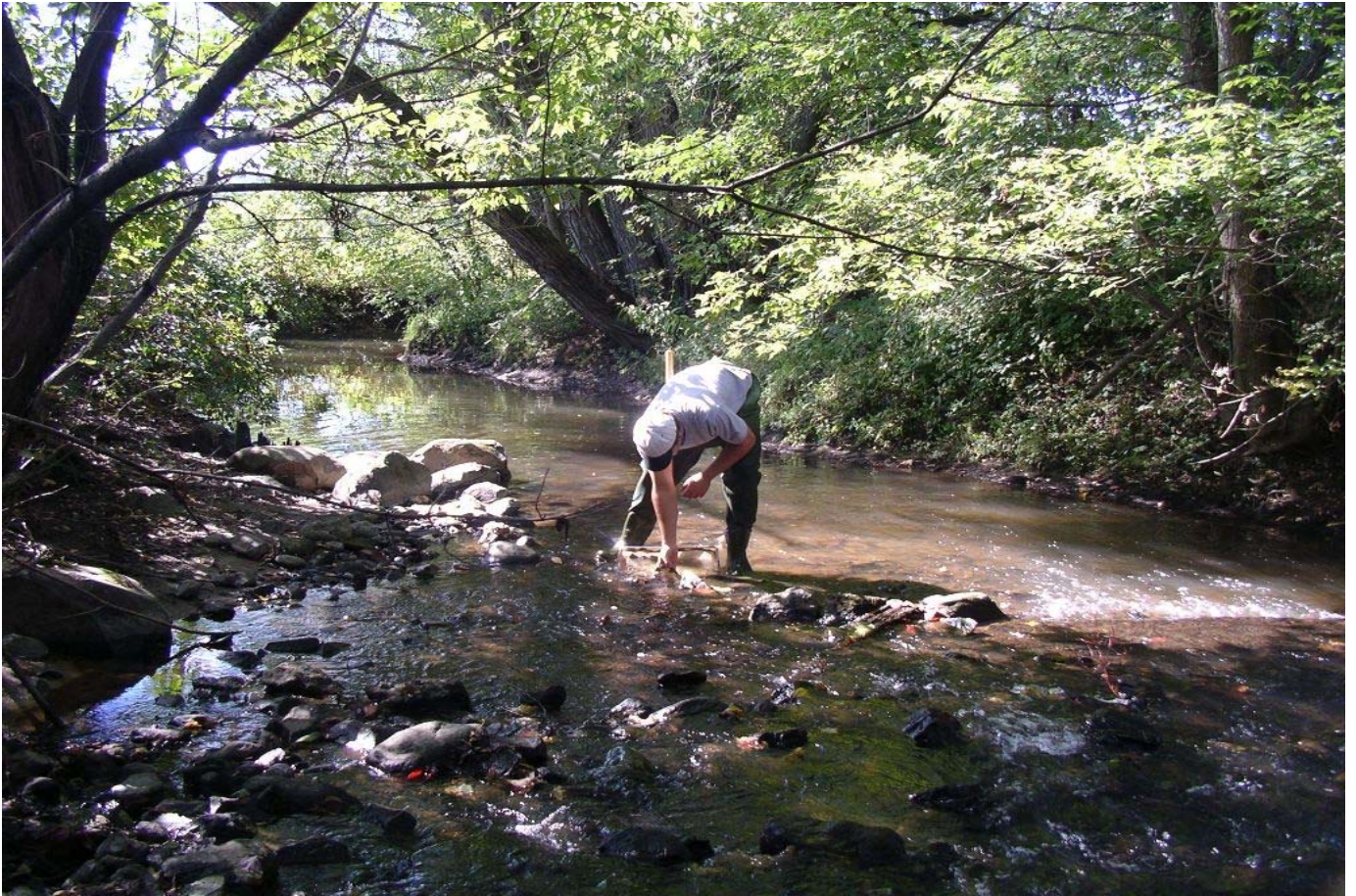


Biological and Aquatic Life Use Attainment Assessment of Moon Brook - 2010



prepared by

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Description of water body:

Moon brook drains a watershed of approximately 5,545 acres located in the City of Rutland and the Towns of Rutland and Mendon in Rutland County Vermont. The headwaters drain the undeveloped forested area of East Mountain and the streams flow through an increasingly residential area below Town Line Road. The Rutland City landfill is located in this area at approximately river mile (RM) 3.3. From there the stream travels through a wooded area until flattening out just upstream of the Combination Pond at RM 2.9. From there the watershed becomes more highly developed characterized primarily by dense residential housing. A second on-stream pond, Piedmont Pond, is situated at river mile 2.4. The stream crosses under Rt. 7 at river mile 1.2 and finally under Forest St. (RM 0.4). Below Forest Street RM 0.3, the brook flattens out in a field before entering Otter Creek. Geomorphologic characteristics of the Moon Brook corridor have been described by Bear Creek Environmental (Phase 1 and Phase 2 Stream Geomorphic Assessment of Moon Brook Watershed, 2006; River Corridor Plan, Moon Brook Watershed, 2008) and the City of Rutland (2006-2008).

Mussey Brook enters Moon Brook just above Forest St. at approximately river mile 0.4. Mussey Brook drains the southeast portion of the Moon Brook watershed and is comprised of similar development patterns but is slightly less urbanized in its mid and upper portions than Moon Brook. Similar to Moon Brook, Mussey Brook also contains two on-stream ponds, both somewhat larger than those on Moon Brook.

The entire length of Moon Brook and its tributaries are Class B waters designated as coldwater fish habitat pursuant to the Vermont Water Quality Standards. Based on land use/land cover mapping estimates, the watershed is nearly evenly divided between developed and forested lands. There is a small portion of the watershed categorized as either agricultural or open space.

Moon Brook is designated as impaired on the 2008 Vermont 303(d) List from its mouth at Otter Creek to a point upstream 2.9 miles due to non-support of aquatic life designated uses. Since all tributaries and the upstream main stem drain to the impaired lower portion of the stream, the entire Moon Brook watershed is considered to contribute to its impairment. The source of the impairment is multiple impacts associated with excess stormwater runoff. It is also likely that temperature modifications (warming) as a result of on-stream impoundments contribute significantly to observed impairments. Temperature data and analysis provided by the City of Rutland have assisted greatly in the identification of temperature as a significant stressor to biological communities in Moon Brook. (City of Rutland, 2005-2008). A further discussion of stressors is included in "Total Maximum Daily Load to Address Biological Impairment in Moon Brook (VT03-05), Rutland County, VT"; VTDEC October 2008.

Summary of Findings

Fish community. Eighteen samples from thirteen sites in Moon and Mussey brooks were assessed for fish community health between 1986 -2008. Of the 15 assessments on Moon Brook, 7 rated *poor*, 5 rated *fair*, two rated *good* and one sample rated excellent. All but one assessment from sampling sites downstream from Combination Pond were rated *fair* or *poor*, thus failing to meet Class B standards. The single exception is the 1993 sample collected at RM 0.3 which was assessed as *good* using "best professional judgment" (BPJ). The two sites above Combination Pond met Class B standards with *excellent* and *good* evaluations for the two years sampled. Neither of the two sites sampled on Mussey Brook met Class B standards, scoring a *poor* at RM 0.1 in 2002 and *fair* in 2004, while the RM 0.4 site, sampled in 2008, rated *fair*.

Macroinvertebrate community. Twenty-eight samples from thirteen stream sites on Moon and Mussey Brooks representing 26 riffle small high gradient "SHG" habitat type samples, and three low gradient habitat samples, have been assessed for macroinvertebrate community health between 1986 and 2008. Twenty-two samples rated *poor* or *fair*, one rated *good*, and four rated *very good* to *good*. All 15 samples taken at and below RM 1.2 below Route 7 rated *fair* to *poor*, failing to meet the Class B standard. The midstream site at RM 1.5 rated *good* in 2001, and *fair* in 2004. From RM 1.8 to 2.9, below Combination Pond, all six assessments rated *poor*. Above

Combination Pond, at RM 3.2, and 3.3, all five assessments rated *good* or *very good*. A single assessment on Mussey Brook in 2008 at RM 0.4 rated *Fair-Poor*.

The aquatic biota does not support its designated use for Class B waters from the mouth of Moon Brook upstream to Combination Pond. Historically fish and/or macroinvertebrate data failed the Class B standard more often than not below Combination Pond. Upstream of the pond the stream consistently meets Class B standards for aquatic life use for both fish and macroinvertebrate communities. It is assumed that standards for aquatic life use for both fish and macroinvertebrate communities are met in the remaining 1.3 miles above RM 3.3.

Summary statement-Overall “weight-of-evidence” summary of findings:

Biological assessment data from Moon Brook provide the basis for impairment designation of the lower 2.9 miles of the main stem of Moon Brook. The data are of high quality and are representative of current conditions. DEC has a high degree of confidence in the application of biological assessments to Moon Brook and in the conclusions drawn from those assessments. DEC is confident in the generic attribution of stressor as “stormwater” stressors resulting from watershed development, erosion, urban runoff as the principal cause of observed biological impairments, with temperature modifications resulting from on-stream ponds likely contributing significantly to the impairments.

Biological Assessment – Discussion:

Biological Index and Criteria Selection - Fish Community. The headwater section above river mile 2.9 (upstream from Combination Pond) was evaluated using the Coldwater Index of Biotic Integrity (CWIBI). This index is normally applicable to stream reaches with drainage areas of 4-30km², but can be applied to communities in slightly smaller drainages where more than one species is collected. Because the lower reaches of Moon Brook support an unusually rich diversity of fish species, the Mixed Water IBI (MWIBI) was used to evaluate the community in those reaches. The MWIBI is responsive to impacts in both cold and warm water situations. Neither IBI can be successfully applied to soft bottomed sites. For purposes of this evaluation the reach between the mouth and RM 0.4 has been designated as a soft-bottomed slow flowing reach. As such, BPJ was employed to assess the fish community sampled at sites below RM 0.5.

Biological Index and Criteria Selection – Macroinvertebrate Community. All sites upstream of and including RM 0.4 with riffle habitat were assessed using the biocriteria for Small High Gradient (SHG) stream type. Criteria of this stream type are normally applicable to cool to cold waters. Moon Brook is designated as cold water fish habitat. Moon Brook is at an elevation greater than 300 feet and the drainage area is small, less than 25 km². Before water temperature data were collected by the City of Rutland, it was unclear if the transition to warm water taxa in the lower reaches of the brook was natural or due to on- stream ponds. Temperature data collected by the City of Rutland has demonstrated that on-stream ponds are most likely responsible for the majority of the temperature increase in the lower reaches of Moon Brook. Three samples have recently been collected in “low gradient” habitat below RM 0.4, at RM 0.3, and RM 0.1. These samples have been evaluated using BPJ, based on a comparison to a dataset from similar higher elevation (>300ft), small (<25 km²) low gradient streams (**Appendix 1**).

Analysis. **Figure 1** shows the locations of all fish and or macroinvertebrate assessments. **Table 1** gives a narrative description of the sample sites.

The upper two sites at RM 3.2 and 3.3 have consistently met Class B biocriteria with a good or better rating for both fish and or macroinvertebrates all four years sampled. The last assessment in 2005 shows the stream continues to support a moderate density brook trout population (**Tables 2 and 3** show fish assemblage metric values). The macroinvertebrate community rated *Very good - Good* in 2005, with a moderate density, and high numbers of total species with pollution-sensitive EPT species being dominant (**Table 4**). The Bio Index

showed the overall taxa composition was of enrichment intolerant species with a B.I. value of 2.40. The proportion of Oligochaeta was slightly elevated, indicating some sediment stress at the site (**Table 5**). The site habitat observations in 2001 showed the stream to be over-widening. The substrate is high in percent sand, and rated as poor in substrate embeddedness (**Table 6**). These sediment habitat observations improved in 2005, and it appears that the biota has responded positively. Water quality data also show that chloride concentrations at the site are above background ranging between 40-70mg/l, indicating that, even in the upper watershed, the stream is receiving significant road/parking lot runoff (**Table 7a**).

Figure 1: Location of biomonitoring sites in the Moon Brook watershed.

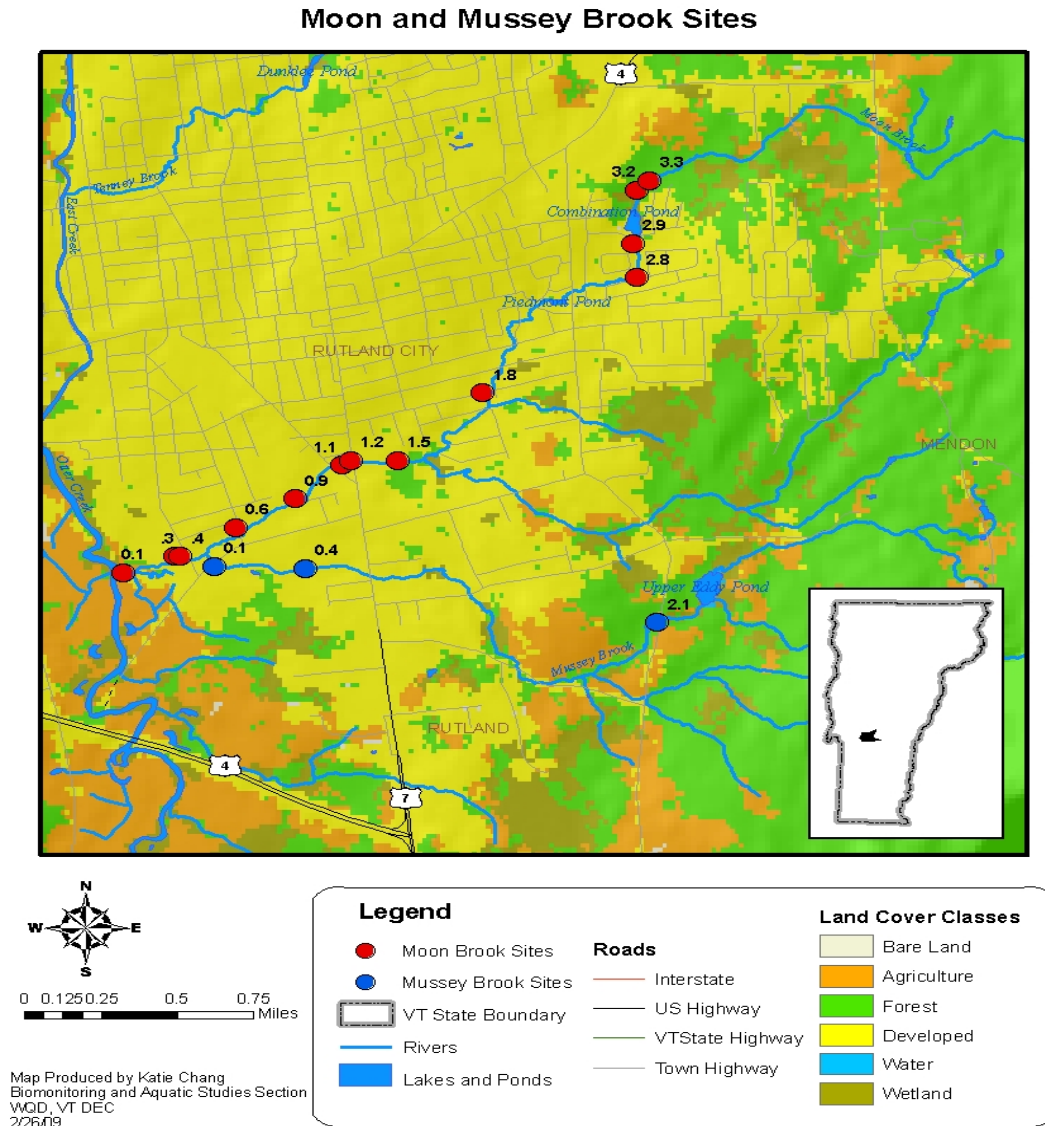


Table 1. A location description of the biological sampling sites on Moon and Mussey Brooks, Rutland, Vt. M - macroinvertebrate, F-fish.

Location	Site (RM)	Community	Description	Latitude	Longitude	Elevation (ft)	DA (Km ²)
Moon Brook	0.1	MF	Located at the mouth of Moon brook, just above confluence with Otter Creek.	43.5935140	72.985633	515	22.0
	0.3	MF	Located below Forest Street Bridge 50m in low gradient habitat.	43.5944444	72.982220	521	21.0
	0.4	M	Located at Forest St. bridge, riffle habitat.	43.5944444	72.981944	522	21.0
	0.9	MF	Located above Porter Street bridge to Howe Center Industrial Park.	43.5977778	72.974444	537	14.0
	1.1	M	Just above Strong's Ave.	43.5997222	72.971389	535	13.8
	1.2	MF	Located above/below Rt 7 bridge.	43.6000000	72.970833	538	13.5
	1.5	MF	Located below footbridge in recreation area off B street	43.6000000	72.967778	540	13.0
	1.8	M	Located adjacent to Jackson Street.	43.6038889	72.962222	544	7.4
	2.8	MF	Parallel to Catherine St.	43.6105556	72.952222	623	4.0
	2.9	M	Located below Sharon street 20m.Below Combination Pond.	43.6125000	72.952500	640	4.2
	3.2	M	Located in old field area above upper pond.	43.6155556	72.952222	658	3.5
	3.3	MF	Located adjacent to old landfill, access from Charter Hill Drive.	43.6161111	72.951389	659	3.5
Mussey Brook	0.1	F	Located upstream from Park St. bridge.	43.5938889	72.979722	535	6.3
	0.4	MF	Located just above small covered bridge in fairgrounds.	43.5937900	72.973770	540	6.1

The next three sites - RM 2.9, 2.8 and 1.8 -have consistently been assessed *poor* by both fish and macroinvertebrates. Increased summer temperatures resulting from the outflow from Combination and Piedmont ponds would seem to be mostly responsible for eliminating brook trout at RM 2.8. Sites further downstream are most likely impacted by a combination of increased water temperature and stormwater as the proportion of developed land increases within the watershed. The fish assemblages at and below RM 2.8 are composed primarily of eurythermal (tolerating wide temperature range) species, with a few warm water species. Except for brown trout, all fish species collected are considered native to Moon brook.

The macroinvertebrate community also illustrates the increased temperature influence of the pond. No Plecoptera species (generally coldwater obligates) were recorded at these sites during a number of assessments, including the last assessment in 2008, and they are generally less common at all lower stations. Other specific coldwater obligate taxa which decrease or are eliminated are *Dolophilodes sp*, *Rhyacophila spp*, *Oulimnius latiusculus*, *Epeorus sp*, and *Peltoptera sp*. Two moderately temperature tolerant filter feeding caddis fly species dominated the community below the ponds. This change in community composition reflects a shift in functional group composition to 71% filter feeders. This shift in functional feeding groups is evident in the very low functional group similarity measures with the reference condition. Also, likely as a result of the ponds, sediment observations below the ponds show less embeddedness and sand present. However, the silt rating (an observation of the resulting silt plume during sampling) increased to moderate levels at these sites, indicating that very fine material was settling on the substrate. Chloride levels continue to increase at these sites indicating that stormwater runoff continues to increase.

At the mid stream site, RM 1.5, macroinvertebrate community integrity appeared to increase slightly in 2001 (*very good -good*), dropping to *fair* however in 2004. The overall number of species and EPT species both increase, and the functional group composition becomes more similar to the expected model for the stream. The order Plecoptera increased to 10 percent of the community in 2004. The fish community did not respond in a similar fashion. Both assessments were *fair*, despite a high number of native species being recorded (13). Habitat observations continue to show increased levels of suspended silt when collecting samples, and the substrate embeddedness rated only *fair* in 2004, the last time sampled. Both of these observations indicate habitat degradation from sediment sources. The percent canopy was lowest at this site (about 50%), which could exacerbate an already temperature-stressed stream, especially at low flows. Chloride continued to increase, with concentrations measuring between 80 and 120mg/l, indicating a trend of increasing stormwater influence on stream water quality.

Macroinvertebrate EPT taxa numbers decline to low levels at downstream stations, below RM 1.2. Bio Index values are consistently elevated, ranging from 5.0 to 6.0. These two community metrics indicate that siltation and nutrients may be contributing to the impaired biological condition in the lower brook. The extremely low numbers of EPT taxa may indicate a potential for sporadic episodes of toxicity from urban runoff.

The lowest downstream sites -RM 0.1 and 0.3- in the low gradient reach shows a macroinvertebrate community of slightly better quality than the communities from the upstream SHG-type sites. Species normally found in this habitat type makes them more resistant to sediment impacts. In comparison to communities from similar less disturbed low gradient streams, however, the Moon Brook RM 0.1 and RM 0.3 community has fewer sensitive species and a greater percentage of the more tolerant animals (see **Appendix 1**). The fish community of these lower sites, while composed of eight species - well within the expected range - was very low in density.

Restoration of Moon Brook and Mussey Brook could be verified by monitoring the fish and macroinvertebrate assemblages at a subset of established sampling sites. Theoretically, fish community IBI values under improving conditions would rise at least into the good range. This would be manifest through shifts from the current dominance of tolerant, generalist species to an assemblage with a greater proportion of benthic insectivores and top carnivores (brook trout). Similarly the macroinvertebrate community should recover to expected levels of structural and functional integrity based on what is found in reference streams. Biomonitoring should continue at selected sites to monitor future watershed improvements. Moon Brook sites should include RM 0.4 or 0.9 and 1.5, 1.8, and 3.3. RM 0.1 and 0.4 should be monitored in Mussey Brook.

Stressor Identification

It is highly probable that multiple factors related to watershed development, erosion, urban runoff, and on stream ponds; resulting in alterations to the biological, chemical and physical characteristics of the stream are contributing to the aquatic life use support (ALUS) impairment. The DEC has relied primarily on biological inference, assessment site habitat observations, and watershed land use to identify the general stressors most likely to contribute to the observed ALUS impairments. Additional data provided by the City of Rutland (temperature and geomorphology), Bear Creek Environmental (geomorphology) and the Upper Otter Creek Watershed Council (water chemistry) have been incorporated into the stressor assessment. Below Combination Pond the biota shows a clear loss of cold water taxa from both macroinvertebrate and fish assemblages. Macroinvertebrate functional group composition is skewed. Some recovery in taxa richness is seen in the mid reaches, where habitat is rated good and temperature stress begins to decrease. In the lower reaches however macroinvertebrate taxa richness again becomes poor, and the bio index again begins to elevate indicating a combination of sediment, nutrient and possible toxic stress associated with stormwater is likely the most significant cause of impairments in these lower reaches (VTDEC Stormwater-Impaired Water Report to the Legislature, 2009).

The percent urban land-use in the Moon Brook drainage (**Table 8**) is high, typical of urban streams. Beginning at about RM 2.8 directly below Combination Pond the proportion of developed land increases from less than 10 percent to 17 percent. By RM 1.5 it more than doubles to 38 percent. Below Route 7 it continues to increase and at RM 0.6 to its highest level of almost 43 percent with a greater percentage of the developed space being classified as medium to high intensity. Generally this level of development will result in significant changes in both the hydrology and sediment loading of a stream. Seven stormwater-impaired streams in the Burlington area average 62% (range 39-96) developed land in their drainages while six “attainment” streams average only 6 % developed land (range 0-18).

Recent DEC studies have modeled the degree of hydrologic alteration, the degree of temperature increases, the geomorphic condition of the channel, and habitat alterations of Moon Brook (VTDEC, 2008, Moon Brook TMDL). The analysis determined that the high and low flow portions of the flow duration curve have been altered when compared to a set of attainment streams. Attainment streams are not “reference” but do meet the Class B ALUS expectations, defined as a moderate change to the biological integrity. The attainment stream for Moon Brook is Tenney Brook, a partially developed watershed that is marginally meeting Class B ALUS expectations with developed land making up 29% of the drainage.

Recent Phase 1 and Phase 2 geomorphic studies of the Moon Brook watershed have identified per cent urban land use, road density, and stormwater input as significant stressors on the hydrology and sediment load of Moon Brook (Bear Creek Environmental, 2008, River Corridor Plan Moon Brook Watershed). The condition of the aquatic habitat as it relates to the physical geomorphology of the stream has been shown to be in fair to poor condition especially below the Route 7 corridor (Bear Creek Environmental 2006). Sedimentation was identified as one of several habitat features that were responsible for the fair to poor habitat rating. As a result it was recommended that stormwater controls be implemented whenever possible in the watershed.

Documented increases in water temperature from constructed on-stream ponds also contribute significantly to the impairment of biota by degrading conditions for cold water macroinvertebrates and fish (Bear Creek Environmental 2008). On-stream ponds also disrupt the longitudinal movement of fish and macroinvertebrates by preventing upstream migration and downstream drift of biota. Additionally on-stream ponds can alter the food web of the stream causing certain macroinvertebrate functional groups to become hyper-dominant and others to decrease or be eliminated.

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Table 2. Fish community metrics from Moon Brook sites (1986-2008) evaluated using the Mixed Water Index of Biotic Integrity (Site RM 0.6, 0.9, 1.5 and 2.8), Cold Water IBI (Site 3.3 and 3.2) and Best professional judgment (Sites RM 0.1 and 0.4).

Site (RM)	Date	IBI and Assessment	Number of Native Species	Number of Intolerant Species	Number of Benthic Insectivore Species	% White Sucker and Creek Chub	% Generalist Feeders	% Insectivores	% Top Carnivores	% Anomalies	Density (#/100m ²) ¹
0.1	10/08/2008	* Poor	8	0	1	25	54	46	0	4	4
0.3	9/30/1986	* Fair	11	1	2	24	88	11	1	0	18
	10/6/1993	* Good	9	1	2	11	95	4	<1	2	103
	9/28/2005	* Fair	9	1	3	39	76	24	0	0	31
Forester St./Porter St.											
0.9	9/21/1991	29 - Fair	9	1	2	46	58	41	1	0	74
	09/25/2002	25 - Poor	8	1	1	60	80	20	0	0.0	19
	10/1/2004	25 - Poor	7	2	2	46	61	37	2	3.7	22
	10/7/2008	31 - Fair	5	0	2	5	15	85	0	0	7
Route 7											
1.5	10/23/2001	29 - Fair	13	3	3	49	78	20	1	0.3	81
	09/25/2002	23 - Poor	7	1	1	65	78	19	3	0.0	12
2.8	9/28/2005	25 - Poor	8	0	1	57	66	33	1	0	143
	9/28/2006	25 - Poor	7	0	1	58	64	37	0	0	128
	10/7/2008	25 - Poor	6	0	1	37	37	63	0	0	65
Combination Pond											
			Number of Intolerant Species	Number of Coldwater Stenotherms	% Generalist Feeders	% Top Carnivores	Brook Trout Density	Brook Trout age classes			Total Density
3.3 ²	10/23/2001	33 - Good	3	2	0	40	7	3			12
& 3.2	9/25/2005	42 - Excellent	1	1	0	100	19	3			19

1. Calculated as numbers captured during first electrofishing run /100m²

MWIBI Range: 9-25 (Poor), 27-29 (Fair), 33-35 (Good), 37 (Very Good), 41-45 (Excellent)

CWIBI Range: 9-25 (Poor), 27 (Fair), 33 (Good), 36 (Very Good), 42-45 (Excellent)

* No IBI was calculated due to lack of accurate reference for soft bottomed sites

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Table 3. Fish community metrics from Mussey Brook site RM 0.1, evaluated using the Mixed Water Index of Biotic Integrity (MWIBI)¹ and best professional judgment.

Site (RM)	Date	MWIBI and Assessment	Number of Native Species	Number of Intolerant Species	Number of Benthic Insectivore Species	% White Sucker and Creek Chub	% Generalist Feeders	% Insectivores	% Top Carnivores	% Anomalies	Density (#/100m ²)
0.1	09/25/2002	25 – Poor	7	1	2	55	59.	41	0	0.0	27.5
	10/01/2004	27 - Fair	8	1	3	32	36	64	0	4.0	12.9
0.4	10/08/2008	* Fair	10	0	2	27	91	8	0	0.4	130

1. MWIBI Range: 9-25 (Poor), 27-29 (Fair), 33-35 (Good), 37 (Very Good), 41-45 (Excellent)

Table 4. Macroinvertebrate Community Metrics from Moon and Mussey Brooks 1986-2008. *

Stream	Site	Date	Community Assessment	Density	Richness	EPT	PMA-O	BI	Oligo%	Ept/EptC	PPCS-F
Moon	0.1*	10/8/2008	Fair*	1334.0	35.0	6.0		5.16	5.8	0.57	
	0.3*	9/28/2005	Fair*	327.0	39.0	7.0		6.60	14.4	0.11	
	0.4	9/30/1986	Poor	54.3	22.0	7.3	55.0	4.58	3.7	0.46	0.53
		10/5/1988	Poor	1229.0	26.5	4.5	21.6	5.75	64.1	0.08	0.34
		9/12/1991	Poor	356.8	28.0	3.5	58.2	5.75	1.1	0.58	0.70
		10/6/1993	Poor	213.5	26.0	4.5	30.9	5.60	32.6	0.11	0.48
		9/20/1994	F-Poor	742.7	44.5	11.0	41.0	5.04	2.2	0.25	0.67
		9/25/1996	F-Poor	1247.2	42.0	9.5	44.6	4.99	4.2	0.31	0.76
		10/4/2001	F-Poor	715.5	31.5	9.0	61.2	5.38	2.5	0.81	0.62
		10/6/2004	Poor	1460.0	27.0	5.0	55.0	5.42	5.5	0.78	0.79
		9/28/2005	Poor	600.0	27.0	6.0	58.8	5.47	1.2	0.82	0.71
	Forester St./Porter St.										
	0.9	9/12/1991	Poor	550.3	35.0	5.0	43.0	6.00	6.2	0.30	0.48
		10/7/2008	F-Poor	2412.0	28.0	11.0	42.9	6.19	0.3	0.98	0.21
	Strong Ave.										
	1.1	10/11/2006	F-Poor	1143.0	33.0	8.0	53.3	6.40	6.8	0.87	0.62
	1.2	10/5/1988	Poor	353.2	22.5	4.5	20.7	5.83	44.6	0.07	0.17
	Route 7										
	1.5	10/4/2001	Vg-Good	3552.0	48.0	19.0	61.7	4.84	0.3	0.79	0.66
		10/6/2004	Fair	2608.0	37.0	10.0	62.8	4.69	0.5	0.77	0.63
	1.8	9/30/1986	Poor	44.0	11.5	5.5	38.4	5.99	1.0	0.99	0.22
		10/5/1988	Poor	206.7	17.0	4.5	59.1	6.04	14.5	0.74	0.40
	2.8	9/28/2005	Poor	757.1	22.0	3.0	55.5	5.58	0.0	0.60	0.44
		9/28/2006	Poor	1110.0	33.0	7.0	55.6	5.83	2.7	0.76	0.37
		10/7/2008	Poor	1380.0	26.0	6.0	57.0	5.83	0.0	0.86	0.51

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Stream	Site	Date	Community Assessment	Density	Richness	EPT	PMA-O	BI	Oligo%	Ept/EptC	PPCS-F
	2.9	9/12/1991	Poor	3150.0	24.0	2.0	48.9	6.44	0.0	0.74	0.25
Combination Pond											
Moon	3.2	10/4/2001	Vgood	969.0	40.0	21.0	70.4	3.05	3.1	0.91	0.68
	3.3	10/6/1988	Vg-Good	298.9	42.5	18.0	78.0	2.55	2.2	0.84	0.59
		9/12/1991	Vg-Good	901.7	49.5	19.5	64.8	3.29	1.1	0.62	0.67
		10/4/2001	Good	691.2	38.5	16.5	57.2	2.14	1.3	0.90	0.45
		9/28/2005	Vg-Good	1076.6	40.0	19.0	58.3	2.40	5.7	0.95	0.56
Mussey	0.4*	10/8/2008	Fair*	1017.0	28.0	6.0		6.85	10.6	0.28	

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Table 5. Percent composition of the major orders and functional feeding groups of the macroinvertebrate community from Moon Brook sites.

Stream	Site	Date	Coleop	Diptera	Ephem	Plecop	Trichop	Oligo	Other	CGath%	CFilt%	Predator	Shred/ Detri	Shred/ Herb%	Scraper%
Moon	0.1*	10/8/2008	11	25	29	0	2	6	27	75	7	14	1	1	2
	0.3*	9/28/2005	9	46	1	0	5	14	24	42	5	49	1	0	3
	Low gradient reaches below this point														
	0.4	9/30/1986	8	49	5	0	33	4	1	28	17	5	1	23	22
		10/5/1988	5	26	0	0	2	64	3	69	4	0	2	18	7
		9/12/1991	24	38	0	0	32	1	4	21	36	3	11	4	25
		10/6/1993	19	37	1	0	3	33	8	37	5	16	5	11	26
		9/20/1994	15	65	3	0	11	2	4	23	32	3	6	17	19
		9/25/1996	18	53	5	1	12	4	7	34	25	8	2	3	26
		10/4/2001	21	21	2	1	51	3	2	13	51	10	1	1	23
		10/6/2004	8	30	0	1	50	5	5	17	57	8	2	5	12
		9/28/2005	14	26	0	0	54	1	4	16	55	9	2	3	16
	0.9	9/12/1991	7	56	1	0	20	6	9	45	21	12	5	9	7
		10/7/2008	6	4	1	0	88	0	1	2	89	2	0	0	6
	1.1	10/11/2006	6	15	1	1	70	7	1	11	69	8	2	3	7
	1.2	10/5/1988	2	49	1	1	1	45	1	46	3	1	0	45	3
Route 7															
Moon	1.5	10/4/2001	25	22	3	2	46	0	2	14	43	9	0	3	27
		10/6/2004	9	43	0	10	35	0	2	25	41	7	0	15	11
Moon	1.8	9/30/1986	3	5	1	1	66	1	23	5	66	2	1	1	26
		10/5/1988	10	20	0	3	51	14	1	18	52	1	0	19	11
Moon	2.8	9/28/2005	15	37	0	0	45	0	3	30	45	9	1	0	16
		10/7/2008	18	17	0	0	63	0	2	12	62	5	0	1	19
	2.9	9/12/1991	2	28	0	0	69	0	1	18	71	3	1	5	2
Combination Pond															
Moon	3.2	10/4/2001	20	11	5	18	43	3	0	8	28	23	17	1	20

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Stream	Site	Date	Coleop	Diptera	Ephem	Plecop	Trichop	Oligo	Other	CGath%	CFilt%	Predator	Shred/ Detri	Shred/ Herb%	Scraper%
	3.3	10/6/1988	21	23	15	11	26	2	2	26	19	19	5	6	25
		9/12/1991	29	32	15	4	18	1	1	30	14	13	4	1	30
		10/4/2001	40	10	4	6	37	1	2	8	18	25	5	0	41
		9/28/2005	42	5	10	6	29	6	2	16	12	22	5	2	42
Mussey Brook															
Mussey	0.4*	10/8/2008	1	32	9	0	1	11	47	77	3	10	0	8	1

Table 6. Physical Chemical measures and habitat observations taken at time of macroinvertebrate sampling from Moon Brook sites 1991-2004.

* Pebble Ct method used for % composition estimates starting in 2004.

Site (RM)	Date	% Boulder	% Cobble	% Coarse Gravel	% Gravel	% Sand	Silt rating 0-5	% Embeddedness	% Canopy	% Filamentous	% Blue -Green	% Moss
0.4	9/12/1991	10	50	20	10	10	0	25-50	80	0	100	0
	10/6/1993	15	40	20	15	10	3	0-5	80	0	50	0
	9/20/1994	15	50	15	15	15	3	25-50	90	0	50	0
	9/25/1996	30	50	10	5	5	3	5-25	80	0	0	5
	10/4/2001	10	56	15	9	9	3	25-50	70	30	25	30
	10/6/2004*	9	73	11	5	2	3	25-50	70	2	0	2
0.9	9/12/1991	0	40	15	15	15	0	50-75	80	100	0	0
1.5	10/4/2001	1	20	40	30	10	3	5-25	50	30	30	5
	10/6/2004*	2	31	50	15	2	2	25-50	40	20	0	0
2.8	9/12/1991	10	60	10	10	10	0	25-50	20	0	50	0
3.2	10/4/2001	5	25	40	20	10	2	50-75	50	35		
3.3	9/12/1991	25	20	15	15	25	0	>75	100	0	0	10
	10/4/2001	10	40	25	20	15	2	>75	100	0	0	1

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Table 7a. W.Q. measures Ph, Alkalinity (Alk), Conductivity (Cond), Chloride (Cl), Sodium , Potassium , Sulfate , Calcium , Magnesium , taken at time of macroinvertebrate sampling from Moon and Mussey Brook site locations 1991-2008. D = Dissolved, * = Duplicate sample, Conductivity in italics is field measurement.

Location	Station	Date	pH	Alk mg/l	Cond umhos/cm	Cl mg/l	DNa mg/l	DK mg/l	TSO4 mg/l	DCa mg/l	DMg mg/l
Moon Brook	0.1	10/8/2008		138	598	95.4	63.3	2.05	7.36	40.5	15.9
		10/8/2008*		143	601	96.3	62.9	2.04	7.42	40.1	15.5
	0.4	9/30/1986	7.7	114	<i>390</i>						
		10/5/1988	7.68	137	<i>510</i>						
		9/12/1991	8.01	135	<i>518</i>						
		10/6/1993	7.77	110	<i>463</i>						
		9/20/1994	7.98	134	<i>522</i>						
		9/25/1996	7.76	125	<i>501</i>						
		10/4/2001	7.86	171	<i>673</i>						
		10/6/2004	7.89	139	641	108	63.1	1.85	8.32	39.2	15.2
		9/28/2005	7.39	144	699	124	65.6	2.19	8.64	39.9	15.8
		2/3/2006			572	118					
		2/17/2006			430	73					
		3/14/2006			546	112	72.2	1.84			
	0.6	10/5/1988			<i>500</i>						
		2/17/2006			485	89.1					
		3/14/2006				131	84.2	1.79		21.6	8.02
	0.9		8.06	128	<i>518</i>						
				135	647	112	67.1	1.96	6.9	36.7	31.1
				136	620	103	68	1.89	7.29	38.4	16
	1.1	10/11/2006		140	715	132	80	2.47	7.91	41.4	17.3
		10/11/2006*		138	715	132	79.4	2.55	7.89	39.7	17.6
	1.2	10/5/1988	8.18	118							

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Location	Station	Date	pH	Alk mg/l	Cond umhos/cm	Cl mg/l	DNa mg/l	DK mg/l	TSO4 mg/l	DCa mg/l	DMg mg/l
	1.5	10/4/2001	8.11	143	638						
		10/23/2001									
		10/6/2005	8.27	135	691	127	74.1	1.72	7.92	37.8	16.2
		2/3/2006			564	122					
		2/17/2006			469	87.1					
		3/13/2006			494	99.9	61.7	1.67			
	1.8	9/30/1986	8.3								
		10/5/1988	8.33	123							
		10/7/2008		105	448	68.9	43.8	1.68	6.36	29.4	12.7
	2.8	9/28/2005	7.55	124	548	85.3	47	1.68	7.92	32.9	14.2
		9/28/2006		131	576	93.2	52.1	1.66	7.17	37.3	16.7
	2.9	9/12/1991	8.01	107	400						
	3.2	10/4/2001	8.31	136							
		10/11/2006		102	455	70.4	39.8	1.57	7.68	30.6	14.1
	3.3	10/6/1988	7.95	89	368						
		9/12/1991	8.31	110	437						
		10/4/2001	8.31	136	538						
		10/23/2001									
		9/28/2005	7.53	118	499	72.4	38.3	1.36	8.44	32.4	14.5
		2/17/2006			272	41.8					
		3/13/2006			291	49.7	30	1.87			
Mussey Brook	0.1	9/25/2002									
		10/1/2004		136	488	64.6	39.2	2.07	7.45	39.6	13.8
		2/17/2006			353	49.6					
		10/16/2006		124	488	70.9	42.3	2.34	7.19	37.8	14
	0.4	10/7/2008		142	512	70.4	45.8	2.21	5.87	39.7	15.1

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Table 7b. W.Q. measures Turbidity, TSS, T Phosphorus, D Phosphorus, T Nitrogen, T Nitrate-Nitrite NOx, Iron Fe, Manganese Mn, Hardness taken at time of macroinvertebrate sampling from Moon and Mussey Brook site locations 1991-2008. D = Dissolved, T=Total, * = Duplicate sample. Observational flow also indicated as Base=not influenced by runoff event and Freshet flow influenced by runoff event.

Location	Station	Date	Flow	Turbidity NTU	TSS mg/l	TP ug/l	TDP ug/l	TN mg-N/l	TNOX mg-N/l	DFe ug/l	DMn ug/l	THC
Moon Brook	0.1	10/8/2008	Base	1.38		21.6	11.3	0.55	0.34	145	36	
		10/8/2008*	Base	1.65		12.1	9.22	0.52	0.36	131	38.2	
	0.3	10/6/2004	Base	1.54	1	11	10	0.53	0.38	309	25.3	161
		9/28/2005	Base	2.7		16.3	8.01	0.57	0.38	86.4	33.6	165
		2/17/2006	Freshet									
		3/14/2006	Freshet	70.5	250					161	57.4	
	0.6	3/14/2006	Freshet	96	234					181	50.9	87
	0.9	10/1/2004	Base	0.69	1	13	12	0.64	0.64	95	31.1	156
		10/7/2008	Base	1.18		11.1	11.2	0.66	0.5	178	37.2	
	1.1	10/11/2006	Base	0.5		17.6	15.5	0.69	0.46	135	57.3	174
		10/11/2006		0.52		19.2	16.2	0.68	0.46	125	54.4	172
	1.5	10/6/2005	Base	0.78	1.1	12	6	0.69	0.53	71.2	29	161
		2/3/2006	Freshet									
		2/17/2006	Freshet									
		3/13/2006	Freshet	48.4	120					192	74.3	89.3
	2.8	10/7/2008	Base	1.33		15.1	9.16	0.65	0.44	254	63.9	
		9/28/2005	Base	0.78		13.5	7.98	0.67	0.46	204	46.3	140
		9/28/2006	Base	0.84		14.6	12.3	0.67	0.49	157	32	162
	2.9	9/12/1991										
	3.2	10/11/2006		0.2		40.3	22	0.92	0.8	50	22.8	135
	3.3	9/12/1991										

Location	Station	Date	Flow	Turbidity NTU	TSS mg/l	TP ug/l	TDP ug/l	TN mg-N/l	TNOX mg-N/l	DFe ug/l	DMn ug/l	THC
	3.3	9/28/2005	Base	0.1		22.6	18.7	1.18	1.08	50	13.6	141
		3/13/2006	Freshet	36.8	115					106	34.7	66.5
	Mussey Brook											
	0.1	10/1/2004	Base	1.65	1	12	9	0.39	0.22	227	30.4	156
		10/16/2006	Base	3.05		13.8	10.7	0.32	0.14	187	52.4	152
		10/16/2006*	Base	3.21		15	9.57	0.48	0.15			
	0.4	10/7/2008	Base	2.98		13.8	7.88	0.32	0.14	215	69	

Table 7c. WQ total metals results collected during 2008 biological sampling at base flows.

Location	Station	SampleDate	TNa mg/l	TK ug/l	TSO4 mg/l	TCa mg/l	TMg mg/l	TFe ug/l	TMn mg/l	Hard mg/l
Moon Brook	0.1	10/8/2008	63.6	2.1	7.4	41.9	16.3	348.0	35.0	172
	0.9	10/7/2008	69.0	1.9	7.3	40.4	16.5	209.0	34.3	169
	1.8	10/7/2008	44.2	1.7	6.4	31.0	13.0	322.0	66.1	126
Mussey Brook	0.4	10/7/2008	45.5	2.3	5.9	42.0	16.0	644.0	66.0	171

Table 8. Land use cover percentages at selected biomonitoring sites within the Moon Brook watershed.

Land Use cover	Moon Brook (RM)					Mussey Brook (RM)	
	0.1	0.6	1.5	2.8	3.2	0.1	2.1
Developed, High Intensity	2.6	3.0	1.3	0.1	0.1	1.7	0.0
Developed, Medium Intensity	10.9	13.2	10.8	2.4	1.0	6.2	0.2
Developed, Low Intensity	10.7	14.0	13.9	8.8	6.1	4.4	0.8
Developed, Open Space	9.7	12.5	12.6	6.3	2.3	3.2	0.2
Developed	33.9	42.7	38.5	17.6	9.6	15.5	1.2
Cultivated Crops	0.2	0.1	0.1	0.3	0.3	0.3	0.1
Pasture/Hay	5.7	3.2	3.4	5.8	6.6	9.6	6.7
Grassland/Herbaceous	0.3	0.3	0.3	0.5	0.6	0.5	0.0
Agriculture	6.2	3.6	3.8	6.6	7.5	10.4	6.7
Deciduous Forest	23.9	25.1	26.9	42.1	46.7	22.9	34.1
Evergreen Forest	15.3	11.9	12.8	15.0	16.1	22.2	22.4
Mixed Forest	14.7	11.1	11.9	13.3	15.0	22.0	30.9
Scrub/Shrub	1.6	1.2	1.1	1.0	0.9	2.3	1.3
Forest	55.3	49.3	52.8	71.4	78.6	69.5	88.7
Palustrine Forested Wetland	3.5	3.7	4.0	3.7	3.9	3.2	1.0
Palustrine Scrub/Shrub Wetland	0.4	0.2	0.2	0.2	0.1	0.7	1.2
Palustrine Emergent Wetland	0.5	0.5	0.6	0.4	0.3	0.4	0.5
Wetland	4.3	4.5	4.8	4.3	4.3	4.3	2.7
Unconsolidated Shore	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bare Land	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Bare Land	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Open Water	0.1	0.0	0.0	0.0	0.0	0.1	0.3
Palustrine Aquatic Bed	0.1	0.0	0.0	0.0	0.0	0.2	0.3
Water	0.1	0.0	0.0	0.0	0.0	0.3	0.6
TOTALs	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: Land cover layer used for these calculations was created by NOAA Coastal Services Center in 2006 using 30-meter resolution Landsat Thematic Mapper and Landsat Enhanced Thematic Mapper satellite imagery according to Coastal Change Analysis Program (C-CAP) standards. Drainage basins were produced using StreamStats, an online GIS application developed by USGS.

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Appendix 1

Table of macroinvertebrate biometrics used to make BPJ assessment of low gradient stream habitat of Moon and Mussey Brooks. COTE=taxa from orders Coleoptera, Odonata, Trichoptera, and Ephemeroptera. % Tolerant = percent of taxa with Bioindex values ≥ 7 , and # INTOL= taxa with BI values ≤ 3 .

Location – “least disturbed”	Density	Richness	COTE	Bio Index	%TOL	#INTOL	Oligo%	EPT
Burnt Meadow Brook	1584	54	30	5.86	31	13	1.0	19
Peach Brook	439	50	24	3.11	7	13	4.7	15.5
Brighton Brook	613	74	22	5.12	0	12	1.5	14
Seymour Brook	3776	50	19	3.87	3	12	0.3	13
Willow Brook	1752	41	17	2.56	0	15	0.0	11
Otter Creek Trib # 27	1264	42	18	2.70	0	15	0.6	16
Button Brook	2264	70	33	3.76	0	33	0.4	26
Sanford Brook	2060	49	17	3.42	4	11	0.4	10
MEAN	1719	53.8	22.5	3.80	5.6	15.5	1.1	15.6
Moon Brook 0.1	1334	35	14	5.16	27	4	5.8	6
Moon Brook 0.3	327	39	14	6.60	34	7	14.4	7
Mussey Brook 0.1	1017	28	11	6.85	63	3	10.6	6

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