

Assessment of Trout Cover and Its Relationship to Trout Abundance in the Batten Kill Main Stem and Four Rivers in Reference Watersheds

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Abstract

Cover is an important habitat component especially for a cover oriented species as the brown trout. This habitat feature was measured at 16 stream sections located among river main stems in four separate watersheds in Vermont. Linear regression and correlation analyses were conducted on estimates of available cover in each study section and four years of population estimates representing yearling and older segments of the trout populations. Significant positive correlations in the Batten Kill between cover abundance and trout standing stock were observed for brook trout but less so for brown trout. While these results may indicate the importance of cover in predicting trout standing stock in some years, they also suggest other factors may be of greater influence on populations in other years. Estimates of cover abundance in the Batten Kill and the four reference rivers are generally well below conditions recommended in the published literature as providing desirable habitat for brown trout. Providing other habitat (water quality) factors, such as summer water temperature maxima, are not limiting trout populations in cover deficient streams and trout mortality due to angling is not a significant limiting factor; river management practices that restore and maintain desired levels of cover in stream channels may help increase yearling and older brown and brook trout abundance.

Introduction

During the mid 1990s a precipitous decline in catchable-size brown trout *Salmo trutta* abundance occurred in the Batten Kill main stem of Vermont that was reflected in annual population assessment surveys conducted by the Vermont Fish and Wildlife Department (VFWD) and in anglers' catch. Prior to this change in the fishery, the Batten Kill was long acknowledged as one of the state's premier wild trout streams, a reputation that extended well beyond its borders. Responding to this development the VFWD formed an interdisciplinary team of aquatic scientists to investigate possible causes of the decline through studies principally funded through cost-share agreements with the U. S. Forest Service, Green Mountain National Forest (USFS). The team was comprised of

representatives of the VFWD, USFS and Vermont Department of Environmental Conservation and the Vermont Cooperative Fish and Wildlife Research Unit based at the University of Vermont.

The team focused considerable attention on possible habitat-associated causes such as water quality, stream geomorphology, flow and temperature regimes, and trout cover. This report presents findings for work conducted to assess the current condition of trout cover in the Batten Kill and four reference streams located in different watersheds within the state, namely the Mettawee, Poultney, Castleton and Dog rivers.

Cover is widely recognized among fisheries managers as an important component defining suitable trout habitat especially in lotic systems. While it has been suggested cover can be difficult to define (Bjornn and Reiser 1991), Binns and Eiserman (1979) described it succinctly as any bank or channel feature “that allows trout to avoid the impact of the elements or enemies.” More specifically cover may consist or be influenced by water depth and turbulence, streambed composition, overhanging or undercut banks, overhanging riparian vegetation, woody debris, and aquatic vegetation (DeVore and White 1978, Raleigh et al. 1986, Bjornn and Reiser 1991). As a habitat component cover is used by trout as refuge from threats posed by extreme environmental events, including harsh winter conditions, periodic floods and high velocity flows, energy conservation, and predator avoidance. The amount and quality of cover habitat present in streams has been shown in some cases to influence trout carrying capacity, i.e. as cover decreases so does trout abundance and vice versa (Broussu 1954, Hunt 1976, Lewis 1969, Thorn 1988, Thorn and Anderson 2001). Cover is an important habitat component of the three trout species inhabiting Vermont streams (brown trout, rainbow trout *Oncorhynchus mykiss* and brook trout *Salvelinus fontinalis*); however, it is generally thought that brown trout, particularly adult fish, have a somewhat more higher association with cover than the other two (Butler and Hawthorne 1968; Raleigh et al. 1984, Raleigh 1986, Raleigh 1982).

The present study evaluated the quantity of various cover types in channel segments of the Batten Kill main stem and the four reference streams. The current condition of cover availability in and between streams was evaluated and compared to desirable conditions reported in the literature.

Site Description

The Batten Kill watershed (Figure 1) is located in the Hudson River basin and has a total area of 450 mi² located in two states. The upper 200 mi² drain the Taconic and Green mountains of Vermont with the remaining 250 mi² in New York. The main stem of the river is 57.6 mi in length originating at East Dorset, Vermont. From there it flows in a generally southward direction 19.8 mi to Arlington, Vermont, where it then heads west another 7.3 mi before crossing into New York. The Batten Kill in Vermont is a wild

trout stream supporting populations of brown and brook trout and has not been stocked since the mid 1970s.

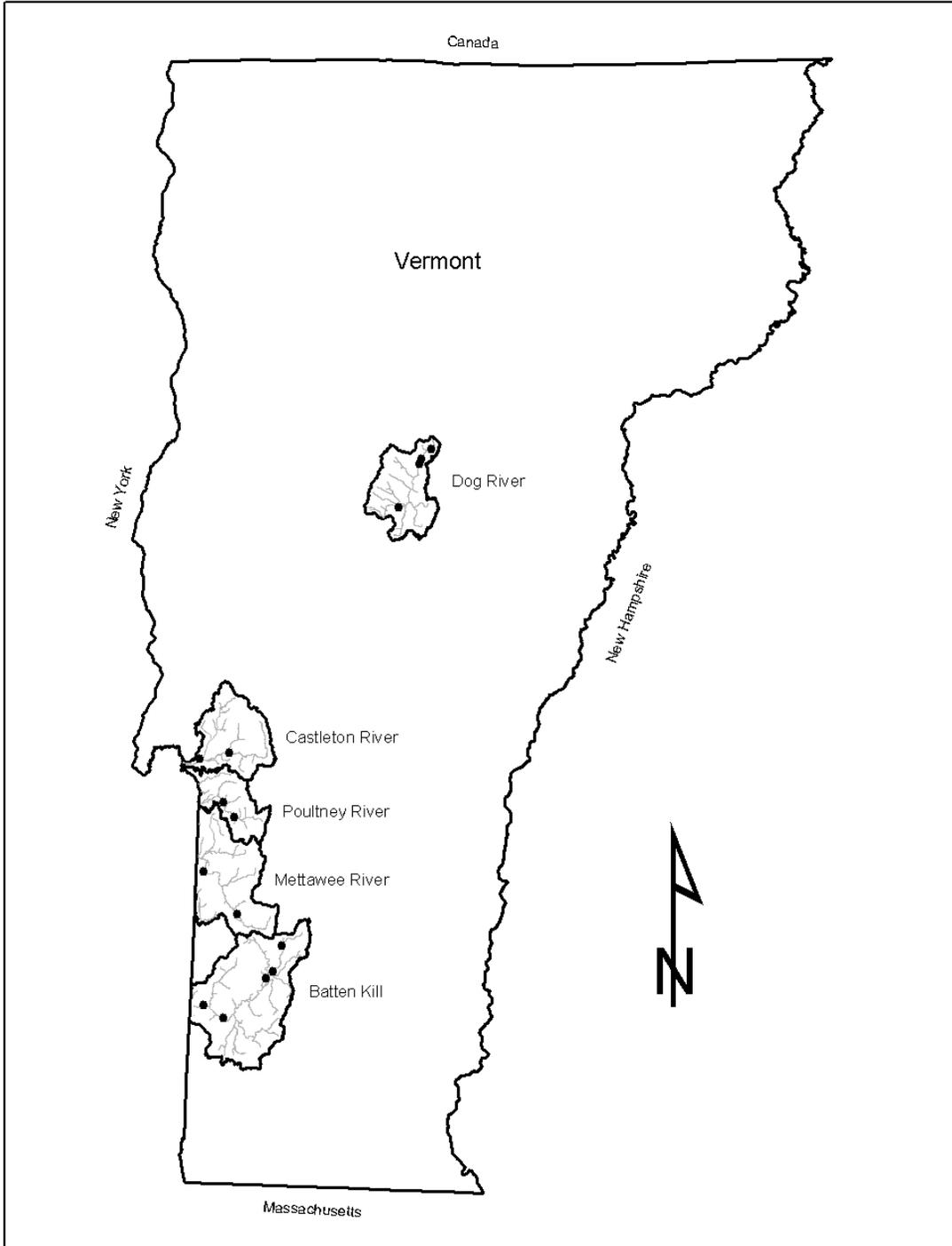


FIGURE 1. Location of the Batten Kill, Mettawee, Poultney, Castleton and Dog river watersheds showing location of cover and trout population assessment sections.

The Poultney River, one of the four reference streams included in this study (Figure 1), flows into Lake Champlain and has a drainage area of 262 mi². The Castleton River with a catchment area of 58 mi² is a tributary of the Poultney River. The Mettawee River also flows into Lake Champlain via the Champlain Canal and has a drainage area of 211 mi². The Dog River with a drainage area of 93 mi² is a tributary of the Winooski River and is also located in the Lake Champlain basin.

Reference streams were selected on the basis of the following criteria: (1) support wild populations of brown and brook trout, (2) not stocked with hatchery trout, and (3) trout population monitoring stations are already established with multiple years population data on record. Additionally, reference sites were selected with the assumption that the existence of abundant wild trout populations were not being confounded by limiting factors, such as water temperature and water chemistry, lending to assessing alone the influence of available fish cover. The Poultney and Castleton rivers like the Batten Kill are wild brown and brook trout streams. The Mettawee and Dog rivers on the other hand not only support wild populations of brown and brook trout but also have wild rainbow trout.

Methods

Many aspects of the survey methods used for this study were influenced by procedures developed by Binns (1982). However, that guidance lacks definition of minimum standards required of the various cover types to be considered effective refuge habitat for yearling and larger trout. Therefore, such criteria were developed from a review of the literature leading to methods used for the current study: *Procedures for Evaluating Trout Cover in Streams* (Cox 2001) (Appendix 1).

These methods were used to measure the amount of trout cover within each of the population monitoring stations located on the Batten Kill main stem and the reference streams. Simple linear regression and correlation analyses were used to determine whether relationships between amount of cover, the independent variable, and trout standing stock, the dependent variable, exist at each of the assessment sites over a span four years, 2001-2004. Trout standing stock was limited to yearling and older trout, because preliminary analysis of annual trout standing stock data from the Batten Kill suggested a population recruitment bottleneck was occurring after the first growing season. Also, smaller brown trout tend to favor riffle habitats dominated by cobble substrates versus older trout which prefer deep water habitats with larger substrate composition and abundant cover in riverine systems (Heggenes 1988). If cover is a

limiting factor, then yearling and older trout are more likely to show a response than juvenile fish.

Electrofishing was carried out using standard VFWD shocking gear consisting of a Georator© portable gas-powered DC generator rated at 250 V, 2 A and 500 V, 1 A output. The generator was positioned either on the stream bank for sites with narrow stream widths or in an aluminum canoe where the channel was wide and greater equipment mobility was needed for effective sampling. One to three individual canoe electrofishing units were used to span the stream channel depending on width of the stream section being sampled. Fish immobilized by the electric field were netted and placed in a temporary holding vessel containing fresh water. After completion of one pass through the sampling section all fish were transferred to a live cage placed in the stream. Successive trout samples were held in separate live cages. A minimum of two passes were made for population estimation.

Captured trout were anesthetized, identified to species and measured for total length (mm) and wet weight (g). Fish were placed in a receptacle with fresh water to recover from the anesthesia and released back to the stream. The maximum likelihood modification of the Zippin method (Carle and Strub 1978) was used to estimate trout populations by species and size class. Annual standing stock, expressed as fish/mi, was obtained at each of the 16 study sites.

Concurrent with the above cover surveys a more general evaluation of riverine geomorphology, in-stream habitat, and riparian conditions was carried out on the Batten Kill main stem. Methods used for this survey are described in Bernier (in preparation). Based on general habitat types (pools and riffles) the river was partitioned into segments assigned a natural stream order (NSO) number from down to up stream. A survey of the lower 20 mi of Batten Kill main stem in Vermont required several years (2000-2003) to complete. A 20% sample of the total number of habitat types surveyed during a particular field season was randomly drawn and evaluated the following field season specifically to estimate total available trout cover and its components: deep water, overhanging bank vegetation, wood, undercut banks, etc.

Correlation and regression analysis was used to test the relationship between the independent variable, percent cover, and the dependent variable, yearling and older trout per mile, within stream sites by year and species as well as combinations of species. Combining all species into a single class may overlook or mask inter-specific differences in the way each relates to and depends on cover (Hartzler 1983).

Results

Cover surveys were conducted at 16 sites (Table 1): Batten Kill, 6; Mettawee River, 2; Poultney River, 2; Castleton River, 2; and Dog River, 4. Data collected from the Mettawee, Poultney and Castleton rivers was not analyzed beyond computing

correlation coefficients (r), because with only two stations per stream r -values were either +1 (Mettawee and Poultney rivers) or -1 (Castleton River).

TABLE 1. Trout cover estimates for stations located on the Batten Kill main stem and reference streams.

Stream	Station identification (elevation, ft)	Station length, ft	Station average width, ft	Total wetted area, ft ²	Adjusted total area, ft ²	Cover area, ft ²	Percent cover
Batten Kill	540	734	81.8	60,041	60,041	144	0.24
	585	655	86.0	56,330	56,330	384	0.68
	655	331	58.0	19,198	17,693	283	1.60
	656	473	53.0	25,069	25,069	162	0.65
	695	507	29.6	15,007	15,007	1,658	11.05
	750	553	21.1	11,668	11,668	493	4.23
Mettawee River	510	547	37.5	20,513	20,364	345	1.69
	745	537	22.7	12,190	11,858	280	2.36
Poultney River	680	514	22.5	11,565	11,565	44	0.38
	730	511	20.3	10,373	10,373	316	3.05
Castleton River	352	605	33.4	20,207	20,207	1,460	7.23
	430	616	26.4	16,262	16,062	759	4.73
Dog River	515	800	46.8	37,440	36,556	1,047	2.86
	555	724	43.3	31,349	31,150	66	0.21
	572	696	24.9	17,330	17,330	204	1.18
	805	500	22.7	11,350	10,485	158	1.51

Estimates of available cover across all 16 study sites ranged from a low of 0.21% to a high of 11.05% with a mean of 2.35% (SD 2.69). Cover estimated at Batten Kill station 695 (11.05%) is suspiciously high being 53% greater than the next largest estimate, 7.23% at Castleton River 352. Bank vegetation was the dominant cover type at Batten Kill 695 (69% of total cover). Although the survey did not rate various cover components within stations with respect to cover quality, this observer judged vegetation at this site to be of poor quality providing trout little refuge due to sparse foliage density in proximity to the water surface. The cover estimate for station 695 may represent an outlier and as such analyses were done with and without it.

Tests for correlation between the variables: available cover and trout abundance using the entire Batten Kill dataset resulted in six out of twelve significant positive relationships (Table 2). When station 695 was not included in the analyses seven significant correlations resulted. Of particular note, brown trout tested alone resulted in only two significant findings: one each with and without station 695 during 2001. In contrast, more significant positive correlations were detected for brook trout than brown trout abundance estimates regressed against cover.

TABLE 2. Pearson correlation coefficient tests for cover habitat on abundance of yearling and older brown and brook trout combined in the Batten Kill, 2001-2004, with and without Station 695. Asterisks indicate significance at $P \leq 0.05^*$ and $P \leq 0.01^{**}$. Significant values are highlighted.

Species	Year	All stations			Without Station 695		
		df	<i>r</i>	<i>t</i>	df	<i>r</i>	<i>t</i>
Brown trout	2001	4	0.761	2.346*	3	0.977	7.933**
	2002	4	0.183	0.372	3	0.798	2.294
	2003	4	0.094	0.189	3	0.392	0.738
	2004	4	0.509	1.183	3	0.640	1.443
Brook trout	2001	4	0.922	4.763**	3	0.853	2.831*
	2002	4	0.484	1.106	3	0.935	4.566**
	2003	4	0.841	3.109*	3	0.661	1.526
	2004	4	0.875	3.615**	3	0.919	4.038*
Brown and Brook trout	2001	4	0.743	2.220*	3	0.965	6.372**
	2002	4	0.427	0.944	3	0.997	22.294**
	2003	4	0.777	2.469*	3	0.641	1.447
	2004	4	0.812	2.782*	3	0.865	2.986*

Linear regression analyses for the Batten Kill sites yielded similar results (Table 3) to the correlation tests reported previously and similarly showed much inter-annual variability. Furthermore, the number of significant relationships occurring between trout abundance and amount of available cover were fewer than determined by correlation tests. For those linear regressions showing significant positive relationships the high r^2 values seem to demonstrate a high percentage of the variability (0.57-0.99%) in trout abundance may be explained by the cover variable. When brown trout were tested alone and station 695 was not included in the analysis, a very significant relationship between trout abundance and cover ($P \leq 0.01$) occurred in 2001.

TABLE 3. Simple linear regression analyses of the annual effects of available cover habitat on abundance of yearling and older brown and brook trout in the Batten Kill, 2001-2004, with and without Station 695. Asterisks indicate significance at $P \leq 0.05^*$ and $P \leq 0.01^{**}$. Significant values are highlighted.

Species	Year	All stations				Without Station 695			
		df	Adjusted r^2	F	P	df	Adjusted r^2	F	P
Brown trout	2001	1,4	0.47	5.51	0.079	1,3	0.94	62.88	0.004**
	2002	1,4	-0.21	0.14	0.729	1,3	0.52	5.25	0.106
	2003	1,4	-0.24	0.04	0.859	1,3	-0.13	0.54	0.514
	2004	1,4	0.07	1.40	0.303	1,3	0.21	2.08	0.245
Brook trout	2001	1,4	0.81	22.75	0.009**	1,3	0.64	8.02	0.066
	2002	1,4	0.04	1.22	0.331	1,3	0.83	20.80	0.020*
	2003	1,4	0.63	9.68	0.036*	1,3	0.25	2.33	0.224
	2004	1,4	0.71	13.11	0.022*	1,3	0.79	16.31	0.027*
Brown and brook trout	2001	1,4	0.44	4.93	0.091	1,3	0.91	40.26	0.008**
	2002	1,4	-0.02	0.89	0.398	1,3	0.99	470.1	0.000**
	2003	1,4	0.50	6.10	0.069	1,3	0.21	2.09	0.244
	2004	1,4	0.57	7.75	0.050*	1,3	0.66	8.88	0.059

TABLE 4. Pearson correlation coefficient tests for cover habitat on abundance of yearling and older trout in the Dog River, 2001-2004, analyzed with and without rainbow trout. Asterisks indicate significance at $P \leq 0.05^*$ and $P \leq 0.01^{**}$. Significant values are highlighted.

Species	Year	df	r	t
Brown trout	2001	3	0.556	0.946
	2002	3	0.999	31.591**
	2003	3	0.167	0.240
	2004	2	0.623	0.796
Rainbow trout	2001	3	0.297	0.440
	2002	3	0.001	1.414
	2003	3	0.261	0.382
	2004	2	0.925	2.434
Brook trout	2001	3	0.010	0.014
	2002	3	0.035	0.050
	2003	3	0.043	0.061
	2004	2	0.736	1.087
Brown and rainbow trout	2001	3	0.331	0.496
	2002	3	0.036	0.051
	2003	3	0.259	0.639
	2004	2	0.387	0.422
Brown and brook trout	2001	3	0.134	0.191
	2002	3	0.165	0.237
	2003	3	0.033	0.049
	2004	2	0.872	1.781
Brown, rainbow and brook trout	2001	3	0.338	0.508
	2002	3	0.050	0.071
	2003	3	0.113	0.161
	2004	2	0.833	1.506

Dog River data analyses resulted in a single significant positive correlation (Table 4). This was for brown trout during 2002. Linear regression analyses (Table 5) are consistent with correlation results.

TABLE 5. Simple linear regression analyses of the annual effects of available cover habitat on abundance of yearling and older brown, rainbow and brook trout in the Dog River, 2001-2004. Asterisks indicate significance at $P \leq 0.05^*$ and $P \leq 0.01^{**}$. Significant values are highlighted.

Species	Year	df	Adjusted r^2	F	P
Brown trout	2001	1,2	-0.04	0.89	0.444
	2002	1,2	1.00	797.3	0.001**
	2003	1,2	-0.46	0.06	0.833
	2004	1,2	-0.22	0.64	0.572
Rainbow trout	2001	1,2	-0.37	0.19	0.703
	2002	1,2	-0.50	<0.01	0.999
	2003	1,2	-0.40	0.15	0.739
	2004	1,2	0.71	5.92	0.248
Brook trout	2001	1,2	-0.50	<0.01	0.990
	2002	1,2	-0.50	<0.01	0.965
	2003	1,2	-0.50	<0.01	0.957
	2004	1,2	0.08	1.18	0.473
Brown and rainbow trout	2001	1,2	-0.34	0.25	0.669
	2002	1,2	-0.50	<0.01	0.964
	2003	1,2	-0.40	0.14	0.741
	2004	1,2	-0.70	0.18	0.747
Brown and brook trout	2001	1,2	-0.47	0.04	0.866
	2002	1,2	-0.46	0.06	0.835
	2003	1,2	-0.50	<0.01	0.967
	2004	1,2	0.52	3.16	0.326
Brown, rainbow and brook trout	2001	1,2	-0.33	0.26	0.662
	2002	1,2	-0.50	<0.01	0.950
	2003	1,2	-0.48	0.03	0.887
	2004	1,2	0.39	2.27	0.373

Apart from the formal study, other cover surveys were also done on the Batten Kill main stem in stream sections representing pool and riffle habitat types identified during the general habitat survey (Bernier, in preparation). Of the 44 habitat sections evaluated 66% were pools and 34% were riffles (Appendix 2, Table 1). Cover estimates represented as a percentage of total wetted area of the habitat unit evaluated ranged from 0-66.6% and have a mean of 7.27% (SD 11.16). Table 2 of Appendix 2 summarizes the overall contribution of each cover type category to the overall cover estimate.

Discussion

Simple linear regression analysis of one independent variable, trout cover, expressed as percent of total wetted area plotted against yearling and older trout standing stock estimates resulted in significant positive correlations but were not consistent within species or years at Batten Kill sites. While this appears to indicate cover is an important habitat variable, other factors may be of greater influence on trout abundance during other years, such as those when no significant correlations were detected. This is not at all unexpected considering the complexity of aquatic systems and the large array of physical and biological conditions that vary temporally between and within streams. Factors, such as stream velocity and water depth, summer stream temperature regime, and food availability, were not taken into account during this study but may be equally or more important determinants of trout carrying capacity than available cover in some years.

Among the 16 study sites evaluated for cover, 14 (86%) had estimates less than 5% of the wetted channel area and all sites with the exception of station 695 were less than 8%. The clustering of cover values at the very low end of the observed range may explain the lack of more significant correlations between cover and fish abundance.

Recommended levels of cover supportive of riverine brown trout populations appear in the published literature. Raleigh et al. (1986) state 35% or more of the wetted stream area should provide adequate cover habitat for adult brown trout. Binns and Eiserman (1979) rated habitat value on the basis of 11 variables or attributes one being cover. Under their system, cover in excess of 55% of total wetted area described the best condition (category 4), followed by 41-55% (category 3), 26-40% (category 2), 10-15% (category 1), and less than 10% as worst (category 0). A study of brown trout habitat in southeast Minnesota streams concluded a total cover area of 20% to be the desired condition (Thorn et al. 1997).

Comparison of cover values estimated for the Batten Kill and the four reference streams to the target values identified above suggest with few exceptions available cover is well below the range of values representing best conditions as presented in the literature. Cover estimates obtained in this study may be lower than measured as other contributors to cover quality were not taken into consideration. For example, a patch of cover equal in size and composition to another were given equal weight, despite clear differences in velocity characteristics. Therefore, effective cover in these streams may be worse than as represented by the reported values. Inoue et al. (1997) found the positive relationship between salmon (*Oncorhynchus masou*) abundance and quantity of available cover to be significant at the stream reach scale which was defined as 10 riffle-pool sequences but to be less important at the landscape scale. They further add, if cover is deficient at a larger scale, such as the sub-basin level, then the effects on trout abundance can be broader. It seems reasonable that this relationship may also hold for other salmonids, and if so, given the extremely low quantity of cover throughout the Batten Kill main stem, it is also reasonable to believe this is a significant limiting factor for its trout populations. Overwintering trout survival is greatly affected by the abundance of

in-stream cover (Cunjak and Power 1987) and stream populations subjected to severe winters, such as typically occur in Vermont, may experience heavy losses especially during their first year of life if this habitat is not present in adequate amounts.

Roy and Nislow (2002) suggest current and historic land uses have altered fluvial systems throughout the Northeast at the expense of salmonid habitat. Alterations have reduced the natural input of habitat serving and forming large wood as a result of extensive clearing and harvesting of mature forests especially within riparian corridors. Furthermore, river channels and fluvial processes have been modified over decades of activities intended to accommodate transportation infrastructures, agriculture, residential and commercial development, and reduce or repair flood damage.

Starting in 2005 state, federal and several nongovernmental organizations undertook a multi-year project, the Twin Rivers Habitat Project, to determine whether restoration of cover habitat in the Batten Kill main stem above densities currently available will increase the survival and abundance of yearling and older trout. Two years of pre-construction trout population estimates were conducted in the treatment reach before increasing the quantity of cover by constructing artificial habitat. In September 2006 over 652 ft of channel having both pool and riffle habitat types was treated by the placement of cover structures (e.g. large wood clusters and rock shelters) increasing cover from 0.7% to about 3.0% but still well below the reported desirable condition levels. Trout population response to the added cover measured by annual population estimates continues and is scheduled for completion in 2011.

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APPENDIX 1.

Procedures for Evaluating Trout Cover in Streams

Pdf file to be inserted

APPENDIX 2.

TABLE 1. Cover estimates for randomly selected habitat units on the Batten Kill main stem.

Section description		Section length, ft	Average section width, ft	Total wetted area, ft ²	Cover, %
NSO #	Pool/riffle #				
4	P2	825	82.8	68,310	2.59
5	R2	170	96.0	16,320	0.37
7	P4	261	91.1	23,777	5.34
23	R8	128	75.0	9,600	4.58
24	P12	305	77.5	23,638	0.95
25	R9	145	83.8	12,151	1.65
30	P15	605	83.3	50,397	10.06
33	P17	933	83.9	78,279	4.25
43	R16	119	77.5	9,092	1.22
66	R23	284	89.5	25,108	1.61
69	P32	795	95.9	75,305	9.66
72	P34	825	83.4	68,805	0.90
74	P35	611	75.6	46,151	10.64
79	R26	155	65.8	10,199	8.59
84	P37	372	84.8	31,359	0.18
99	R28	238	76.5	17,824	0.17
108	P48	653	63.1	41,186	21.28
117	P52	241	59.9	14,444	0.50
119	R34	100	51.0	5,100	0
120	P53	381	72.1	27,478	21.23
125	P55	384	68.0	26,093	4.38
138	R41	127	84.0	10,668	0.05
146	R44	743	80.9	60,109	3.99
151	P64	541	63.0	34,110	20.86
153	P65	273	56.5	15,424	1.74
174	P75	1,247	58.3	71,455	14.58
192 & 194	P84 & P85	276	43.8	12,089	3.85
201	P87	444	55.5	24,642	15.17
204	R48	273	51.7	14,114	3.45
217	P95	2,212	37.6	83,171	20.23
218	P96	1,324	39.8	52,695	22.09
235	P106	295	45.6	13,452	10.07
239	P109	1,612	51.7	82,668	4.38
241	R51	357	54.0	19,278	2.78
253	P116	132	36.3	4,792	12.06
255	P117	60	30.6	1,836	7.57
265	P122	294	37.5	11,025	6.31
269	P125	88	48.6	4,277	6.10
280	R61	400	55.3	22,120	0.90

285	P131	77	42.0	3,234	66.60
291	P134	136	38.0	5,168	1.35
292	R66	334	49.3	16,466	1.37
303	R70	68	21.0	1,428	9.10

TABLE 2. Percentage composition of trout cover by cover type for 44 sampled habitats units (pools and riffles) on the Batten Kill main stem.

Cover types	Total	Pool	Riffle
Pool habitat \geq 2 ft depth	54.27	55.58	32.98
Overhanging bank vegetation	11.62	10.90	23.38
Rock riprap	10.86	10.25	20.75
Coarse rock substrate	10.58	11.17	0.94
Wood	7.77	7.25	16.19
Aquatic vegetation	2.89	3.06	0
Wood associated with overhanging bank vegetation	1.27	1.07	4.50
Undercut bank	0.28	0.30	0.08
Velocity refuge	0.18	0.12	1.18
Artificial fish habitat structure	0.17	0.18	0
Bridge abutments	0.10	0.11	0
Total cover area, ft ²	105,764	6,095	99,669