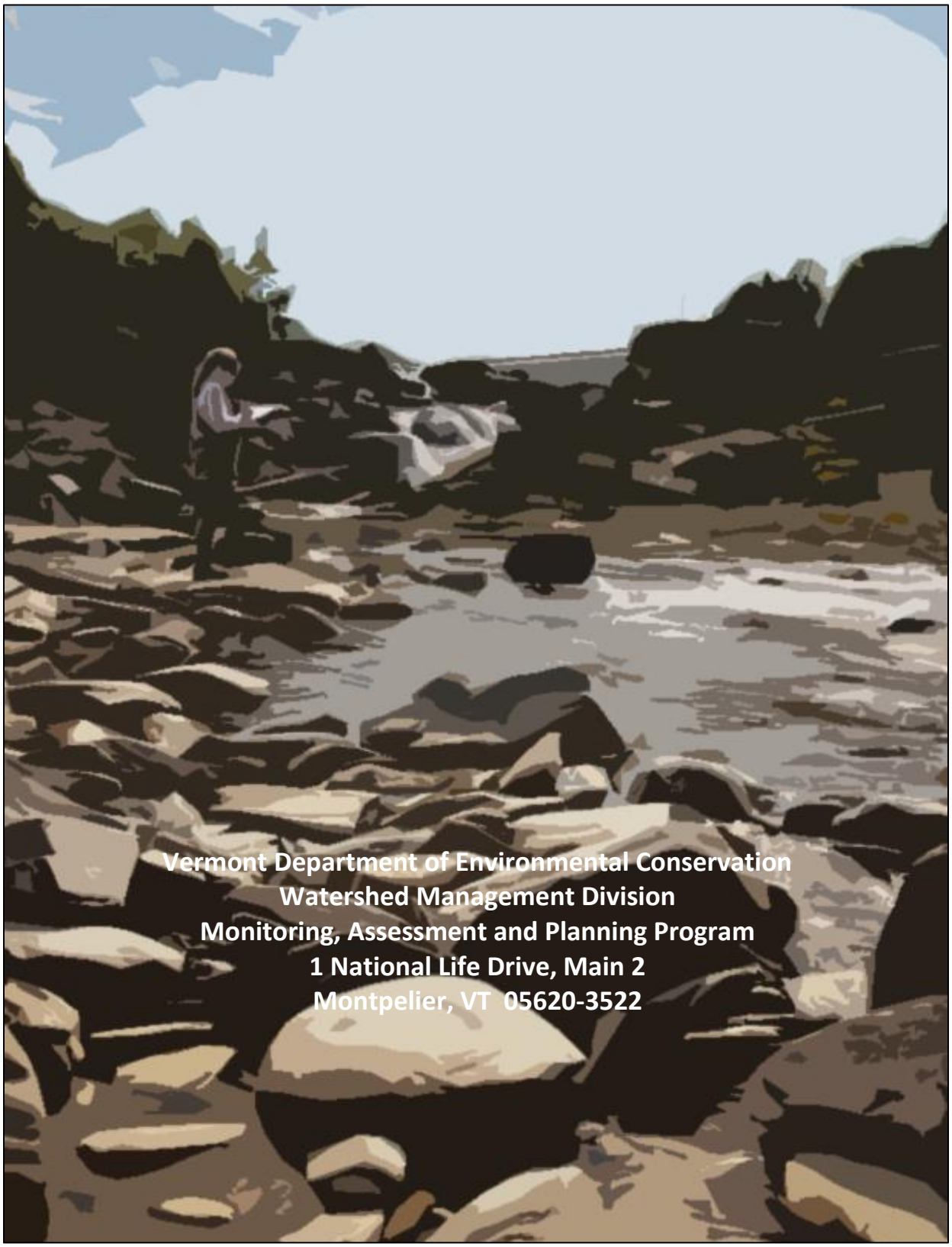
Assessing the Biological Condition of Vermont's Wadeable Streams 2008-2012:

Results of a statewide probability-based survey



Vermont Department of Environmental Conservation
Watershed Management Division
Monitoring, Assessment and Planning Program
1 National Life Drive, Main 2
Montpelier, VT 05620-3522

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ACKNOWLEDGEMENTS

The completion and analysis of this survey is the result of the collaborative efforts of many groups and individuals. Primary thanks goes to the members of the Vermont Department of Environmental Conservation (VTDEC) Biomonitoring Section (past and present) that helped coordinate the survey and perform the field sampling and laboratory processing to produce the final data: Doug Burnham, Katie Chang, Jim Deshler, Brian Duffy, Steve Fiske, Neil Kamman, Jim Kellogg, Rick Levey, Rich Langdon, Aaron Moore, Heather Pembrook, and Jen Stamp. The US EPA national office and Region 1 provided essential support, both financial and technical. In particular, Richard Mitchell provided the data on NRSA wadeable streams, and Tony Olsen gave indispensable assistance on sampling design, site selection, and numerous iterations of data analysis.

EXECUTIVE SUMMARY

This report presents the biological condition of Vermont's wadeable streams based on the results of a statewide probability-based survey. This is the second such survey that has been performed by VTDEC. The continuation of these surveys on a five-year cycle allows us to examine trends in the condition of Vermont's streams and helps us understand how physical and chemical stressors are affecting biological health over time. These statewide surveys also coincide with US EPA's National Rivers and Streams Assessment (NRSA), which allows us to compare Vermont's streams to regional and national conditions.

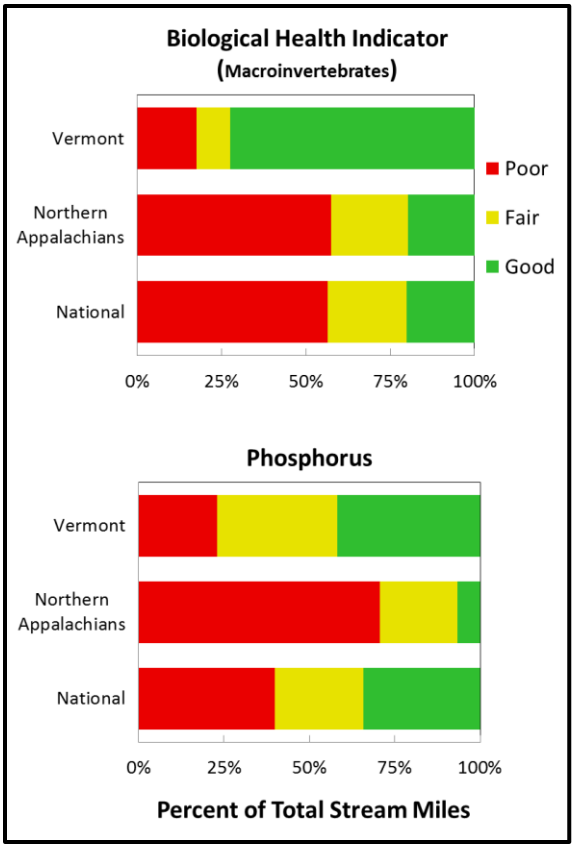
Fish surveying at Fayville Branch, Glastenbury (VTDEC)

This survey was designed to assess the ecological integrity of Vermont's waterways using indicators of stream biological health and chemical pollution. Results of this study found that over 70% of wadeable stream miles in Vermont meet (and in some cases significantly exceed) the goals established by the Clean Water Act. There seems to be a downward trend in biological condition when comparing the results of this survey to the first probabilistic survey. While this may be a cause for concern, a likely explanation for the change was the occurrence of Tropical Storm Irene in 2011, which caused several sites sampled during that year to fail to meet standards for aquatic life use. While the biological condition of many Vermont streams has recovered from the effects of this storm, floods of this magnitude are expected to become more frequent as a result of our changing climate.

Watershed development was extremely low throughout the streams used in this survey, reflecting the rural nature of our State. Consequently, pollutants often associated with land development (like chloride and sediment) were not significant stressors for biological communities when examined at the statewide scale. However, the survey revealed ongoing impacts to biological health due to nutrient

enrichment resulting from agricultural influences.

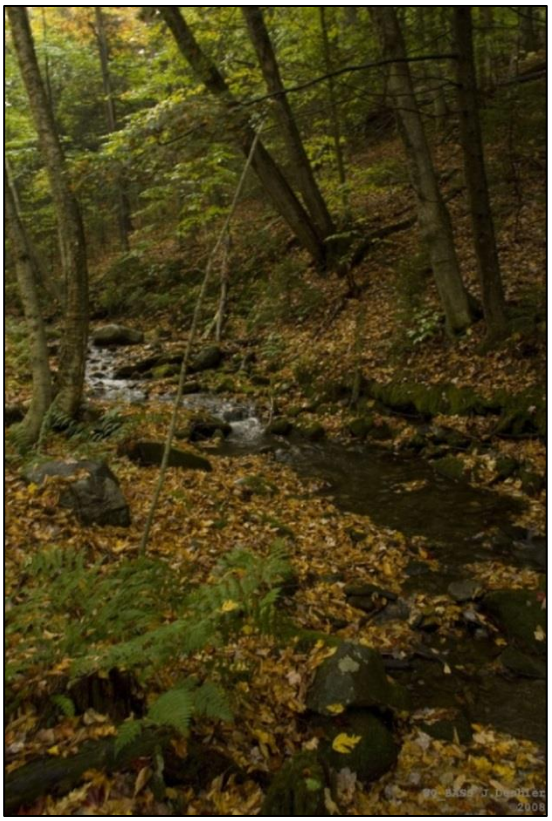
When Vermont results are compared to streams nationally and in our Northern Appalachians eco-region, it is evident that Vermont has more stream miles in good condition for nearly every indicator tested. For example, 70% of stream miles exhibited the highest level of biological health for macroinvertebrate communities, compared to only 20% of streams regionally and nationally. Similarly, when compared to the eco-region and nation, more stream miles in Vermont rated well for the chemical pollutants nitrogen, phosphorus and salinity. Only 23% of stream miles were rated as having excessive phosphorus (a significant water quality problem in some areas of Vermont) compared to 71% the eco-region (which includes the rest of New England, and parts of New York, Pennsylvania and Ohio).



While the results of this study show that biological communities in our streams are at risk from environmental stressors, the biological health of our running waters can be successfully managed to reduce these threats. Notwithstanding water quality problems in some of the largest surface waters of the State (e.g., Lakes Champlain and Memphremagog), the relatively good water quality and biological condition of our streams compared to those in other parts of the country suggests that current management and protection efforts can be successful. Continuing and improving on these efforts should produce even more encouraging results.

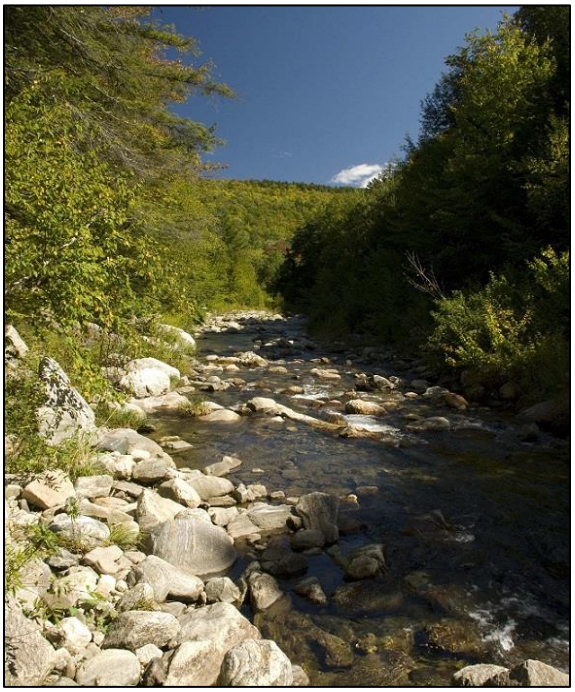
INTRODUCTION

The Vermont Department of Environmental Conservation (VTDEC) manages the state's surface waters to maintain ecological integrity and recreational sustainability, as described in our Surface Water Management Strategy (www.watershedmanagement.vt.gov/swms.html). The Department's numerous monitoring and assessment programs are some of our most important tools used to achieve these goals. VTDEC's Biomonitoring and Aquatic Studies Section has been conducting stream biomonitoring since 1986. Fish surveys and macroinvertebrate sampling are conducted annually throughout the state's wadeable streams during a September 1st to October 15th index period. From this community data VTDEC has developed biocriteria using fish Indices of Biotic Integrity (IBI's) and individual macroinvertebrate metrics (VTDEC, 2004). Assessment ratings are given to each community on a five tiered scale from *Poor* to *Excellent*, indicating an increasingly higher level of biological integrity. Communities rated as *Poor* or *Fair* fail to achieve designated aquatic life use standards established by the Vermont Water Quality Standards (http://www.vtwaterquality.org/rulemaking/htm/rules.htm). Ratings of *Good* and *Very Good* support standards for Class B waters, and *Excellent* ratings support standards for Class A(1) waters.



Chase Brook Tributary 2, Chester (VTDEC)

VTDEC also collects an abundance of data relating to ambient stream water chemistry and physical habitat in conjunction with the biological surveys. This information is used to help explain patterns in biological community condition and the potential effects of environmental stressors. Historically, VTDEC's biomonitoring resources have been directed towards streams of particular management interest. Efforts have focused on the identification of impaired streams and tracking their recovery after remediation activities, compliance monitoring below National Pollutant Discharge Elimination System (NPDES) discharges, identification of very high quality waters for increased protection, and the



North Branch Ball Mountain Brook, Jamaica (Jim Deshler)

sampling of long-term reference sites to observe the effects of climate change. This type of **targeted monitoring** allows VTDEC to evaluate the biological condition resulting from management efforts within a specific stream or watershed, but doesn't give an unbiased assessment of the overall statewide condition of Vermont's flowing waters. To address this limitation, Vermont began implementing probability-based surveys in 2002 in partnership with US EPA. **Probabilistic monitoring** concentrates on randomly selected wadeable stream reaches. This statistical design allows for an unbiased estimation of the biological condition of Vermont's wadeable streams with measurable confidence.

VTDEC's Biomonitoring Section uses a rotational sampling schedule where annual efforts focus on a subset of major watersheds, with all watersheds of the state are monitored over a 5-year period. With assistance from US EPA, Vermont's probabilistic stream surveys were designed to coincide with this rotational cycle, as well as the National Rivers and Streams Assessment (NRSA), which is also conducted every five years (http://water.epa.gov/type/rsl/monitoring/riverssurvey/). By using this sampling design, we can estimate the biological condition of Vermont's wadeable flowing waters at five year intervals and track the principal environmental stressors that may be contributing to this condition. We can also investigate long-term trends in stream biological condition and compare current conditions to results found at regional and national scales.

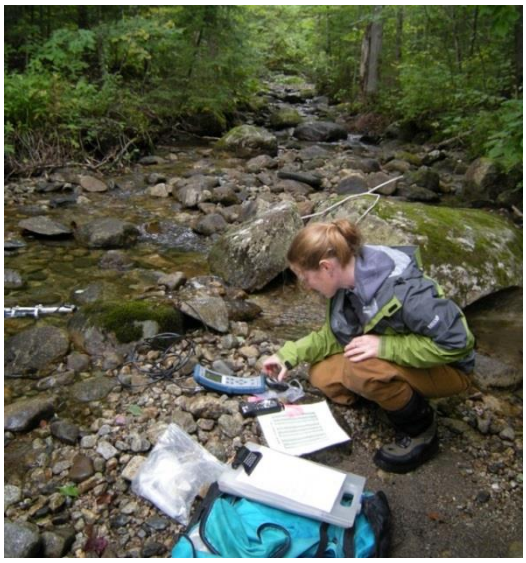
Vermont recently completed its second probabilistic wadeable stream survey during 2008-2012. Results of the first probabilistic survey (2002-2006) have been reported in detail (VTDEC, 2008). The results and analysis presented in this report focus on the results of VTDEC's second statewide survey and comparisons with both the first survey and the 2008-2009 NRSA.

METHODS

Site Selection and Sampling Design

Stream sites were randomly selected from the 1:5000-scale Vermont Hydrographic Database stream layer, which contains an estimated target population of 11,229 wadeable (1st-4th order) stream miles. Sites were selected by the EPA using a Generalized Random Tessellation Stratified design (Olsen et al., 2012). This is a spatially-balanced survey design, using equal probability of site selection across stream orders. The current design methodology differed slightly from the 2002-2006 survey which used a geographically stratified rotational hex design (VTDEC, 2008), however both surveys offered the same fundamental randomized selection criteria. The US EPA site selection also included a list of overdraw sites that provided alternate locations for cases where primary sites were inaccessible, or where site visits indicated that the reach was too large to be considered wadeable.

VTDEC has previously set a target of seventy-five sites for its probabilistic surveys. This number was determined to be an optimal tradeoff for maximizing confidence levels in the statewide estimation of biological condition, while at the same time minimizing the strain on VTDEC's limited resources for targeted monitoring efforts. A total of 76 wadeable stream sites were visited for probabilistic monitoring between 2008 and 2012. It was determined that three of these sites were inaccessible due to access constraints (Table 1). Seventy-three sites were assessed for macroinvertebrate communities, with 58 of these sites also being assessed for fish. Of the 15 sites that were not assessed for fish, site visits determined that eight were too large for VTDEC wadeable fish methodology. The remaining seven were either not fished due to field logistics, or an IBI was not able to be calculated due to field sampling conditions (including inadequate reach sampling lengths and the influence of nearby impoundments on the fish community). Sites surveyed covered 15 of 17 major watershed basins (Appendix 1). Monitoring of probabilistic sites generally coincided with VTDEC's rotational watershed cycle (Figure 1).



Water quality monitoring (VTDEC)

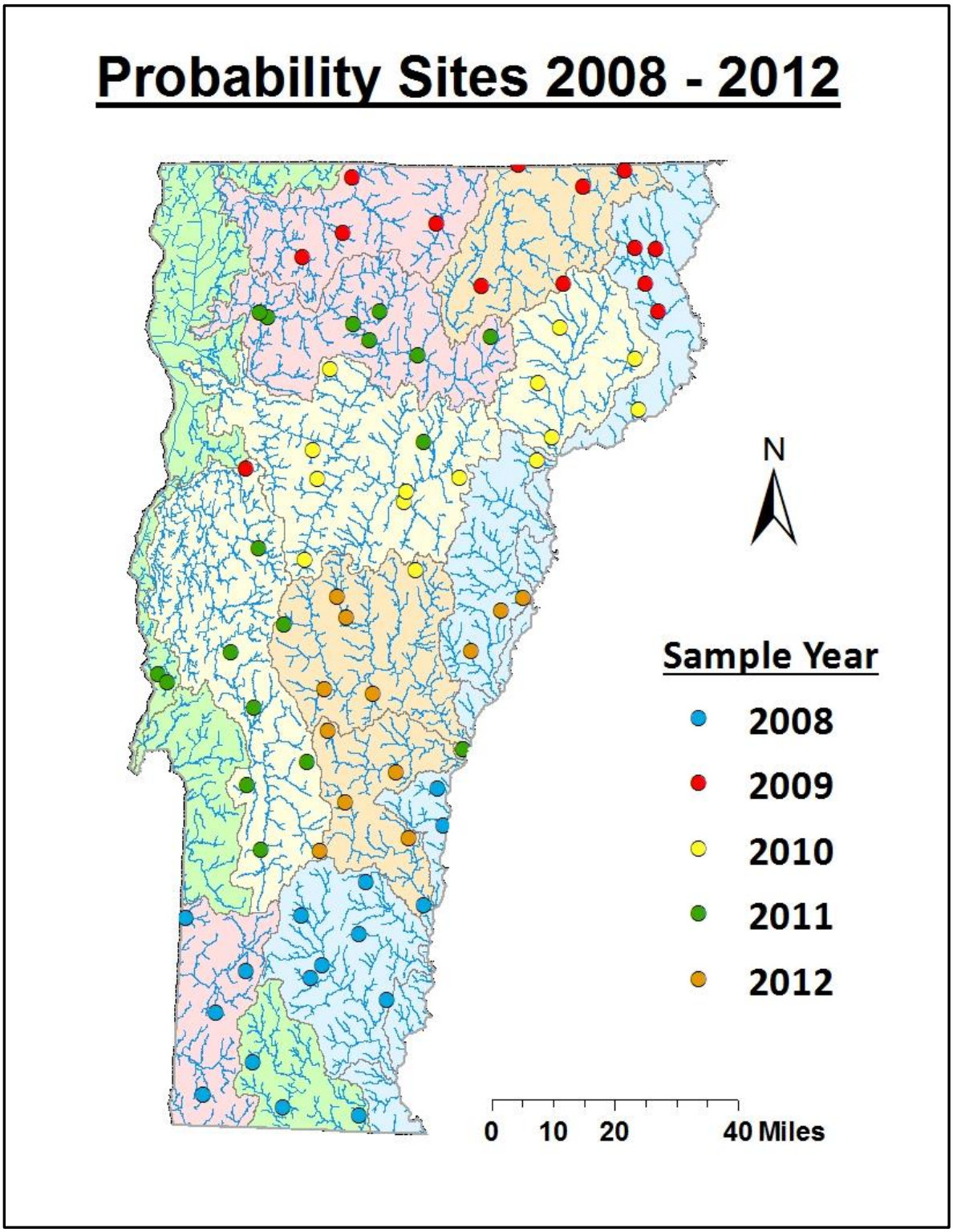
Table 1: A breakdown of estimated Vermont wadeable stream miles, based on the EPA site selection. Target streams include all 1st-4th order wadeable streams. Of 76 wadeable streams visited, three were deemed inaccessible. Assessment ratings are based on the lower of the fish and macroinvertebrate scores, or just the macroinvertebrate ratings for the 15 sites where fish surveys were not performed.

		Total Sites	Estimated Stream Miles	% of Total Miles Represented by Survey
Total Target Streams		**76**	**11,229**	
Not Assessed		*3*	*603*	*5.4*
Assessed		*73*	*10,626*	*94.6*
	Small High Gradient (SHG)	36	5,239	49.3
	Medium High Gradient (MHG)	24	3,496	32.9
	Warm Water Moderate Gradient (WWMG)	7	1,020	9.6
	Low Gradient Slow Winder (SW)	6	871	8.2
	Excellent	15	2,030	19.1
	Very Good	20	2,935	27.6
	Good	20	2,633	24.8
	Fair	11	1,703	16.0
	Poor	7	1,324	12.5

Sampling Methodology

Vermont DEC's methodologies for macroinvertebrate collection and processing, fish sampling, water chemistry collection, and physical habitat measurements are described in detail in the Water Quality Division Field Methods Manual (VTDEC, 2012). Macroinvertebrates are collected from representative riffle habitats (when available) using a 500um mesh kick-net. A 0.25m^2 area upstream of the net is disturbed by hand for 30 seconds, and all pieces of substrate are dislodged and rubbed clean of attached organisms. This is repeated at a total of four riffle locations throughout the reach representing a full range of water velocity, and composited into a single sample. In low gradient stream reaches where riffle habitats are not available, a sweep-net method is used.

Figure 1: Probabilistic sites sampled over the five-year cycle between 2008 and 2012. The color of the stream sites roughly coincides with the color of the watersheds in the VTDEC monitoring rotation for that year. The rotational schedule was adjusted slightly during this cycle, which is why some sites and watersheds don't line up precisely.



The same 500um net is used to sample areas considered to be productive macroinvertebrate habitats within the low gradient reach (e.g., woody debris jams, overhanging submerged vegetation, root wads). The net is thrust into the habitat from the downstream direction, and pulled back and forth to dislodge attached organisms. The thrusting and sweeping motions are repeated several times in order to collect all dislodged macroinvertebrates. A total of four samples are taken within the sample reach, allowing for a comparable sample to those collected in riffle habitats. All macroinvertebrates samples are preserved in a minimum of 75% ethanol.

Macroinvertebrate samples were processed by spreading preserved samples on a 24-square gridded tray and picking organisms from debris using 2x magnification. VTDEC subsample methods require the processing of at least 25% of the total sample, *and* a minimum of 300 organisms (the entire sample is processed if less than 300 organisms are found). All organisms (including Chironomidae) are identified to the lowest practical taxonomic level, with a target of genus or species.

Fish were collected and surveyed using a backpack electrofisher. Sampled stream section lengths varied from 75m to 150m depending on the mean stream width at the assigned

Brook Trout, New Haven River Tributary 27, Lincoln (Jim Deshler)

coordinates. A single pass was made in an upstream direction, and fish were netted and placed into buckets of water. Streams over 6 meters wide were sampled with two electrofishers moving upstream in tandem. Streams over 12 meters in width were shocked on the banks, sampling five meters out from each shore simultaneously. Fish were identified to species, inspected for external abnormalities, enumerated and released.

Physical habitat and water chemistry measurements were collected for all biological sampling events to document potential environmental stressors. Physical habitat

measurements include wetted and bank full width, weather conditions, categorical flow velocity, canopy cover, embeddedness, silt rating, stream bank condition, and substrate composition. At most sites, VTDEC's pebble count methodology was used to collect substrate composition data, which incorporates standardized periphyton/algae cover and thickness observations. Ambient water chemistry data collected at most sites includes both in-situ measurements (pH, water temperature, and conductivity) and grab samples for laboratory processing (nutrients, metals, anions, and alkalinity).

Macroinvertebrate Sampling, Lamoille River, Fairfax (Jim Deshler)

Data Analysis

Sites were assigned ratings on the five-tiered scale for both macroinvertebrate and fish communities (Table 2) according to VTDEC biocriteria and assessment methodology (VTDEC, 2004). Macroinvertebrate metrics were scored according to stream type; small high gradient (SHG), medium high gradient (MHG), warm water moderate gradient (WWMG), and low gradient "slow winders" (SW). Fish were assessed using the Vermont Coldwater Index of Biological Integrity (CWIBI) for cold water sites that naturally supported between two and four native species. Sites that supported at least five native species (both cold and warm water) were assessed using the Vermont Mixed Water IBI (MWIBI). No numerical criteria were applied to small streams maintaining only brook trout populations; these sites were assessed by professional judgment based on trout density and size-class distribution. Assessment results are given separately by community, and a "combined" assessment rating is also presented. The combined rating was derived from the lower of the fish or macroinvertebrate ratings, or the macroinvertebrate rating alone in cases where fish were not sampled.

The number of assessments in each category (*Poor*, *Fair*, *Good*, *Very Good* and *Excellent*) was

used to estimate the statewide biological condition. This was done by calculating the number of stream miles in each assessment category (based on the total of 11,229 statewide miles) using R programming scripts developed by US EPA statistician Tony Olsen (Olsen.Tony@epa.gov). Ninety-five percent confidence intervals were calculated to show the precision of the estimates based on sample size. Biological assessments were used to calculate both the total number of miles in each category, as well as the *percent* of stream miles in each category. Differences in GIS stream layers used for site selection, and potential differences in the method for screening non-target streams from the dataset, led to slightly different estimates of the total number of wadeable stream miles for the probability surveys ending in 2006 and 2012.

Fish identification at White Creek, Rupert (VTDEC)

Due to this discrepancy, results presented in this report focus primarily on the *percent* of stream miles in each assessment category when making comparisons between the two surveys.

Results from the 2008-2012 statewide probability survey were used to draw regional and national comparisons to the 2008-2009 National Rivers and Stream Assessment (NRSA). NRSA is a national effort to gauge the health of the country's rivers and streams that also uses a randomized site selection design and is conducted on a five-year cycle. The draft report from the 2008-2009 NRSA was recently released, and includes both national data and results from each of nine eco-regions (US EPA, 2013). EPA uses a coarser three-tiered assessment scale (*Poor*, *Fair* and *Good*), which were aligned to Vermont's state thresholds for meeting aquatic life use standards (Table 2). While the physical parameters analyzed by NRSA did not correspond with statewide habitat data collected by VTDEC, we were able make comparisons for three major chemical stressors. Statewide data for total phosphorus, total nitrogen, and salinity (measured by conductivity) were compared to NRSA data using EPA's three-tiered assessment thresholds (Table 3).

Table 2: VTDEC's five-tiered assessment ratings and their equivalent to NRSA's three-tiered assessment scale. These equivalents were determined by the professional judgment of VTDEC biologists using narrative descriptions from the Vermont Water Quality Standards.

VTDEC		NRSA
Poor **Fair**	Failure to meet Vermont's Aquatic Life Use Standards	**Poor**
Good	Meets Class B standards; moderate departure from reference condition	**Fair**
Very Good **Excellent**	"Very High Quality Waters", Meets Class B and A(1) standards; at or near reference condition	**Good**

Table 3: Chemical parameters collected as a part of both VTDEC's probability survey, and EPA's National Rivers and Streams Assessment (NRSA). The NRSA's chemical thresholds for the Northern Appalachians eco-region (below) were used to assign assessment ratings for VTDEC samples.

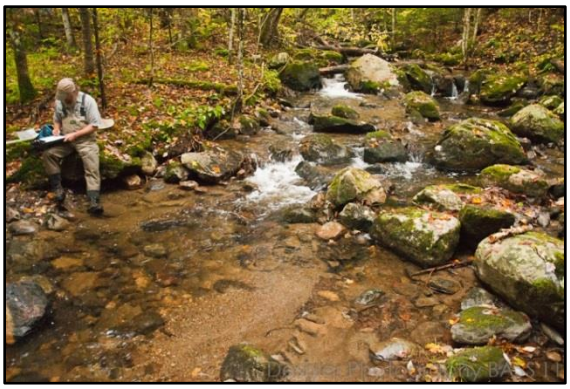
Chemical Stressor	Poor	Fair	Good
Total Phosphorus (ug/L)	> 15.7	8.2-15.7	< 8.2
Total Nitrogen (ug/L)	> 441	329-441	< 329
Salinity (Conductivity, uS)	> 1000	500-1000	< 500

RESULTS

Biological Condition (2008-2012), and Comparison to the 2002-2006 Survey

The results of the survey show that the overall biological condition failed to meet Vermont's standards for aquatic life use (i.e., rated as *Poor* or *Fair*) in only 29% of stream miles assessed (Figure 2). This is a notable increase when compared to only 12% rated as *Poor* or *Fair* in the 2002-2006 survey. This change appears mostly due to a corresponding decline in stream miles previously rated as *Good*, which were down from 43% in 2006 to 25% in 2012. The total percent of stream miles receiving *Very Good* and *Excellent* combined assessment ratings was nearly identical between the two surveys (45% vs. 47%), however there was a slight shift in biological condition from *Excellent* to *Very Good* between 2006 and 2012.

Disparity between macroinvertebrate and fish community assessments often reflects differences in sensitivity to different stressors. Consequently, independent assessments of both communities can result in an ecologically broader and more robust measure of stream biological condition. When communities were examined separately, we saw a dramatic decline between surveys in the percent of



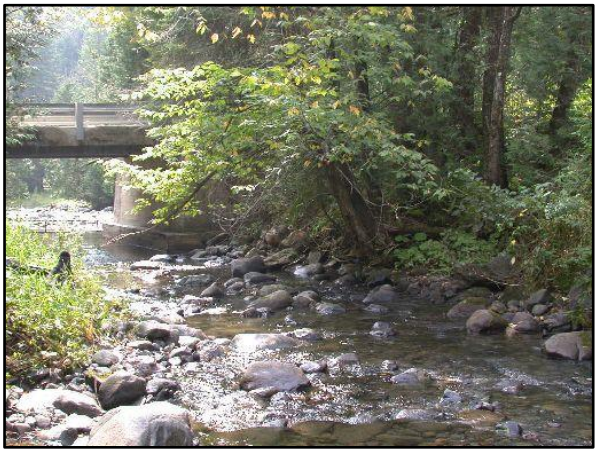
New haven River Tributary 27, Lincoln (Jim Deshler)

stream miles in *Good* biological condition for macroinvertebrates (Figure 3). However, this decline in the middle of the assessment rating scale coincided with a proportionate increase in both *Fair* ratings (which fail to meet Vermont's standards for aquatic life use), and *Excellent* ratings (indicating achievement of Class A(1) reference expectations).

When macroinvertebrate assessments were separated by stream type, we see that the increase in streams miles rated as *Excellent* occurred in both SHG and MHG streams (Figure 4). The shift in stream miles from *Good* to *Fair* seems to have disproportionately occurred in SHG streams. While both WWMG and SW streams had more *Very Good* and *Excellent* assessments in 2012, sample size for these stream types is quite small. It is also important to note that estimates for stream miles by stream type were not given confidence limits or tested for statistical differences, and the results are only used to examine potential trends. The proportion of stream miles assessed in each

macroinvertebrate stream type is nearly identical between the probability surveys ending in 2006 and 2012 (Figure 5). This supports the ability of the slightly different randomized site selection designs to allow for a comparison of biological condition between surveys. The figure also demonstrates that the majority of stream miles in Vermont are represented by Small High Gradient (SHG) streams (typically 1st and 2nd order).

The greatest difference in fish community condition was a proportionate shift from stream miles rated as *Excellent* in the 2002-2006 survey, to *Very Good* in the 2008-2012 survey (Figure 6). The percentage of stream miles failing to meet standards for aquatic life use (i.e., *Poor* and *Fair*) increased only slightly in the 2008-2012 survey, while *Good* assessments were nearly the same. Fish communities in both surveys that were assessed with the CWIBI (small, low order streams) received more *Very Good* and *Excellent* ratings when compared to MWIBI assessments (Figure 7). The number of CWIBI assessments that were rated as *Excellent* decreased from 49% in the 2002-2006 survey to 30% in the 2008-2012 survey, although the total percentage of *Very Good* and *Excellent* ratings actually increased from 62% to 75%. The biological condition of stream miles evaluated with the MWIBI showed little difference between the surveys ending in 2006 and 2012 and the percent of assessments failing to meet aquatic life use standards was nearly identical (19% vs. 21%).



Houghton Brook, Danville (VTDEC)

Figure 2: The proportion of stream miles in each *combined* VTDEC assessment category. The error bars represent 95% confidence intervals. Shaded bars represent the results of the 2008-2012 survey, while unshaded bars show the results of the previous probability survey (2002-2006). Dashed lines on the bar chart separate streams that fail to meet aquatic life use standards (red), as well as "very high quality" streams at or near the expected reference condition (green).

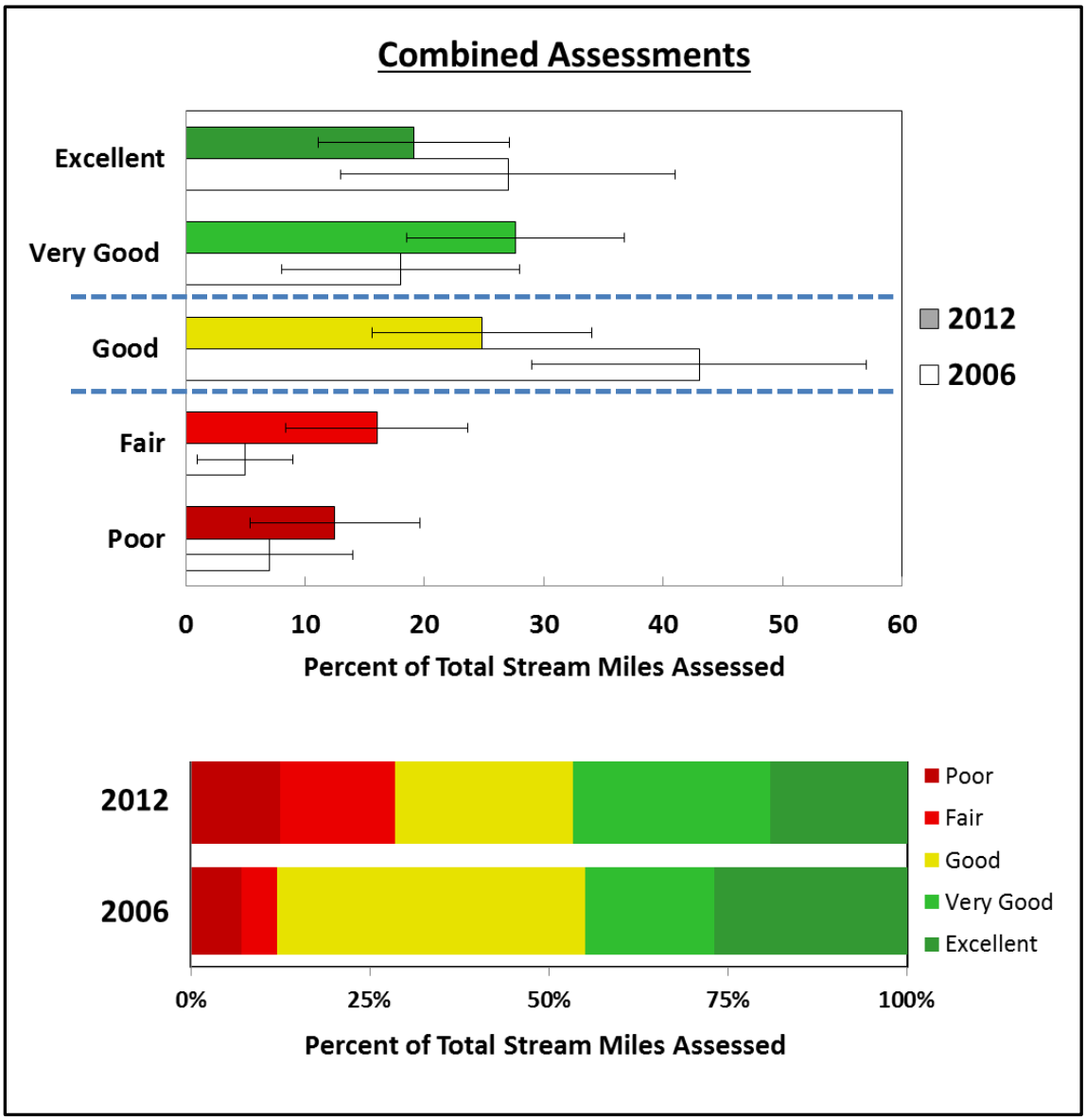


Figure 3: The proportion of stream miles in each macroinvertebrate assessment category for both the 2002-2006 and 2008-2012 probability surveys. The bar chart at the top of the figure shows the 95% confidence intervals for the stream mile estimates, while the bottom shows the cumulative percent for each survey.

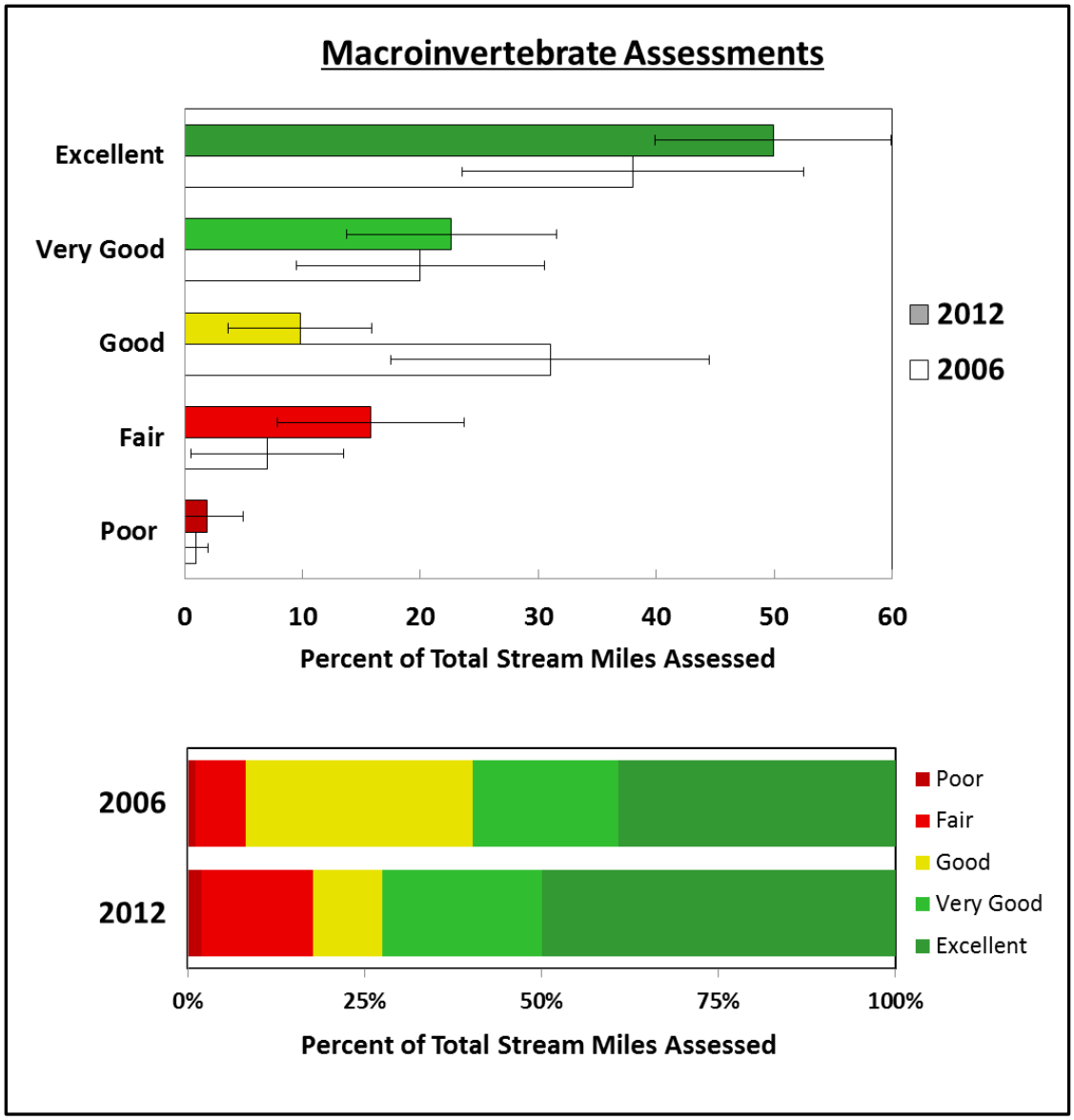


Figure 4: Percent of stream miles for macroinvertebrate assessment categories broken down by stream type, including both the 2002-2006 and 2008-2012 surveys. Sample sizes for each stream type are shown at the right side of each bar.

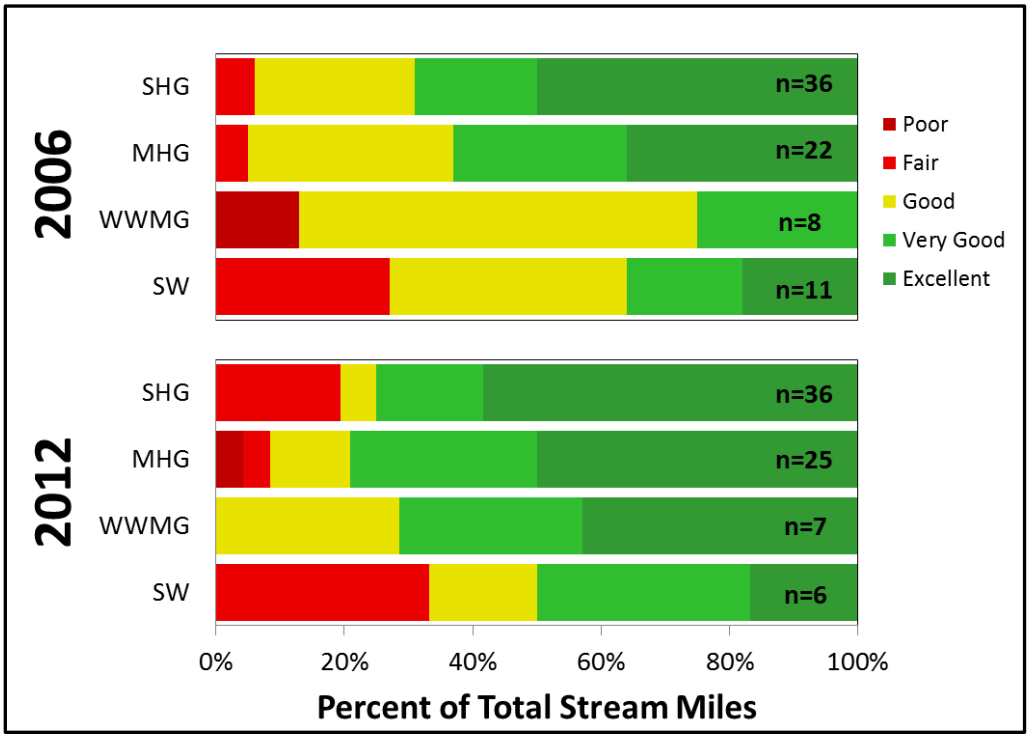


Figure 5: Relative proportions of all assessed stream types for the probability surveys ending in 2006 and 2012. Small high gradient (SHG), medium high gradient (MHG), and warm-water moderate gradient (WWMG) types correlate to increasing stream size, while "slow winder" (SW), refers to a low gradient streams not necessarily related to stream size.

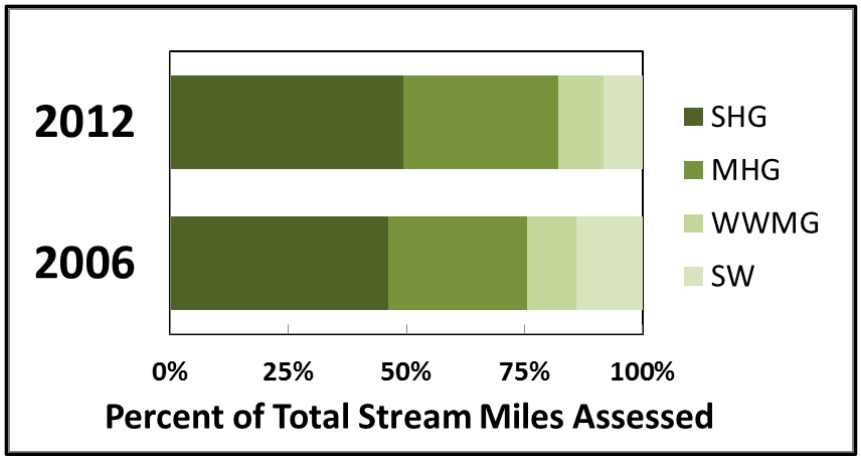


Figure 6: The proportion of stream miles in each fish assessment category for both the 2002-2006 and 2008-2012 probability surveys. The bar chart at the top of the figure shows the 95% confidence intervals for the stream mile estimates, with "not assessed" representing target sites that received macroinvertebrate assessments but were not monitored for fish. The bottom portion of the figure shows the cumulative percent of *assessed stream miles only*.

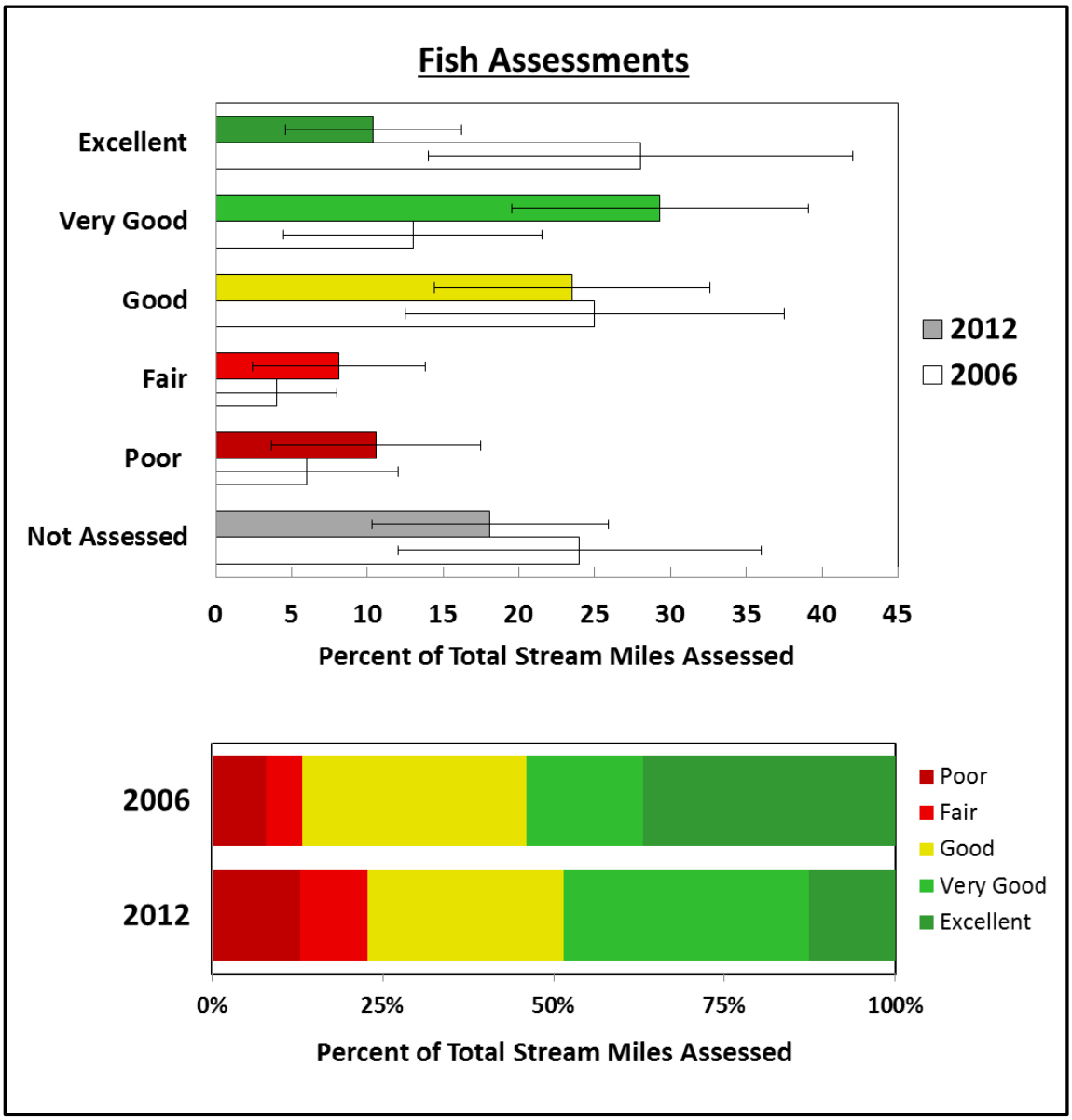
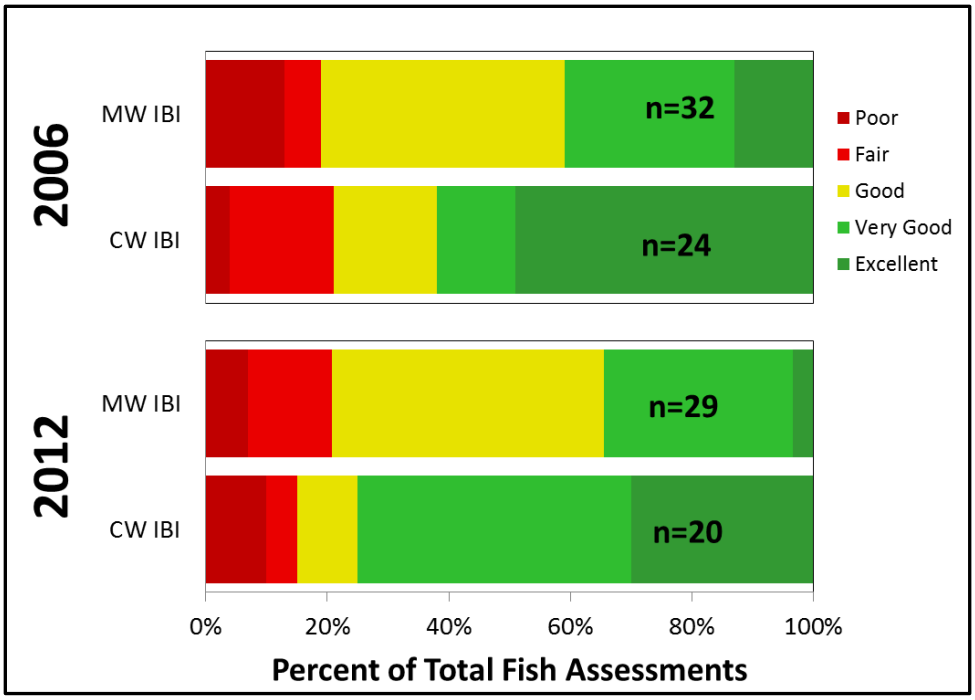


Figure 7: Percent of fish assessments broken down by mixed-water (MW IBI) and cold-water (CW IBI) indices, including both the 2002-2006 and 2008-2012 surveys. Sample sizes for each IBI type are shown at the right side of each bar. Assessments for streams maintaining only brook trout populations are not included.



Environmental Stressors

Twenty-five percent of sites assessed in the 2008-2012 survey failed to meet aquatic life use standards for at least one of the biological communities (Table 4). Of these, there were 10 sites where one community failed while the other showed full aquatic life use support, and there were only two instances where macroinvertebrates and fish received the exact same rating on the five-tiered assessment scale. To fully understand what is independently driving the biological condition of each stream community, we need a deeper understanding of the chemical and physical stressors that are causing degradation.

The VTDEC Surface Water Management Strategy highlights 10 major stressors that are contributing to declining water quality in Vermont. Table 4 examines the sites from the 2008-2012 survey that failed to meet aquatic life use standards, and highlights the likely stressors involved in degraded biological condition based on the community fingerprint, habitat observations, and water quality data.

Table 4: Streams that failed to meet Vermont's aquatic life use standards (i.e. "Poor" or "Fair") in the 2008-2012 survey based on *combined assessment rating.* Possible stressors (outlined in VTDEC's Surface Water Management Strategy) were extracted from assessment narratives. Colored text indicates differences in pass/fail status between the fish and macroinvertebrate assessments.

Stream (River Mile)	DEC Site ID	Sample Date	Combined Assessment	Bug Stream Type	Invert Assessment	Fish IBI Type	Fish Assessment	Possible Stressors
Deerfield River (52.4)	650000000524	9/17/2008	**Poor**	MHG	Poor			**Thermal Stress** (below reservoir with cold profundal water release)
Lye Brook (4.2)	592500000042	9/10/2008	**Poor**	SHG	Fair			**Acidification** (low pH, resulting in low invert richness & abundance)
Fayville Branch (3.7)	591401010037	9/10/2008	**Poor**	SHG	Fair	-	Poor	**Acidification** (low pH, resulting in low invert richness & abundance, low brook trout density)
Pekin Brook (2.9)	496304000029	10/6/2011	**Poor**	MHG	Fair	MW	Poor	**Channel Erosion** (Scour, resulting in low invert richness/density & low fish density. Likely due to unusual 2011 flood flows)
Eddy Brook (1.8)	554101050018	10/12/2011	**Poor**	SHG	Fair	-	Poor	**Channel Erosion** (Scour, resulting in low invert richness/density, & low trout density, likely due to unusual 2011 flood flows)
South Stream (5.1)	601100000051	9/11/2008	**Poor**	WWMG	**Very Good**	MW	**Poor**	**Thermal Stress, Nutrient Loading** (site located below pond/wetland complex, altering communities)
Jacob Brook (0.6)	463700000006	9/19/2011	**Poor**	SHG	**Very Good**	CW	**Poor**	**Uncertain** (fish community dominated by tolerant Blacknose Dace)
Beaver Brook (1.7)	123200000017	9/12/2012	**Poor**	SHG	**Excellent**	CW	**Poor**	**Uncertain** (fish community unusual due to 1 sculpin and no brook trout, reassessment recommended)
Godin Brook (1.4)	425600000014	9/10/2009	**Fair**	SHG	Fair	MW	Fair	**Nutrient Loading** (elevated P and N concentrations, and excessive algae cover on substrate)
Johns River (1.6)	360000000016	9/16/2009	**Fair**	SW	Fair	CW	Fair	**Nutrient Loading** (elevated P and N concentrations, and excessive algae cover on substrate)
Tyler Branch (6.1)	423800000061	9/9/2009	**Fair**	SHG	**Fair**	Both	**Good**	**Nutrient Loading, Land Erosion** (Cause uncertain, biotic index suggests possible enrichment, embeddness also moderately high)
West Branch Little River (7.3)	493238000073	9/7/2010	**Fair**	SHG	**Fair**	-	**Very Good**	**Channel Erosion** (High flows and scour resulting in community dominated by the rapid colonizer *Baetis tricaudatus*)
Robbins Branch (1.4)	136208000014	10/4/2011	**Fair**	SHG	**Fair**	CW	**Very Good**	**Channel Erosion** (Scour, resulting in very low invert density, due to unusual 2011 flood flows, specifically Tropical Storm Irene)
East Creek North Fork (0.4)	560200000004	10/12/2011	**Fair**	SW	Fair			**Nutrient Loading, Channel Erosion** (incised banks and lack of invert habitat in reach, community dominated by tolerant taxa)
Wild Branch (0.1)	465200000001	9/19/2011	**Fair**	MHG	**Good**	MW	**Fair**	**Nutrient Loading** (high densities of tolerant taxa, excessive algae cover on substrate)
North Branch Black River (4.9)	081500000049	9/20/2012	**Fair**	MHG	**Very Good**	MW	**Fair**	**Land Erosion** (excess of sand noted at site and in riffle habitats)
Black River (36.4)	080000000364	9/20/2012	**Fair**	SW	**Very Good**	MW	**Fair**	**Uncertain** (difficulty in fishing site and lack of appropriate Fish IBI model for stream type may affect site assessment)
Batchelder Brook (0.5)	133325000005	9/27/2012	**Fair**	SHG	**Very Good**	MW	**Fair**	**Uncertain** (evidence of very low water levels prior to sampling may have excluded fish community)

The two most common stressors causing biological communities to fail to meet aquatic life use standards appear to be nutrient loading (five sites) and channel erosion (five sites). Other stressors at biologically degraded sites include acidification in two high gradient mountain streams and thermal stress linked to a continuous profundal cold water dam release, both of which reduced the density and richness of the fish and/or macroinvertebrate communities.

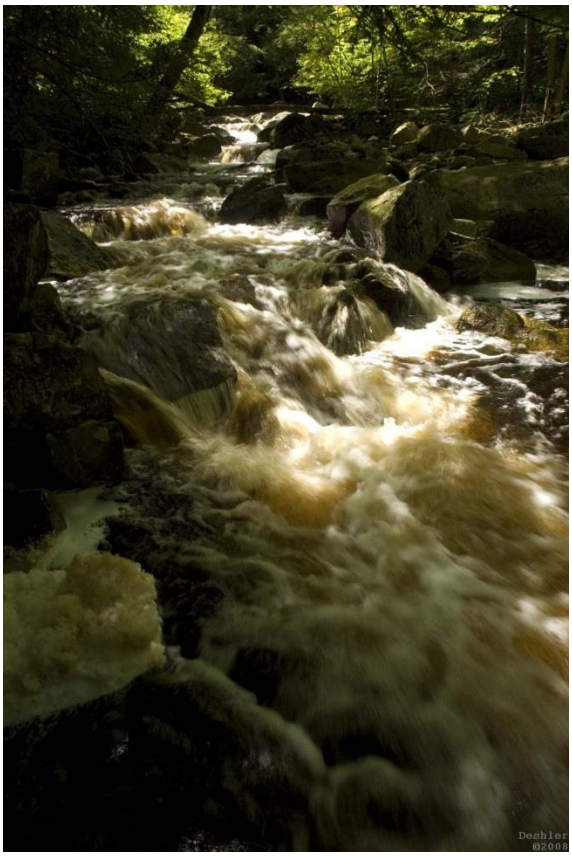
For sites that appear to be affected by nutrients, all have elevated phosphorus and/or nitrogen concentrations, and three have substantial agricultural activity throughout their watersheds (>30%). Macroinvertebrate metrics at these sites show that while overall density and richness are relatively high, the communities have elevated biotic index values, indicating a dominance of enrichment tolerant taxa. These communities also deviate significantly from the relative proportion of macroinvertebrate taxonomic orders and functional groups that would be expected at reference quality sites. The imprint of nutrient loading on fish community was similar to what was seen in the macroinvertebrate samples. Streams stressed by excessive nutrients that would normally be dominated by cold water taxa (e.g., Brook Trout and Slimy Sculpin) showed a shift towards enrichment tolerant taxa (particularly Blacknose Dace).

Of the streams that appear to be affected by channel erosion, one is in a heavily agricultural area (North Fork East Creek) that also exhibits nutrient stress. This stream had deeply incised banks which generally provide less macroinvertebrate habitat, and the community was dominated by two enrichment tolerant taxa (*Hyallela azteca* and *Callibaetis sp.)*. The other four streams stressed by channel erosion had undergone significant flood scouring events prior to sampling. In each of these cases, the deterioration of the biological condition was attributed to extremely low macroinvertebrate density and/or richness following flood flows. Three of these sites were undeniably affected by Tropical Storm Irene, which depressed invertebrate abundance in reference streams throughout the state (Moore and Fiske, 2012). Streams that were affected by flood scour prior to sampling also exhibited depressed fish

Eddy Brook following TS Irene, Mendon (Jim Deshler)

densities, though not always to the same extent as macroinvertebrates.

To further examine the potential effect of environmental stressors, land use variables, habitat observations, and water quality parameters were associated with the macroinvertebrate and fish community assessments (Figures 8 and 9). Watershed development occurs at relatively low levels throughout these probability sites (0-7%). As a result, variables often correlated with land development (i.e., chloride, conductivity, percent fine sediments and embeddedness) did not seem to be related to macroinvertebrate or fish community health in this survey.



Lye Brook, Manchester (Jim Deshler)

Nutrient enrichment in agricultural areas may be responsible for lowering macroinvertebrate and fish community health. Streams located in watersheds with the highest percentage of agricultural land use, and with high concentrations of nitrogen and phosphorus, appear more likely to have *Fair* macroinvertebrate and fish assessments. Fish communities assessed as *Poor* seem to be responding to variables unrelated to either development or agriculture related stress. Table 4 suggests that acidification, channel erosion, and thermal stress all contributed to *Poor* fish community ratings. It should be noted that variability in the stressor data is extremely high, and the data set in this survey is too limited for examining the significance of the trends.

Figure 8: Box plots showing watershed land use and a suite of potential stressors for macroinvertebrate assessment ratings from the 2008-2012 probability survey. Boxes represent the 25th and 75th percentiles, with a center line depicting the median value. Bars represent the 10th and 90th percentiles, and dots denote outliers. *Poor* is not included, as only one site was rated as such (due to thermal stress).

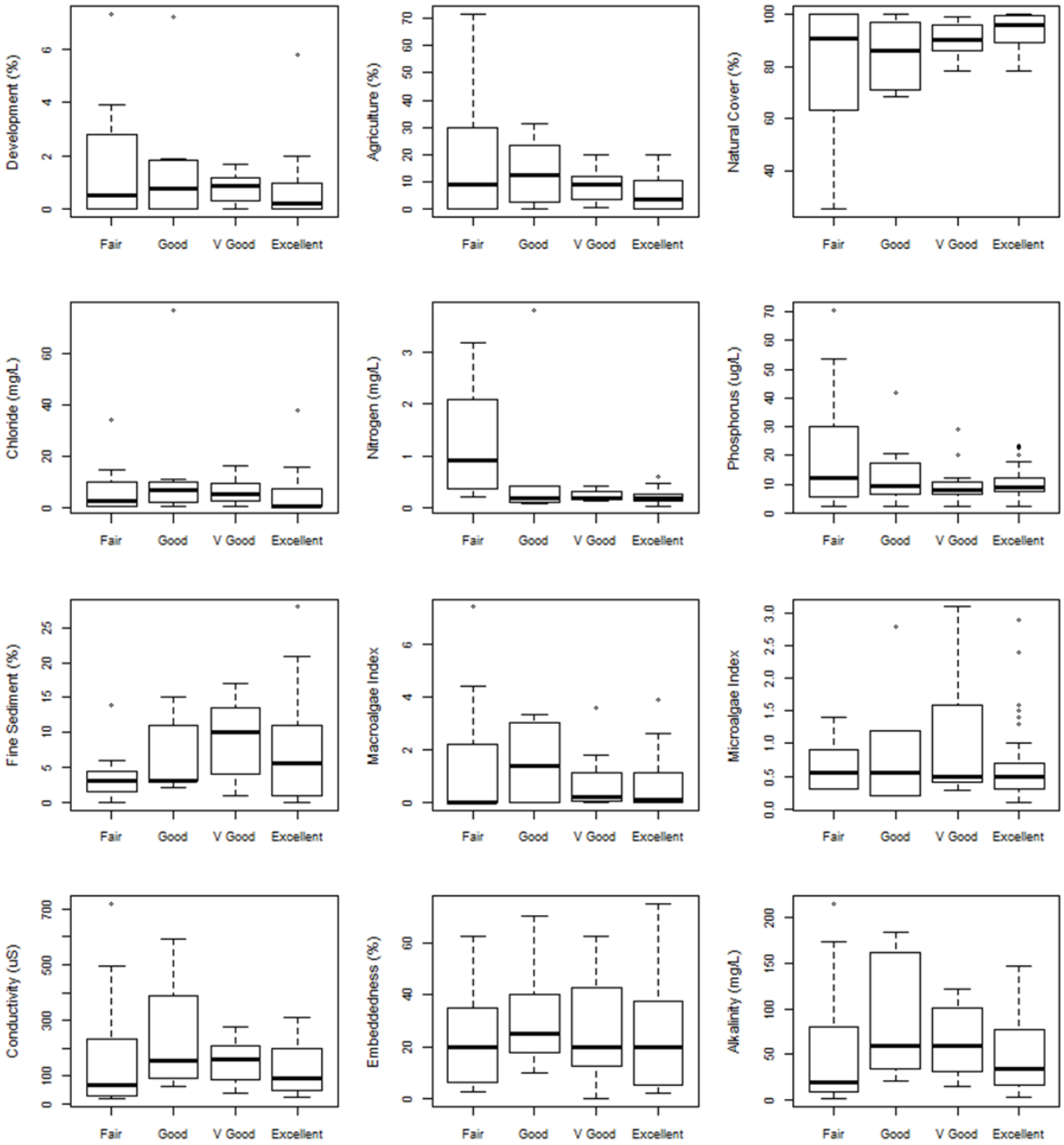
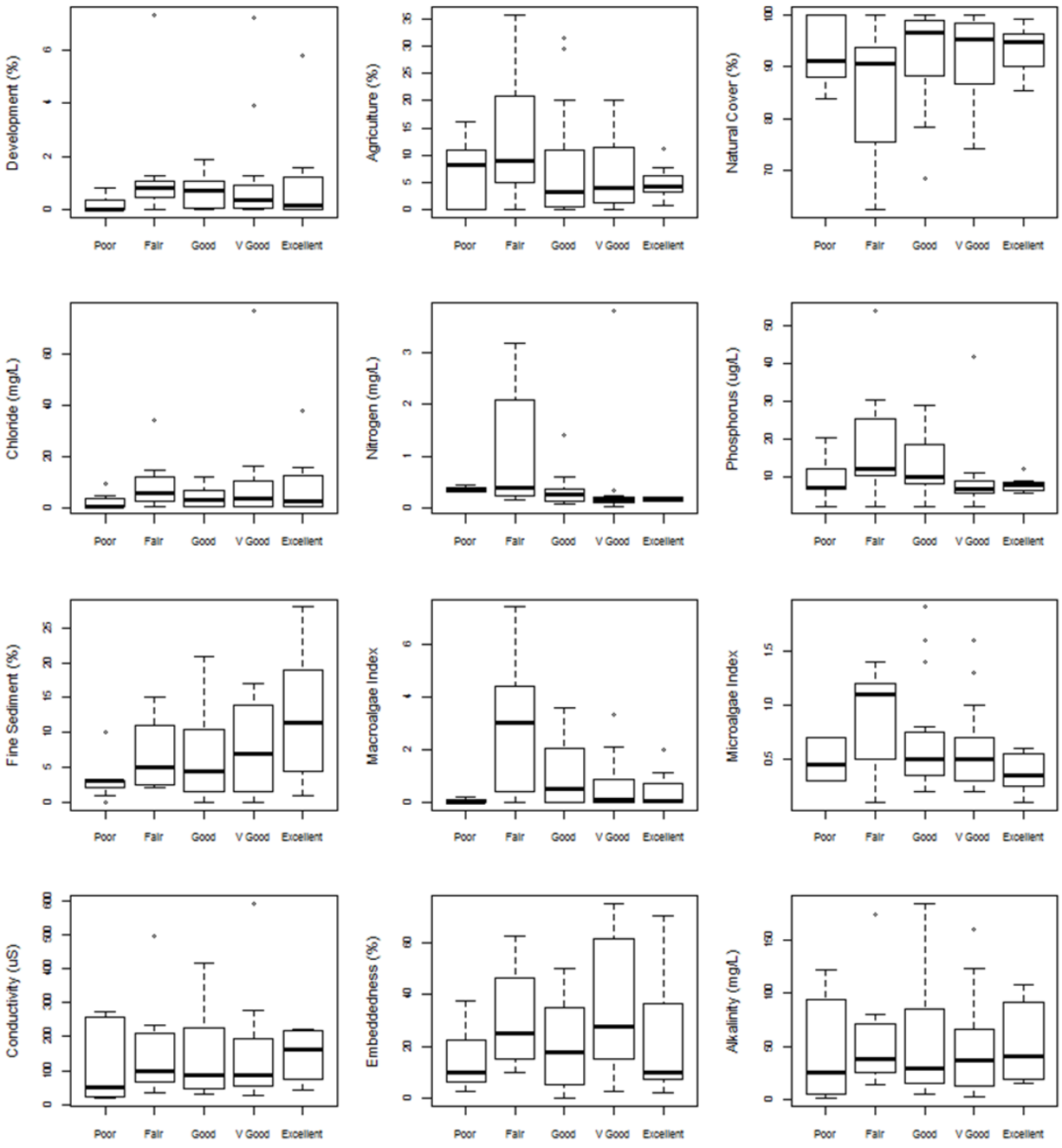


Figure 9: Box plots showing watershed land use and a suite of chemical and physical stressors for fish assessment ratings from the 2008-2012 probability survey. Boxes represent the 25th and 75th percentiles, with a center line depicting the median value. Bars represent the 10th and 90th percentiles, and dots denote outliers.



National and Regional Comparisons

The US EPA's 2008-2009 NRSA survey includes biological and chemical assessments from throughout the continental United States, as well as data partitioned into nine distinct eco-regions (with Vermont included in the Northern Appalachians eco-region; USEPA, 2013). To assess biological condition, NRSA uses multi-metric indices, and rates sites on a three-tiered scale (*Poor*, *Fair*, and *Good*). For comparison, we grouped VTDEC's five-tiered biological ratings and drew equivalents to the NRSA's ratings (Table 2) based on narrative descriptions of biological condition within the Vermont Water Quality Standards and VTDEC's biological criteria (VTDEC, 2004). For chemical parameters, we are able to directly compare total phosphorus, total nitrogen, and salinity (measured by conductivity), and assign our sites as *Poor*, *Fair*, or *Good* rating based on regional threshold values assigned by NRSA (Table 3).

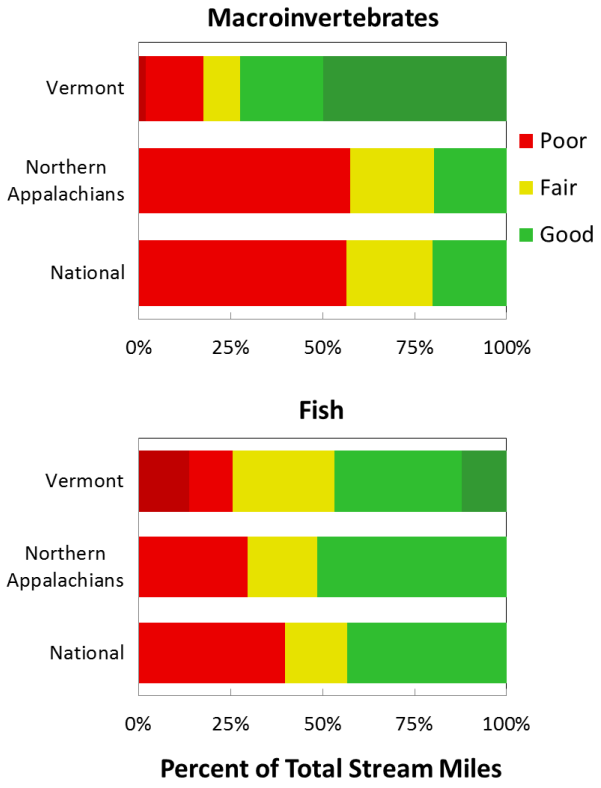


Figure 10: Results from VTDEC's 2008-2012 probability survey and US EPA's 2008-2009 National Rivers and Streams Assessment showing the cumulative percentage of biological assessment ratings at the state, eco-region (Northern Appalachians), and national scales. For comparison, both shades of red at the state level equate to "Poor", while both shades of green are "Good".

Comparisons of macroinvertebrate assessments show that over 70% of stream miles in Vermont are in *Good* biological condition, compared to only 20% at both the national and regional (Northern Appalachians) scales (Figure 10). Consequently, the percent of stream miles in *Poor* condition is much lower in Vermont (18%) than was found regionally or nationally (56%). This comparison shows that Vermont's macroinvertebrate communities are in much better biological condition than those found within our eco-region as a whole. Fish assessments at the state and regional scale are relatively similar to the national biological condition. Forty-seven percent of Vermont streams showed *Good* biological condition on this assessment scale, compared to 52% in the

Northern Appalachians eco-region, and 43% throughout the United States.

A comparison of chemical stressors also shows that Vermont has a higher proportion of stream miles in *Good* condition relative to regional and national scales (Figure 11). For salinity (an indicator of development and road density) none of the Vermont streams were rated *Poor*, and only one stream was above the 500 uS threshold to rate as *Fair*. A vast majority of stream miles in Vermont were rated as *Good* for nitrogen compared to national and regional data, with only 20% of sites falling below this threshold. Phosphorus, which is viewed as a significant water quality problem in Vermont, showed more stream miles with *Poor* and *Fair* ratings when compared to other stressors statewide, yet a far less percentage of *Poor* assessments than regional or national scales. In fact, the percent of stream miles rated *Poor* for phosphorus was nearly three times lower in Vermont (23%) than in the Northern Appalachians eco-region (71%).

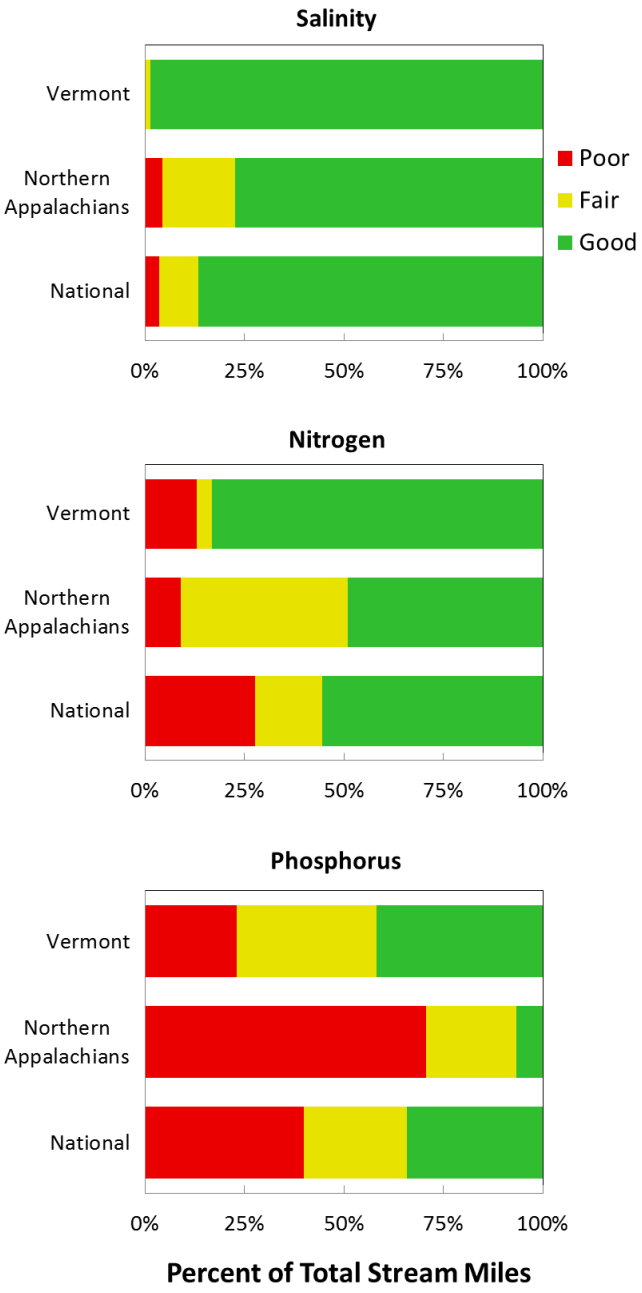


Figure 11: Results from VTDEC's 2008-2012 probability survey and EPA's 2008-2009 National Rivers and Streams Assessment showing the cumulative percentage of assessment ratings at the state, eco-region (Northern Appalachians), and national scales for three chemical stressors. Regional and national chemical thresholds were set by NRSA, and the Vermont assessments use the Northern Appalachian regional thresholds.

CONCLUSIONS

Incorporating probability based surveys into VTDEC's biomonitoring program allows for an unbiased assessment of the biological condition of Vermont's wadeable streams, and helps to show the statewide importance of a variety of environmental stressors. Repeating these surveys over time will allow VTDEC to track stream biological condition long-term, and to adjust management efforts toward appropriate stressors through its Surface Water Management Strategy (http://www.watershedmanagement.vt.gov/swms.html). These ongoing probabilistic surveys also coincide with EPA's National Rivers and Streams Assessments, allowing VTDEC to compare statewide trends to national and regional conditions. The completion of a second probability survey in Vermont has provided some interesting insights.

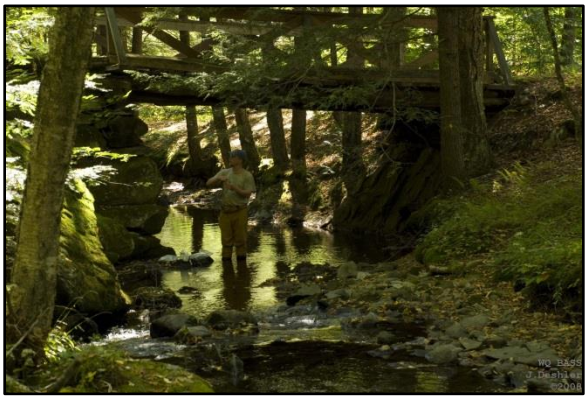
Sawmill Brook, Greensboro (Jim Deshler)

Comparing combined assessments between the 2002-2006 and 2008-2012 surveys shows that a substantial percentage of stream miles shifted from *Good* to *Fair*. This particular threshold shift was primarily driven by changes in the macroinvertebrate community. Biological condition in the fish community showed the strongest change at the upper end of the rating scale, with a shift from stream miles rated as *Excellent* to those rated as *Very Good*. Confidence limits in stream mile estimates did show significant overlap between these two surveys, and the completion of future surveys will help show whether these trends are genuine or a result of random variability.

A closer examination of assessments within each biological community shows that downward trends in biological condition often occurred in smaller headwater streams (SHG macroinvertebrate communities, and fish assemblages assessed with the CWIBI). Furthermore, the overall change in biological condition between the surveys seems to be accounted for in large part by flood flows from Tropical Storm Irene in 2011. VTDEC biologists pinpointed these scouring flows as the driving factor for *Fair* assessments at several sites, and a decline in brook trout density at some Irene impacted sites was noted to have decreased IBI scores for fish communities. While it may not seem appropriate to draw conclusions on

overall trends due to one major storm occurring just before the sampling index period, it is important to note that the frequency and magnitude of this type of disturbance is expected to increase as a result of climate change.

The results of probabilistic surveys can improve our understanding of how chemical and physical stressors affect the biology of Vermont's streams over time. Examining fish and macroinvertebrate assessments separately can shed light on how these communities are affected differently. An examination of sites failing to meet Vermont's aquatic life use standards shows that these communities are being affected by several of the major water quality stressors addressed in VTDEC's Surface Water Monitoring Strategy. Watershed land development seems to be relatively low at these randomly selected sites, and corresponding levels of chloride and sedimentation do not seem to be affecting the biological condition. The environmental data does suggest that nutrient enrichment from agricultural areas may contribute to declining macroinvertebrate community health, but confidence in this trend is weakened by variability in the results. This pattern seems to be true for the fish as well, though other stressors (i.e., acidification, erosion, thermal stress) appear to be responsible for fish



Grassy Brook, Brookline (Jim Deshler)

communities in the poorest condition. Understanding the complex connections between environmental variables and trends in the biological data is challenging, but these trends suggest prospective focus areas, and the accumulation of data from ongoing surveys should help shed light on these issues.

Despite the noticeable effects of water quality stressors on stream communities in Vermont, the comparison between US EPA's NRSA and VTDEC's statewide probability survey indicates that Vermont streams are in considerably better condition both biologically and chemically when compared to regional and national results. It should be noted that while these comparisons are weakened by the fact that VTDEC and NRSA use different sampling protocols, the overall differences are too large to discount. While the findings of this survey suggest that Vermont has comparatively good water quality in a larger context, we should

strive to further protect our streams against environmental stressors. Continued vigilance and conservation of our aquatic resources is essential to prevent a further deterioration of the biological condition.

Kilburn Brook Trib 1, Hartford (Jim Deshler)

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Appendix 1: Information for 73 probability monitoring sites 2008-2012, including major watershed and fish and macroinvertebrate assessments.

Stream (River Mile)	VTDEC Site ID	Sample Date	WBID	Basin	Bug Comm Type	Invert Assessment	Fish IBI Type	Fish Assessment
South Stream (5.1)	601100000051	9/11/2008	VT01-03	Battenkill, Walloomsuc, Hoosic	WWMG	Very Good	MW	Poor
Lye Brook (4.2)	592500000042	9/10/2008	VT01-05	Battenkill, Walloomsuc, Hoosic	SHG	Fair	-	Not Assessed
Fayville Branch (3.7)	591401010037	9/10/2008	VT01-06	Battenkill, Walloomsuc, Hoosic	SHG	Fair	BPJ	Poor
White Creek (10.6)	590100000106	10/8/2008	VT01-07	Battenkill, Walloomsuc, Hoosic	MHG	Excellent	BPJ	Very Good
Seymour Brook (3.2)	551901000032	10/18/2011	VT03-04	Otter Creek, Little Otter, Lewis	SW	Excellent	BPJ	Good
Hollow Brook (2.5)	533600000025	9/23/2009	VT03-08	Otter Creek, Little Otter, Lewis	SHG	Excellent	MW	Very Good
New Haven River Trib 27 (0.5)	551227000005	10/4/2011	VT03-11	Otter Creek, Little Otter, Lewis	SHG	Excellent	CW	Excellent
Sugar Hollow Brook (3.0)	553102000030	10/11/2011	VT03-13	Otter Creek, Little Otter, Lewis	MHG	Excellent	CW	Very Good
Ira Brook (1.3)	553604000013	10/11/2011	VT03-15	Otter Creek, Little Otter, Lewis	MHG	Very Good	CW	Very Good
Eddy Brook (1.8)	554101050018	10/12/2011	VT03-16	Otter Creek, Little Otter, Lewis	SHG	Fair	BPJ	Poor
Mill River (17.4)	554600000174	9/20/2012	VT03-17	Otter Creek, Little Otter, Lewis	SHG	Good	BPJ	Good
Otter Creek (92.4)	550000000924	10/11/2011	VT03-18	Otter Creek, Little Otter, Lewis	MHG	Very Good	-	Not Assessed
East Creek North Fork (0.4)	560200000004	10/12/2011	VT04-03	Lower Lake Champlain	SW	Fair	-	Not Assessed
Sanford Brook (1.0)	560402000010	10/12/2011	VT04-03	Lower Lake Champlain	WWMG	Good	MW	Good
Godin Brook (1.4)	425600000014	9/10/2009	VT06-04	Missisquoi	SHG	Fair	MW	Fair
Black Creek (14.5)	423100000145	9/11/2009	VT06-05	Missisquoi	SW	Very Good	MW	Good
Tyler Branch (6.1)	423800000061	9/9/2009	VT06-06	Missisquoi	SHG	Fair	Both	Good
Taft Brook (2.1)	428400000021	9/8/2009	VT06-08	Missisquoi	SHG	Very Good	MW	Very Good
Lamoille River (19.3)	460000000193	9/19/2011	VT07-02	Lamoille	WWMG	Good	-	Not Assessed
Lamoille River (20.9)	460000000209	9/19/2011	VT07-02	Lamoille	WWMG	Very Good	-	Not Assessed
Lamoille River (45.0)	460000000450	9/19/2011	VT07-04	Lamoille	WWMG	Excellent	-	Not Assessed
Gihon River (7.4)	463200000074	9/19/2011	VT07-15	Lamoille	MHG	Very Good	MW	Good
Jacob Brook (0.6)	463700000006	9/19/2011	VT07-16	Lamoille	SHG	Very Good	CW	Poor
Wild Branch (0.1)	465200000001	9/19/2011	VT07-19	Lamoille	MHG	Good	MW	Fair
Sawmill Brook (1.8)	468000000018	9/13/2011	VT07-22	Lamoille	SHG	Excellent	MW	Very Good
Ridley Brook (1.7)	493000000017	8/30/2010	VT08-04	Winooski	SHG	Excellent	BPJ	Good
Winooski River (59.8)	490000000598	9/10/2010	VT08-07	Winooski	WWMG	Excellent	-	Not Assessed
Spicer Brook (0.4)	496908000004	9/21/2010	VT08-08	Winooski	SHG	Excellent	CW	Very Good
West Branch Little River (7.3)	493238000073	9/7/2010	VT08-12	Winooski	SHG	Fair	BPJ	Very Good
Pekin Brook (2.9)	496304000029	10/6/2011	VT08-14	Winooski	MHG	Fair	MW	Poor
Stevens Branch (2.2)	495600000022	9/9/2010	VT08-16	Winooski	MHG	Good	MW	Very Good

Mad River (21.9)	494000000219	9/3/2010	VT08-18	Winooski	MHG	Very Good	MW	Good
Dowsville Brook (2.9)	494014000029	9/2/2010	VT08-19	Winooski	SHG	Excellent	CW	Excellent
First Branch White River Trib 28 (0.8)	132528000008	8/31/2010	VT09-04	White	SHG	Excellent	BPJ	Excellent
Batchelder Brook (0.5)	133325000005	9/27/2012	VT09-06	White	SHG	Very Good	MW	Fair
Riford Brook (0.9)	133317000009	9/18/2012	VT09-06	White	SHG	Excellent	CW	Good
Locust Creek (4.7)	133600000047	9/12/2012	VT09-07	White	MHG	Very Good	MW	Very Good
Robbins Branch (1.4)	136208000014	10/4/2011	VT09-07	White	SHG	Fair	CW	Very Good
Tweed River (3.2)	134600000032	8/31/2012	VT09-07	White	MHG	Good	MW	Good
Beaver Brook (1.7)	123200000017	9/12/2012	VT10-08	Ottauquechee, Black	SHG	Excellent	CW	Poor
Seaver Brook (1.2)	080500000012	9/23/2008	VT10-12	Ottauquechee, Black	SHG	Very Good	CW	Very Good
Black River (36.4)	080000000364	9/20/2012	VT10-15	Ottauquechee, Black	SW	Very Good	MW	Fair
North Branch Black River (4.9)	081500000049	9/20/2012	VT10-16	Ottauquechee, Black	MHG	Very Good	MW	Fair
Chase Brook Trib 2 (0.1)	073102000001	10/9/2008	VT11-04	West, Williams, Saxtons	SHG	Excellent	BPJ	Very Good
Saxtons River (20.3)	060000000203	9/22/2008	VT11-06	West, Williams, Saxtons	SHG	Excellent	CW	Very Good
Grassy Brook (5.5)	031200000055	9/23/2008	VT11-11	West, Williams, Saxtons	SHG	Excellent	CW	Very Good
West River Trib 31 (0.1)	033100000001	9/23/2008	VT11-12	West, Williams, Saxtons	SHG	Excellent	CW	Very Good
North Branch Ball Mountain Br (0.4)	032804000004	9/18/2008	VT11-15	West, Williams, Saxtons	MHG	Excellent	MW	Excellent
Flood Brook (4.0)	034200000040	9/16/2008	VT11-18	West, Williams, Saxtons	MHG	Excellent	MW	Good
Deerfield River (52.4)	650000000524	9/17/2008	VT12-01	Deerfield	MHG	Poor	-	Not Assessed
Red Mill Brook (0.7)	652105000007	9/11/2008	VT12-02	Deerfield	SHG	Excellent	MW	Good
Green River Trib 6 (1.7)	670600000017	9/24/2008	VT12-06	Deerfield	SHG	Excellent	CW	Very Good
Kilburn Brook Trib 1 (0.2)	VTT132601002	10/6/2011	VT13-06	Lower Connecticut	SHG	Excellent	CW	Excellent
Lulls Brook (5.9)	110000000059	9/8/2008	VT13-07	Lower Connecticut	MHG	Very Good	MW	Very Good
Mill Brook (3.1)	100000000031	10/2/2008	VT13-08	Lower Connecticut	MHG	Excellent	-	Not Assessed
Abbot Brook Trib #3 (0.6)	150407030006	9/7/2012	VT14-02	Stevens, Wells, Waits, Ompom	SHG	Excellent	CW	Excellent
Middle Brook (6.3)	151002000063	9/7/2012	VT14-03	Stevens, Wells, Waits, Ompom	SHG	Excellent	CW	Excellent
Waits River (2.4)	170000000024	9/6/2012	VT14-04	Stevens, Wells, Waits, Ompom	WWMG	Excellent	MW	Good
Stevens River (4.0)	200000000040	9/8/2010	VT14-09	Stevens, Wells, Waits, Ompom	MHG	Excellent	MW	Very Good
Stevens River (4.0)	200000000040	9/10/2012*	VT14-09	Stevens, Wells, Waits, Ompom	MHG	Very Good	MW	Good
Water Andric (0.8)	210500000008	9/2/2010	VT15-03	Passumpsic	SW	Good	MW	Good
Houghton Brook (1.6)	211105070016	9/8/2010	VT15-04	Passumpsic	SHG	Very Good	CW	Excellent
Arcadia Brook (2.0)	212519000020	9/17/2009	VT15-07	Passumpsic	SHG	Good	-	Not Assessed
Calendar Brook (4.8)	212502000048	9/13/2010	VT15-07	Passumpsic	MHG	Excellent	-	Not Assessed
Rogers Brook (0.6)	211230000006	9/13/2010	VT15-09	Passumpsic	MHG	Excellent	MW	Good
Black Branch Nulhegan River (2.6)	280300000026	9/15/2009	VT16-11	Upper Connecticut, Nulhegan, Paul	MHG	Excellent	MW	Good

North Branch Nulhegan River (4.4)	280600000044	9/22/2009	VT16-11	Upper Connecticut, Nulhegan, Paul	MHG	Excellent	MW	Very Good
Paul Stream (8.8)	260000000088	9/15/2009	VT16-13	Upper Connecticut, Nulhegan, Paul	MHG	Excellent	MW	Good
Paul Stream (15.9)	260000000159	9/15/2009	VT16-13	Upper Connecticut, Nulhegan, Paul	SHG	Excellent	-	Not Assessed
Miles Stream (2.1)	220000000021	9/13/2010	VT16-16	Upper Connecticut, Nulhegan, Paul	MHG	Excellent	-	Not Assessed
Johns River (1.6)	360000000016	9/16/2009	VT17-01	Lake Memphremagog	SW	Fair	CW	Fair
Holland Pond Trib 3 (0.5)	350504030405	9/16/2009	VT17-02	Lake Memphremagog	SHG	Excellent	-	Not Assessed
Number Six Brook (0.5)	320700000005	9/17/2009	VT17-03	Lake Memphremagog	SHG	Very Good	CW	Good
Stevens Brook (3.0)	381402000030	9/17/2009	VT17-10	Lake Memphremagog	SHG	Excellent	-	Not Assessed