Appendix B MesoHABSIM

In developing this plan, fish habitat in the Stony Clove Creek was assessed using an experimental model, MesoHABSIM, developed by Piotr Parasievicz and the Instream Habitat Program at Cornell University. This appendix presents an excerpt from the full report on this work, which includes the Executive Summary and Methods sections. Excerpts of the results of this report are contained in each of the management unit descriptions.

The full report is available upon request:

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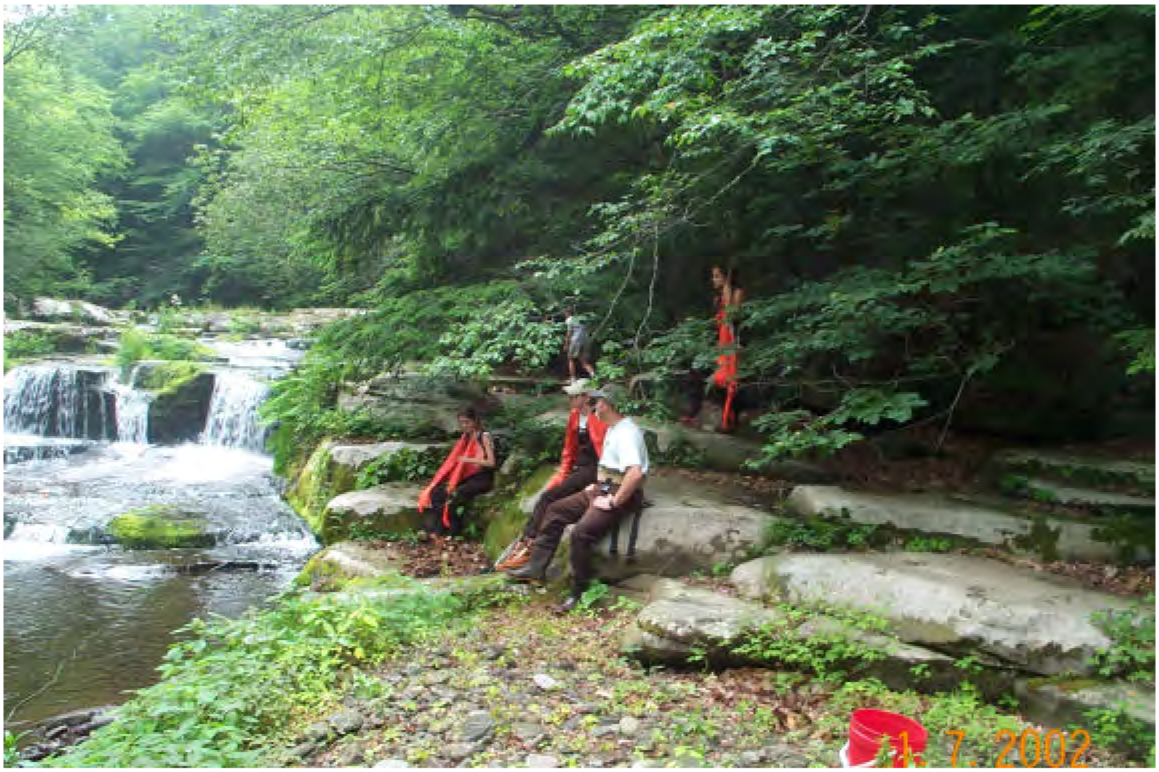
Fish Habitat Assessment on Stony Clove Creek, NY using MesoHABSIM



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EXECUTIVE SUMMARY

Fish habitat assessment on Stony Clove Creek, NY using MesoHABSIM

Piotr Parasiewicz, Sarah Beth Ehmann, Piper Corp
July 2003

The Stony Clove Creek, located in Greene and Ulster counties, flows through the central Catskill Mountain region of eastern New York. The Creek begins between Hunter Mountain and Plateau Mountain, and runs down the valley near State Highway 214 for approximately 10 miles. In the town of Phoenicia, the Stony Clove joins the Esopus River, eventually emptying into the Ashokan Reservoir and supplying New York City with nearly ten percent of its drinking water.

From a physical standpoint, the Stony Clove Creek faces river management problems due to historical hydrological alterations, impaired aquatic fauna and fisheries, and dramatic seasonal fluctuations in flow. The US Environmental Protection Agency (EPA) has recognized hydrological and habitat modifications as major contributors to non-point source pollution. The New York City Department of Environmental Protection (DEP), in partnership with the Greene County Soil and Water Conservation Districts, is restoring stream channel stability in priority sub-basins in order to improve water quality in city reservoirs. This study was therefore prompted by the need to develop a comprehensive, multi-objective Stream Management Plan.

To help accomplish this task, the Instream Habitat Program of the Department of Natural Resources at Cornell University and the Greene County Soil and Water Conservation District conducted a detailed instream habitat study of the main stem of the Stony Clove. This project also served to demonstrate the applicability of a newly-developed instream habitat modeling technique (MesoHABSIM) in conjunction with the Target Fish Community approach in the integration of aquatic habitat management, flood protection and water quality protection. Using fish habitat as an indicator of ecological health, this study investigates the availability of suitable fish habitat under low-flow conditions.

We identified habitat selection criteria for the target fish community on the basis of the observations of fish abundance and a detailed literature search. This provided a baseline for assessing the status of the fauna and habitat in the Stony Clove Creek. The NYS DEC and the Cornell University Department of Natural Resources (DNR) provided relevant literature and fisheries data; the DNR also supplied us with data from the Beaver Kill watershed. We conducted additional experiments to evaluate the precision of our applied technique. This included: 1) the comparison of fish collection data with data obtained by the USGS in the same locations, 2) the analysis of the repeated survey performed during a calibration exercise, and 3) the calculation of habitat availability using two different suitability criteria.

We computed two target fish communities, one based on data from seven Hudson River tributaries, and a second based on data from the Beaver Kill watershed. Both communities identified slimy sculpin, blacknose dace, longnose dace, brook trout and white sucker as the top five species. Together with staff from the Greene County Soil and Water Conservation district, we mapped habitat along nine miles of Stony Clove

three times, each time under different flow conditions ranging from 0.1 to 1.0 cubic feet per second per square mile drainage. To determine fish habitat selection criteria, we sampled 500 grids (1 m x 6 m) using the pre-positioned grid electro-fishing technique developed by Bain et al. (1985). We collected data from approximately 300 grids in the Stony Clove, sampling the remaining grids in the Upper Round Out, Stewart Brook, Spring Brook, Trout Brook, and Willowemoc. We captured 2,255 fish, recording the habitat attributes associated with the grid in which each fish was caught.

We used these data to calculate fish response functions for the five dominant species of the target community, in addition to two introduced trout species (brown trout and rainbow trout), using logistic regression. We then analyzed these response functions in conjunction with our habitat maps, calculating the probability of fish presence for each habitat unit. For each species, we combined the areas of habitats with probabilities greater than 50% to measure habitat availability for that species; we also calculated the amount of habitat available to the entire community. To analyze habitat quantity and stability, we developed habitat-flow rating curves for 21 previously delineated management units, as well as for the entire river. We subsequently compared the observed habitat structure with the target community structure, as well as with the community structure observed during the Stony Clove portion of our electro-fishing survey. To analyze habitat deficits, we simulated habitat restoration and analyzed projected changes in the fish community composition.

This project led to the following conclusions:

1) Of the two target fish communities evaluated, the structure based on Hudson River data best matches the recently observed Stony Clove fish community.
2) The present fish population is low in density, and dominated by slimy sculpins and dace species; it has an abundance of brown and rainbow trout, but minimal brook trout.
3) The majority of introduced trout are stocked fish, which have very low winter survival rates (we caught only a few brown or rainbow trout that were two or more years old).
4) Trout are reproducing, and the required amount of nursery habitat is available.
5) Overall habitat conditions for the target fish community are relatively good, and remain stable over the range of low flows.
6) The lower portions of the river show entrenchment in the low-flow channel; this causes habitat instability.
7) The presence of brown trout negatively impacts brook trout habitat availability.
8) Channel improvements that introduce woody debris, boulders and pools could dramatically improve brook trout habitat conditions.
9) Possible channel improvements can be simulated and evaluated with the MesoHABSIM model.
10) The applied fishing and mapping techniques performed well when evaluated for effectiveness.
11) MesoHABSIM can quantify major habitat deficits, thereby providing guidance for stream management.

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1. INTRODUCTION

The demand for ecological studies of running waters has grown significantly over recent decades as a result of an increased appreciation for the value of stream water (Petts 1984, Naiman et al. 1995). Such studies often assess the effects of human activity on aquatic ecosystems, thereby providing better options for the management and protection of these resources (e.g. Baxter 1961, Stalnaker and Arnette 1976, Rabeni and Jacobson 1993). Developing appropriate assessment techniques for these studies requires a sound understanding of functional processes (Karr et al 1981, Naiman et al. 1995); improvements in this understanding have already resulted in the rapid advancement of assessment technology in recent years (for review see Bain et al.1999, Gordon et al. 1992, Parasiewicz and Dunbar 2000).

One major area of development has been the introduction of qualitative and quantitative models for the characterization of physical habitat. The best known of these, the Physical Habitat Simulation System (PHABSIM), is an integral part of the U.S. Government method for setting stream flow limits (Bovee 1982). Such models are based on the observation that aquatic biota respond to physical habitat patterns within a stream (Heede and Rinne 1990, Wright et al., 1993, Statzner *et al*. 1988). The spatial distribution of physical attributes (e.g. depth and velocity), combined with observed biological responses to fluctuations in these attributes, provides a basis for projecting the consequences of ecosystem alterations (Milner et al. 1985, Stalnaker 1995).

This report presents the results of the habitat analysis conducted by the Cornell University Department of Natural Resources on the Stony Clove Creek in the Catskills region of eastern New York. We used a newly-developed instream habitat modeling technique (MesoHABSIM[1]) as a means of integrating aquatic habitat management, flood protection and water quality protection needs into our analysis.

The New York City Department of Environmental Protection (DEP) has expressed interest in incorporating the above methodology into the presently used geomorphic approach to develop a Stream Management Plan for the Stony Clove watershed in Greene and Ulster Counties, NY. In the first phase of this collaboration, we combined MesoHABSIM and the Target Community Approach (Bain and Meixler, 2000) with habitat-assessment work conducted by the Greene County Soil and Water Conservation District. The project goal was to demonstrate the applicability of MesoHABSIM and Target-Fish-Community-based habitat assessment approach to the Stream Management Plan by establishing a target fish community for the Stony Clove.

The following tasks were performed in this phase of the project:

1) Performing a literature search and establishing a comprehensive list of potentially occurring fish species.
2) Consulting local and state government agencies and citizen groups to obtain information about naturally occurring fish species; selecting representative data sets.

[1] Parasiewicz, P. 2001. MesoHABSIM: A concept for application of instream flow models in river restoration planning. Fisheries 26:6-13.

3) Defining the target fish community and computing a model of target community structure. Submitting these definitions to the New York State Department of Environmental Conservation.
4) Demonstrating the habitat mapping approach to agency staff members .
5) Computing a habitat model for selected species and life stages.
6) Assessing habitat conditions for the target fish community in each management unit over a range of low flows.
7) Reporting on steady-state habitat conditions in management units for the Stream Management Plan
8) Presenting and discussing Phase I findings with involved agencies and citizens groups

This report presents our data collection and analysis techniques, findings, and conclusions as to the status of fish habitat in the Stony Clove.

2. METHODS AND STUDY SITES

2.1 Study Site

The Stony Clove Creek is located in the central Catskill Mountain region of eastern New York (Figure 2.1) and flows through a 32.3 square mile watershed in the counties of Ulster and Greene. The creek is 10.2 miles in length (9 miles were mapped for the study), beginning between Hunter Mountain and Plateau Mountain. The Stony Clove's headwaters begin in the towns of Hunter and Lexington. The river flows down the valley near State Highway 214. The largest tributary is Warner's Creek which enters the Stony Clove before Chichester. In the town of Phoenicia, the Stony Clove joins the Esopus River which empties into the Ashokan Reservoir, supplying New York City with nearly ten percent of its drinking water. The Ulster County portion of the watershed is located in the towns of Shandaken and Woodstock.

There are two gauges in the Stony Clove Creek watershed. One is located on the Stony Clove Creek near the town of Phoenecia. Data has been collected since February 1997 and records from this gauge show a range of discharges from a maximum of 9,000 cfs to a minimum of 4.4 cfs. The second gauge is located on Hollow Tree Brook, a tributary near the town of Lanesville. The recorded discharges at this gauge ranged from 263 cfs to 0.29 cfs. Due to the Stony Clove's geologic location (it is surrounded by mountains), it experiences problems from flooding, poor water quality, and human activities. Some of the factors that impact the Stony Clove are steep slopes, poorly drained soils, glacial geology, and rainfall patterns (www.gcswcd.com).

2.2 Field Surveys

2.2.1 Habitat Survey

2.2.1.1 Survey Technique

In order to develop a habitat distribution model, we applied the MesoHABSIM technique of data collection (Parasiewicz 2001). MesoHABSIM operates at a large scale and allows for the collection of habitat data within the entire stream. In this study, we measured the spatial distribution of hydro-morphological units (Table 2.1 and Appendix

1) and the associated physical attributes that influence fish distribution. Mapping of HMUs was facilitated by the use of a Personal Digital Assistant (PDA) and the program ArcPad (ESRI). We downloaded aerial photographs to the PDA and mapped HMUs as a top layer.

We took seven random measurements within every HMU for mean column velocity, depth, and dominant substrate. We used a Dipping Bar (Jens 1968) to measure mean column velocity and depth. For all other physical attributes used in the analysis (Table 2.2), we entered the observed abundance (none, some, or much) in each unit into an ArcPad table attached to the corresponding polygon. For substrate definitions, we referred to the choriotop classification system based on Austrian Standard ON M6232 (Table 2.3). In order to ensure consistency among data, one day was spent calibrating mapping techniques between the involved agencies. Three teams of two people (one person using the palm pilot, the second person using the dipping bar) mapped the same stretch of river and subsequently discussed and compared results so as to maintain a high degree of regularity while mapping.

We conducted the mapping surveys described above for the entire study site under three different flow conditions (approximately 0.1, 0.3 and 1.0 cubic feet per second per square mile of drainage area (cfsm)), as calculated from gauge readings, which were given in cubic feet per second (cfs). Recalculating flow to cfsm allowed us to better represent flow at different sections of the creek. Due to more dramatic habitat changes at lower flows, we selected two low-flow conditions for mapping (0.1 and 0.3 cfsm). Although for each survey we mapped the entire study area at approximately the same flow, flows fluctuated slightly from day to day (Table 2.4). In order to account for these minor fluctuations, we divided the creek into 15 sections according to flow conditions. The New York City DEP and the Greene County Soil and Water Conservation District had already divided the creek into 21 management units on the basis of a geo-morphological classification system. To facilitate data analysis, we superimposed the original 15 sections onto these management units (Figure 2.2). Portions of some management units were mapped on different days and consequently at different flows; we divided these management units into smaller sites according to flow at the time of mapping. We then weighted the habitat areas calculated for each site by the proportion of length to management unit length; we added these proportions to represent the habitat available in the unit.

2.2.1.2 Chronology for Mapping

The first survey of mesohabitat distribution in the study area took place between 18 June and 21 June 2002. We delineated 238 mesohabitats at an average flow of 1.54 cfsm. Due to considerable flow fluctuations, however, we did not map the entire study area during this period; we completed the high-flow mapping survey during Spring 2003, delineating 84 additional mesohabitats at an average flow of 2.22 cfsm. We conducted the second survey between 3 July and 12 July 2002. During this survey we mapped a total of 618 mesohabitats at an average flow of 0.35 cfsm. The third survey took place between 16 August and 25 September 2002 at an average flow of 0.13 cfsm; the study area contained 795 mesohabitats under these low-flow conditions, however, mapping for this survey was not continuous due to flow fluctuations.

2.2.2 Fish Survey

2.2.2.1 Survey Technique

To determine the composition of the Stony Clove Creek fish community and to calculate functions relating fish response to environmental conditions, we conducted an electro-fishing survey using the pre-positioned grid technique developed by Bain et al. (1985). Each 1 meter x 6 meter grid consisted of two 6 meter parallel cables running upstream and attached at each end to a 1-meter long PVC pipe. The grids were fished with a Honda EX1000 generator and 15 Amp Coffelt VVP-2C transformer, using 350 volts of alternating current. One person controlled the power while two others gathered fish stunned within the grid. We identified and measured each fish prior to its release. We sampled each grid individually, but placed them in groups of four, allowing 15 minutes between placement and sampling.

For each HMU containing a grid, we measured depth, velocity and choriotop in seven randomly selected locations, and recorded the mesohabitat type and characteristics, stream location, cover and gradient. We took additional depth, velocity and choriotop measurements at all of the four corners of each grid fished; in contrast to the habitat survey, the fish habitat was described at both the micro and meso scale.

2.2.2.2 Chronology for Fish Survey

The purpose of the fish survey was to identify the habitat suitable for each of the five dominant species of the Stony Clove target community. We conducted all sampling between 1 July and 8 August 2002, identifying 4114 fish representing 19 species over the course of the study. We sampled a total of 456 grids in three different general locations. From 1 July to 18 July we sampled 269 grids in the Stony Clove. We placed these grids in several stretches along the creek (Figure 2.3) which were intended to be descriptive of the entire MesoHABSIM study area.

The fishing sites are as follows: Stretch 1 is located in the immediate vicinity of Edgewood Falls, Stretch 2 between Wright Road and the end of Mountain Road, Stretch 3 between Jensen Road and the middle of Beecher Road, Stretch 4 between the bottom of Beecher Road and the Stony Clove Rod and Gun Club, Stretch 5 between Silver Hollow Road and Grubman Road, Stretch 6 between the Chichester Bridge and Silver Hollow Road, and Stretch 7 between the Chichester Bridge and School Lane.

Due to low flow conditions on the Stony Clove, we completed the last portion of the electro-fishing survey on similar streams, so as to avoid biases due to fish crowding. From 29 July to 1 August, we sampled 107 grids on the Upper Round Out, a stream approximately 35 miles the Stony Clove (Figure 2.1), placing approximately 24 grids in each of four different stretches. From 5 August to 8 August, we sampled an additional 80 grids in tributaries of the Beaver Kill, located approximately 55 miles from the Stony Clove. We placed between 16 and 24 grids in each of the four tributaries: Trout Brook, Spring Brook, Stewart Brook and Willowemoc (Figure 2.1).

2.3 Data analysis

2.3.1 Target Fish Community

To compare the observed Stony Clove fish community to that which would be expected to occur in a healthy lower Hudson tributary, we defined a reference-stream-based target community in a series of steps, following methods described by Bain and Meixler (2000).

We first referred to Page and Burr (1991) and Smith et al. (1986) to generate a list of fish species known to occur in the Hudson River. From this list we eliminated species known to occupy habitat not found in the Stony Clove (e.g. weedy pond, deep water or large river species), thus reducing the list to 30 native species representing a fauna that could exist in the Stony Clove. We added species-specific information on habitat and water quality requirements to the list.

We then selected reference streams based on available fish community data. The New York Department of Environmental Conservation provided fish population data for eight streams in the Hudson River Watershed, including the Stony Clove, between 1957 and 1989. We also used Cornell University fish data for 38 streams in the adjacent Beaver Kill/Delaware River watershed of Southeastern New York in 2000 (Smith 2003). Twelve of the Beaver Kill streams contained three or fewer recorded species; we eliminated these streams, thereby narrowing the analysis to 26 Beaver Kill streams and 7 Hudson River tributaries (excluding the Stony Clove). We developed a third target community using historic Stony Clove data.

For each river, we determined the relative abundance of each species by dividing the total number of individuals representing each species by the total number of recorded fish. We then calculated the expected proportion by adding the relative abundance of each species across each river, ranking the species (1 = highest abundance), excluding introduced species (brown and rainbow trout), and dividing the reciprocal of the ranks by the sum of all reciprocal ranks. For the purposes of this study, we defined the target community as the species with the five highest estimated abundances: slimy sculpin, brook trout, white sucker, longnose dace, and blacknose dace.

We used a percent model affinity procedure to compare the calculated expected proportions of each native species in the reference streams to proportions observed during the 2002 electro-fishing survey on the Stony Clove. The affinity of the Stony Clove sites to the reference stream was calculated as:

(1) $$\% \text{ similarity} = 1.00 - 0.5 * S\,(|P_e - P_o|)$$

where P_e = expected proportion and P_o = observed proportion

We developed two affinities for comparison, one based on the 26 Beaver Kill/Delaware River watershed streams, and one based on the 7 lower Hudson River tributaries. We made an additional comparison between the historic and current Stony Clove data to note any changes that might have occurred. We used these comparisons to determine which fish species occurred at expected abundances, which were under-represented, and which were overly abundant in the current Stony Clove community.

2.3.2 Fish Density

Our survey was intended to evaluate habitat suitability for the target community, as opposed to determine fish abundance in every reach along the study area. However, because we did not distribute the grids randomly across the study area but lumped them into sampling sites, the average number of adult fish captured with electro-grids can be used to measure fish density per site. Therefore, we included the average number of fish caught in a grid (standardized to square meter grid area) in the report. Numbers for all species caught are provided in the results section, but the analysis focuses only on the five dominant target community species.

2.3.3 Fish Response Functions

To calculate the fish response functions, we described each fishing grid using the same environmental characteristics used to develop the habitat database, as well as by the species and size of all fish captured. We also included Upper Round Out and Beaver Kill fishing data in this portion of the analysis. The environmental attributes were independent variables and the fish species were dependent variables in regression models describing habitat preference. We employed a stepwise forward logistic regression model (using SPSS) to identify the characteristics of habitat that is used vs. habitat that is not used by each fish species. The model uses likelihood ratios to determine which parameters should be included in following regression formula:

(2) $$\mathbf{R=e^{-z}}$$

where:

- e = natural log base
- z $= b_1 \cdot x_1 + b_2 \cdot x_2 + \ldots\ldots + b_n \cdot x_n + a$
- $x_{1..n}$ = significant physical variables
- $b_{1..n}$ = regression coefficients
- a = constant

We established the b coefficients using an iterative process; they represent how the attributes influence the dependent variable in the data set. Here one should note that this mathematical formula is based on proportions of occupied/non-occupied areas observed during the survey and do not capture all possible circumstances or represent mechanisms of fish behavior. Furthermore, fish presence is largely due to a combination of environmental factors; interpreting the influence of individual parameters in the formula is therefore somewhat limited in applicability.

To distinguish suitable habitat, we used binary dependent variables indicating presence and absence and, in a second model, high and low abundances. We used all available data for the first model, for the second we used only data from grids in which fish were caught.

We also established two models to analyze the influence of scale on the formula. One model used meso-scale hydraulic habitat data (i.e. seven random measurements of velocity, depth and substrate for each HMU); the other used data collected at the corners of each grid. We observed no significant difference between the two models, and therefore used only the meso-scale model for the fish habitat analysis.

We calculated models for adult fish only[2]. To account for behavioral differences between the species, we determined a separate threshold for high and low abundances. For gregarious species (e.g. slimy sculpin, brook trout, white sucker, brown trout and rainbow trout), we set the threshold value at two fish per electrogrid (i.e. 6 m^2); for solitary species (blacknose and longnose dace), we set this value at one fish per electrogrid.

From the output of the logistic regression function, we obtained two important data values: the predictive power of the model, and b-value values for all attributes considered significant for habitat use (Table 2.5 & 2.6). The predictive power value (see below) measures the accuracy of the model in predicting presence/absence and high/low abundance. The beta values indicate the strength and direction (+ or -) of the association between each habitat attribute and fish presence and level of abundance.

To evaluate the model, we calculated the probability of presence/high abundance (p) for each data point in the set according to the formula:

(3) $$p = \frac{1}{(1+e^{-z})}$$

Using a cut-off value of 50%, we predicted fish presence/abundance for each data point and compared these predictions with the original values of the dependent variable (i.e. fish presence). The predictive power of the model is therefore equal to the proportion of correct predictions.

2.3.4 Hydro-Morphology

We generalized observations of cover, substrate, vegetation structure, and riparian area to describe the macrohabitat character of each section. For every representative site, we calculated averages and standard deviations for depth (AD, SD), column velocity (AV, SV), and Froude's[3] number (AF, SF). To generate these values, we summarized the means and standard deviations of seven random measurements (taken in every mesohabitat) and weighted these values according to the mesohabitat area within each section. In contrast to the typical fluvial-morphlogical approach, our work focused primarily on the low flow channels. To compare wetted area under low-flow conditions to bankfull area, we calculated the ratio of average wetted width to bankfull width, which indicated the degree to which the low-flow channel was entrenched. The level of entrenchment could affect habitat conditions considerably by limiting the widening of the

[2] We calculated response functions for young-of-the-year (YoY) for trout and for the other target species. However, due to discrepancies between our scale of observation (HMU) and the scale at which YoY fish utilize their environment, this data was not conclusive and results were showing very low amounts of nursery habitat available in the Stony Clove. This was obviously incorrect and therefore the models were disregarded.

[3]Froude number here is a gross approximation that has been shown to correlate with species and HMU distribution (Jovett 1993, Vadas and Orth 1998). Low numbers indicate dominance of "slow-deep" and high numbers "fast-shallow" habitats.

wetted area, causing steep increases in velocity and depth (Figure 2.4). In this "acceleration phase", habitat tends to be dominated by deeper runs, which could potentially reduce habitat suitability (Parasiewicz 1996 and 2002).

2.3.5 Fish Habitat

2.3.5.1 Habitat database

We checked the data collected during the three habitat surveys for errors and merged them into a GIS database. For each site, we used ArcMap to construct digital maps of HMU distribution (Appendix 2), in which each record associated with an HMU-polygon contained 46 field observations describing the mesohabitat. We broke down attributes with multiple categories (e.g. mesohabitat type, dominating choriotop) into collections of variables in binary form. For each measurement of depth and velocity, we calculated the Froude number according to the following formula:

(4) $$\frac{Vm}{(9.81 \times D)^{0.5}}$$

Where:

- Vm = mean column velocity
- D = depth

We grouped the seven velocity and depth measurements and choriotop estimates into several more general classes, producing a relative quantitative distribution (Table 2.2). This transformation yielded a data structure that:

- realistically represented measurement accuracy
- corresponded with the sensitivity of adult fish to environmental circumstances
- was more applicable in the calculation of fish presence probabilities.

2.3.5.2 Probability of presence

For each mesohabitat mapped during the survey of representative sites, we used formula 3 to calculate the probability of presence and high abundance for every species. We considered habitats in which both probabilities had an average higher than 0.5 to be suitable for fish. From this, we constructed digital maps of the sites showing areas of suitable habitat at measured flow conditions (Appendix 3).

2.3.5.3 Habitat-flow rating curves

To compare the amount of suitable habitat available under multiple flow conditions, we projected the wetted suitable area to describe the entire bankfull area. That is, bankfull area remains constant in respect to flow, while wetted area generally increases. To account for this, we divided the width of the wetted area by the width of the bankfull area at several locations throughout each site, assuming that the average of these values accurately described the ratio of wetted to bankfull area for the entire site. We then multiplied the suitable wetted area by this ratio, so as to standardize suitable area for the full range of studied flows.

For each site, we plotted this relative habitat area (% wetted bankfull area (WBA)) against discharge. We then interpolated habitat values between 0.1 and 1.2 cfsm by applying a polynomial curve fit to the data, thereby constructing flow/habitat rating curves for the five target fish species, as well as for rainbow trout, and brown trout. We used these rating curves to analyze suitability for each species in each of the 21 management units.

As the above analysis does not account for the fact that a given habitat is frequently suitable for more than one species, we calculated community habitat quantity using a different approach. Adding the above habitat values would result in the repeated counting of areas used by multiple species. In reality, suitable habitat area is likely much smaller, due to competition and predation. Without sufficient life history information, however, we are unable to determine the precise mechanisms that favor one species over another in such situations. To define the total amount of suitable habitat for the entire community therefore, we counted such "multiple-occupant" areas only one time. This approach described the present conditions more realistically and allowed us to maintain conservative estimates, thus ensuring that wetted area always exceed available habitat. We addressed areas of "multiple occupancy" in each site by calculating the ratio of total suitable area for *all* species (counting area in suitable HMUs for each occupant species) to area suitable for *any* species (counting area in suitable HMUs only once, regardless of the number of species it contains). This "habitat overlap" factor would be 1 for sites with no overlap and higher with increased overlap. Habitat overlap can be interpreted in two ways. If the total amount of available habitat (as calculated above) is high, a high overlap factor is more desirable, as it indicates higher habitat availability and diversity. If the amount of available habitat is low (and thus species compete for space), a lower overlap factor indicates reduced competitive pressure and therefore better conditions.

To construct composite rating curves representing habitat availability for the entire study area, we summarized the suitable habitat sections, weighting them by the section-length ratio. Habitat for each species was analyzed separately and cumulatively as above. We also compared the distributions of available habitat among the five species with the distribution of the habitat that would best support the target community structure. Here we assumed that habitat structure corresponds to community structure in a 1:1 ratio (Bain and Meixler 2000). To compare target habitat structure with the actual structures occurring under the three selected flows, we applied an affinity index (Novak & Bode 1992). The final analysis was performed using the resulting cumulative rating curve and affinity factors.

3 RESULTS

3.1 Target Fish Communities

3.1.1 Seven Hudson Rivers

The reference streams for this analysis were Ox Clove, Hollow Tree Brook, Warner Creek, Esopus Creek, Round Out Creek, Sugarloaf Brook, and Stone Cabin Brook. Data for 4,702 fish were provided in a historical database. Slimy sculpin was the most abundant fish, numbering (2,166 recorded individuals). Blacknose dace (922), brown trout (575), rainbow trout (342), white sucker (331), brook trout (245), and longnose dace (92) were also common. Tesselated darter, cutlips minnow, creek chub, pumpkinseed, and rock bass were also observed, but in smaller quantities (less than 20 individuals each).

The target community based on these Hudson River tributaries shows proportions similar to those presently observed in the Stony Clove (Figure 3.1). Slimy sculpin comprises over one-third (40%) of the target community. Blacknose dace (20%), brook trout (8%), and white sucker (7%) are also expected in relatively high frequency. Longnose dace, cutlips minnow, tessellated darter, rock bass, creek chub, and pumpkinseed are represented in small quantities within this community.

3.1.2 Beaver Kill Watershed

Cornell University personnel collected 4,000 fish from 26 streams in the Beaver Kill Watershed. Slimy sculpin (1030 individuals) and brook trout (953 individuals) were the most common fish in this area. Brown trout (629 individuals), blacknose dace (343), and longnose dace (289) were the next most common fishes caught. Rainbow trout (168) and common shiner (117) also had a fair representation. Margined madtom, tessellated darter, cutlips minnow, white sucker, and sea lamprey each are present in minimal amounts. American eel, creek chub, longnose sucker, brown bullhead, pumpkinseed, and large mouth bass were also present, but scarce.

Brook trout had the highest expected proportions in the Beaver Kill watershed target community (33%) (Figure 3.2). Slimy sculpin (17%), blacknose dace (8%), and longnose dace (7%) also constitute a large expected proportion. White sucker, common shiner, creek chub, tessellated darter, and marginated madtom occur in limited quantities within the watershed. Sea lamprey, cutlips minnow, American eel, pumpkinseed, brown bullhead, longnose sucker, and chain pickerel are also present, but in minute quantities.

3.1.3 Historic Stony Clove

Data for 802 fish were obtained from historic surveys on the Stony Clove (Figure 3.3). The most abundant fish was rainbow trout (245 recorded individuals). Brown trout (160), blacknose dace (155), and white sucker (129) were also abundant. Species with moderate populations included longnose dace (48), cutlips minnow (47), and smallmouth bass (28). Brook trout, slimy sculpin, tessellated darter, and rock bass were also present in small quantities.

The target community created with historic Stony Clove data is quite different from the community observed during the 2002 Stony Clove fishing survey (Figure 3.4). According to this model, white sucker (31%) and blacknose dace (20%) should be most frequent. Longnose dace (12%), cutlips minnow (10%), and slimy sculpin (8%) should appear in moderate quantities, and brook trout, rock bass, and tessellated darter have small expected proportions.

3.2 Fish Density

We collected a total of 1839 fish from 269 grids in the Stony Clove. On average, we caught were 1.1 fish per square meter. Twenty of the grids contained no fish. Slimy sculpin and brown trout were the most common fishes, with 437 and 419 individuals caught, respectively. Blacknose dace and longnose dace were also abundant, with 308 and 254 individuals caught. Rainbow trout (217) and cutlips minnow (107) had modest representations; brook trout (46) and white sucker (46) had low representations. We also observed bluegill, pumpkinseed, and spottail shiner, but in negligible amounts.

To provide a greater amount of data for calculating habitat response functions, we collected fish from additional streams, specifically Upper Round Out and four tributaries of the Beaver Kill River (Stewart Brook, Spring Brook, Trout Brook, and Willowemoc). We recorded 2,255 fish during this portion of the survey. On average, we observed 2.01 fish per square meter. Slimy sculpin (1399) was the most abundant fish; blacknose dace (337), brook trout (201), and brown trout (81) were also common. Longnose dace (69), rainbow trout (54), white sucker (42), and common shiner (33) had fair representations. Creek chub, cutlips minnow, yellow bullhead, golden shiner, tessellated darter, rock bass, and yellow perch were present, but in minute quantities (each with less than 20 individuals caught)

We incorporated young-of-the-year fish into our target community, as they are included in the historical data we obtained. 24.6% of the fish captured in the Stony Clove were young-of-the-year. Brown trout and brook trout populations consisted of 41.5% and 41.3% young-of-the-year (YoY), respectively. Over a quarter of blacknose dace (38.6%), cutlips minnow (36.4%), and rainbow trout (35.5%) populations were also comprised of YoY. Longnose dace (8.66%), white sucker (2.2%), and slimy sculpin (0.23%) populations had the lowest percentages of juveniles within the Stony Clove samples. The observation could be due in part to the very small size of the YoY.

Stony Clove Sites

3.2.1 Site 1

Site 1 flows from downstream of Ostrander Road to Edgewood Falls. We collected 94 fish from 21 grids, averaging 0.8 fish per square meter. Twelve grids contained no fish. The most abundant fish was brown trout, with 76 individuals recorded. The only other two species found at this site were brook trout and slimy sculpin, with 10 and 8 individuals caught, respectively.

3.2.2 Site 2

We collected 138 fish from 19 grids at Site 2, which runs from the end of Mountain Road to Wright Road. On average, there were 1.2 fish per square meter. Slimy sculpin was the most common fish at this site, with 68 individuals caught. Brown and rainbow trout were also common, with 44 and 22 individuals caught, respectively. Brook trout had a sparse representation.

3.2.3 Site 3

From Jensen Road to the middle of Beecher Road, we fished 51 grids, catching a total of 346 fish. On average, we caught 1.1 fish per square meter. Slimy sculpin was the most common fish in this site, with 182 individuals caught. Brown trout (64), blacknose dace (39), and rainbow trout (39) had a modest representation. Longnose dace, brook trout, and white sucker all show a limited presence.

3.2.4 Site 4

Site 4 extends from the end of Stony Road to the Stony Clove Rod and Gun Club. We caught 431 fish in 54 grids, averaging 1.3 fish per square meter. One grid did not contain any fish. Slimy sculpin (130 individuals), brown trout (110), and longnose dace

(94) were the most common fishes in this section. Rainbow trout and blacknose dace had moderate representations, with 46 and 37 individuals recorded, respectively. Brook trout, cutlips minnow, and white sucker were all only slightly represented.

3.2.5 Site 5

We collected a total of 182 fish were from 28 grids at Site 5, located upstream of the Silver Hollow Bridge. On average, we caught 1.1 fish per square meter. Brown trout and rainbow trout were the most common species, with 49 and 39 individuals caught, respectively. Slimy sculpin (32) and cutlips minnow (20) were also common. Blacknose dace, longnose dace, and brook trout had modest representations; bluegill and white sucker were present only in negligible quantities within this site.

3.2.6 Site 6

We fished 45 grids in Site 6, which runs from the Silver Hollow Bridge to 1000 m downstream of the Chichester Bridge, and collected a total of 323 fish. On average, there were 1.2 fish per square meter, with only one grid containing no fish. Longnose dace (85 individuals) was the most common fish at this site. Cutlips minnow (62 individuals), blacknose dace (59), rainbow trout (42), and brown trout (40) all had modest representations. White sucker, slimy sculpin, brook trout, and pumpkinseed were present, but in small quantities.

3.2.7 Site 7

We fished 51 grids at Site 7, which runs from School Lane to roughly 2000 feet downstream of the Chichester Bridge. We caught a total of 325 fish, averaging 1.1 fish per square meter. Six grids contained no fish. Blacknose dace was the most common fish at this site, with 160 individuals recorded. Longnose dace (54), brown trout (36), and rainbow trout (29) were also common. Cutlips minnow, white sucker, and slimy sculpin had fair representations, while brook trout and spottail shiner were present but rare.

Other Streams

3.2.8 Upper Round Out

We fished 107 grids at the Upper Round Out, collecting a total of 971 fish. On average, we recorded 1.5 fish per square meter. Slimy sculpin wass the most common fish at this site, with 881 individuals caught. Brook trout was a distant second (73 individuals). Blacknose dace, brown trout, rainbow trout, rock bass, and longnose dace all had minute representations.

3.2.9 Stewart Brook

In this stream we fished 16 grids, collecting 349 fish. On average, we caught 3.6 fish per square meter. Blacknose dace is the most common fish in this section, with 127 individuals caught. White sucker (42), brown trout (39), commoner shiner (33), rainbow trout (27), longnose dace (23), and slimy sculpin (20) all had fair representations. Creek chub, cutlips minnow, brook trout, yellow bullhead, golden shiner, and tessellate darter were all only slightly represented.

3.2.10 Spring Brook

In Spring Brook, we fished 24, catching a total of 491 fish. On average, we collected 3.4 fish per square meter. Blacknose dace and slimy sculpin were the most common fishes in this stream, with 196 and 177 individuals caught, respectively. Longnose dace (43), brook trout (35), rainbow trout (21), and brown trout (12) all had modest representations, while creek chub, cutlips minnow, and yellow perch were present in only small quantities.

3.2.11 Trout Brook

We fished 24 grids in Trout Brook, collecting 232 fish. On average, we collected 1.6 fish per square meter. Slimy sculpin was the most common fish in this site, with 177 individuals caught. Brook trout (29) and brown trout (24) were a distant second and third. Longnose dace had a sparse representation.

3.2.12 Willowemoc

We fished 16 grids in this stream, collecting a total of 212 fish. On average, we collected 2.2 fish per square meter. Slimy sculpin was the most common fish at this site, with 144 individuals. Brook trout (56) has a modest representation, while blacknose dace, rainbow trout, and brown trout were present only in small quanitites.

3.3 Regression Results

3.3.1 Slimy Sculpin

The regression model for slimy sculpin presence (Table 2.5) has a predictive power of 80.9%. Habitat attributes associated with the presence of slimy sculpin are runs (B=1.04), macro-lithal substrate (B=2.15), submerged vegetation (B=1.53), and canopy cover shading (B=0.63). Attributes associated with slimy sculpin absence are mega-lithal substrate (B=-2.40), clay (B=-1.31), boulders (B=-0.75), and overhanging vegetation (B=-.76). The regression model for high/low abundance has a predictive power of 76.9%. This model indicates that glides (B=1.17), areas with submerged vegetation (1.62), and shallow waters (less than 25 cm, B=1.39) are associated with high abundance of slimy sculpin. Attributes associated with low abundance are ruffles (B=-1.14) and overhanging vegetation (B=-0.47).

3.3.2 Blacknose Dace

The regression model for blacknose dace presence has a predictive power of 77.2% (Table 2.5). The model indicates that areas with clay (B=1.82) and overhanging vegetation (B=0.85) are associated with blacknose dace presence. Ruffles (B=-3.95), rapids (B=-1.57), submerged vegetation (B=-1.29) and woody debris (B=-.43) are associated with blacknose dace absence. The regression model for high/low abundance has a predictive power of 73%. This model does not associate any attributes with high abundance, but indicates that velocities between 60 and 75 cm/s (B=-5.74) correspond with low abundance.

3.3.3 Brook Trout

The regression model for brook trout presence has a predictive power of 72.1% (Table 2.5). Habitat attributes associated with the presence of brook trout are macro-lithal substrate (B=1.82) and canopy cover shading (B=90). Fast-flowing water was found to be associated with the absence of brook trout (45-60 cm/s, B=-2.80, 60-75 cm/s, B=-4.24). The regression model for high/low abundance has a predictive power of 89.1%. The results of this model show that deep (75-100 cm, b=10.00), slow-moving (15-30 cm/s, B=6.01) areas are associated with high abundance of brook trout. Other attributes associated with high abundance are riffles (B=3.14) and woody debris (B=2.31). Attribute associated with a low abundance of brook trout are velocities of 30-45 cm/s (B=-6.10) and depth of 25-50cm (B=-4.13).

3.3.4 White Sucker

The regression model for white sucker presence has a predictive power of 94.3% (Table 2.5). Habitat attributes associated with the presence of white sucker are pools (B=1.27), micro-lithal substrate (B=3.30), clay (B=0.95), and riprap (B=0.70). The model does not associate any attributes with white sucker absence. The regression model for high/low abundance has a predictive power of 78.6%. This model does not associate any attributes with high abundance for this species, but indicates that meso-lithal substrate (B=-6.16) and boulders (B=-3.09) correspond with low abundance.

3.3.5 Longnose Dace

The regression model for longnose dace presence has a predictive power of 79.6% (Table 2.5). It indicated that pelal (clay/silt) substrate (B=18.11), backwaters (B=5.17), habitat with clay (B=1.03) and overhanging vegetation (B=.80) are associated with presence of longnose dace. Attributes associated with the absence of longnose dace are slow-moving waters (less than 15 cm/s, B=-6.48) and submerged vegetation (-1.94). The regression model for high/low abundance has a predictive power of 66.9%. Velocties of 15-45 cm/s (15-30 cm/s, B=2.16, 30-45 cm/s, B=3.38) are associated with high abundance of longnose dace. The model does not associate any attributes with low abundance.

3.3.6 Brown Trout

The regression model for brown trout presence has a predictive power of 72.1% (Table 2.6). Hydo-morphological units associated with the presence of brown trout are sidearms (B=2.83), fast runs (B=2.71), ruffles (B=0.82) and pools (0.73). Boulders (B=.34) are also associated with brown trout presence. Habitat attributes associated with brown trout absence are depths of 50-75 cm (B=-2.51) and submerged vegetation (B=-0.76). The regression model for high/low abundance has a predictive power of 81.8%. This model indicates that pools (B=1.34) are associated with high abundance of brown trout. The model does not associate any attributes with low abundance.

3.3.7 Rainbow Trout

The regression model for rainbow trout presence has a predictive power of 76.7% (Table 2.6). The model does not associate any attributes rainbow trout presence, but indicates that riffles (B=-.89) and submerged vegetation (B=-1.21) correspond to rainbow trout absence. The regression model for high/low abundance has a predictive power of 87%. It indicates that fast runs (B=2.11) are associated with high rainbow trout abundance, but does not associate any attributes with low abundance.

3.4 Habitat Survey

3.4.1 Study Site

The Stony Clove is characterized by an abundance of boulders and shallow margins. Canopy cover-shading is present in fairly high quantities, while riprap, overhanging vegetation, and woody debris are less frequent. Submerged vegetation and undercut banks are scarce. The dominating substrate across the entire study site is macro-lithal. Mega-lithal and meso-lithal substrate is also abundant.

3.4.1.1 Hydro-morphology

At lower flows (range of 0.10-0.14 cfsm), the creek consists mainly of runs (23.5%) and riffles (16.1%), (Appendix 2.1). Rapids occur less than half as frequently (5.7%) as they do under medium-flow conditions, while ruffles nearly double in frequency (13.2%). Pools (11.2%), backwaters (9.7%) and glides (9.6%) also occur frequently. Cascades (4.5%), plunge pools (1.0%), and fast runs (0.9%) are all present in small quantities.

The entire creek is also dominated by runs (20.9%) and riffles (19.7%) at medium flows (range of .23-.57 cfsm). Rapids (12.1%) and pools (11.8%) are also present in moderate quantities. Cascades (7.8%), ruffles (7.1%), and glides (6.6%) make up a smaller percentage of the creek; plunge pools (3.6%), backwaters (3.1%), and fast runs (1.9%) occur at low frequencies.

Under higher-flow conditions (range of 1.08-2.22 cfsm), the creek is composed largely of rapids (24.9%), runs (15.9%), and ruffles (15.9%). Both rapid and ruffle percentages are twice as great as they are for medium-level flows. Pools (7.1%), fast runs (6.2%), and sidearms (6.0%) are present in smaller quantities; cascades, plunge pools, backwaters, and glides occur infrequently. The total number of HMUs decreased from 795 to 353 as flow levels increased. Wetted area for the entire study site is 46% at .1 cfsm, and increases more steeply with initial increases in flow (63% at .5 cfsm, 70% at 1 cfsm).

3.4.1.2 Habitat for Fish

The entire study site has a fairly stable level of total suitable habitat, within the range of approximately 40-50% wetted-bankfull area (WBA) (Figure 3.5). Total suitable area peaks at 0.6 csfm. Slimy sculpin has the most suitable habitat, which is relatively constant at slightly under 30% WBA. Black nose dace also has a high amount of suitable habitat, which peaks at 0.4 cfsm (27% WBA) and then decreases as flow continues to increase. Brook trout has little habitat (under 5% WBA), especially at higher flows. The presence of brook trout habitat is highest at flows under 0.8 cfsm. White sucker and long nose dace habitat follow similar patterns. Habitat for these species is highest at 0.6 cfsm (11% WBA) and then diminishes at higher flows. White sucker habitat occurs at slightly higher flows than longnose dace habitat, and the difference between the two species increases as flow increases. Rainbow trout and brown trout habitat occur infrequently. Habitat for brown and rainbow trout habitat increase slightly as flow increases, but never exceed 5% WBA. The habitat overlapping factor is highest at lower flows and then decreases as flow increases (1.7 species per habitat unit at 0.1 cfsm, 1.6 at 0.5 cfsm, 1.4 at 1.0 cfsm).

3.4.2 Management Unit 1

This MU runs from the beginning of Stony Clove Creek to Notch Inn Road bridge. It is 680 meters long and contains a total of three bridges, all near Notch Inn Road. The stream runs relatively close to Route 214 throughout most of this unit.

3.4.2.1 Hydro-morphology

This Management Unit is characterized by an abundance of boulders and canopy cover shading and some woody debris. The substrate in this section is largely macro-lithal. At flows of 0.57 cfsm, this site is somewhat shallow (Average depth (AD) = 22 cm, standard deviation (SD) = 8), fast-flowing (Average velocity (AV) = 30 cm/s, SD = 17), and has an average Froude number of 0.25 (SD = 0.15). At these flows, the site is composed of 32 hydro-morphological units (HMUs), primarily ruffles, riffles, and runs (21.9%, 21.9%, and 18.8%, respectively) (Appendix 2.2). Under higher-flow conditions (average flow=2.2 cfsm), this site is composed of 40 HMUs. The frequency of rapids increases significantly (30%). Runs also increase (27.5%), while ruffles and riffles decrease (7.5% each). As flow decreases to .14 cfsm, glides become the most frequent mesohabitat (27.5%), with runs as a close second (24.6%). Ruffles become less abundant (decrease from 21.9% to 1.5%). Rapids also decrease significantly (from 15.6% to 2.9%). WBA is 28% at .1 cfsm and increases rapidly as flow increases (59% WBA at 0.5 cfsm, and 78% WBA at 1 cfsm).

3.4.2.2 Habitat for fish

Overall, this Management Unit has a moderate amount of suitable habitat (Figure 3.6). Total habitat steadily increases with flow (27% at 0.1 cfsm, 38% at 0.5 cfsm, 46% at 1.0 cfsm). Slimy sculpin has the most habitat, which peaks at the low flows (27% WBA at 0.1 cfsm) and decreases as flow increases. Blacknose dace habitat is lowest at 0.5 cfsm (15% WBA), and increases at lower and higher flows (16% WBA at 0.1 and 1.0 cfsm. Brook trout habitat is highest at 0.1 cfsm (9% WBA) and decreases as flow increases (5% WBA at 0.5 cfsm, 2% WBA at 1.0 cfsm). Suitable habitat for white sucker is lowest at 0.5 cfsm (6% WBA), and increases at lower and higher flows (12% WBA at 0.1 cfsm, 8% WBA at 1.0 cfsm). Longnose dace has minimal suitable habitat (3% WBA at 0.1 cfsm, 0% WBA at 0.5 cfsm, 1% WBA at 1.0 cfsm). Both brown trout and rainbow trout have very low levels of suitable habitat (under 1% WBA). The habitat overlapping factor is highest at 0.1 cfsm (2.5 species per habitat unit) and decreases as flow increases (1.3 at 0.5 cfsm, 1.1 at 1.0 cfsm).

3.4.3 Management Unit 2

This MU stretches for 600 meters downstream of the Notch Inn Road bridge. Also nearby Route 214, this section includes some areas of bedrock located roughly 200 meters from the end.

3.4.3.1 Hydro-morphology

This Management Unit is characterized by an abundance of boulders, canopy cover shading, and shallow margins. Woody debris also occurs on a moderately frequent basis. Riprap and overhanging vegetation are present in smaller quantities. The substrate is largely mega-lithal. At a flow of 0.4 cfsm, the site is fairly shallow (AD=24 cm, SD=10), moderately fast-flowing (AV=30 cm/s, SD=17), and has an average Froude number of 0.26 (SD=.17). At these flows, the site is composed of 30 HMUs, with cascades being the most abundant (26.7%), followed by pools and riffles (16.7%) (Appendix 2:3). Runs (13.3%) and sidearms (10%) are also present in moderate amounts. Under higher flows (average flow=2.2 cfsm), cascades increase to 33.3% and remain the most abundant HMU. Runs and rapids also increase (26.7% and 16.7% respectively), while pools decrease (3.3%) and side arms disappear. At lower flows (average flow = 0.14 cfsm), runs are also more abundant than at moderate flows (26.3%). Glides and ruffles also increase (from 3.3% to 10.5%, and 3.3% to 12.3%, respectively). Backwaters are present under low-flow conditions (5.3%). Wetted area is 48% at 0.1 cfsm and increases fairly sharply as flow increases (70% WBA at 0.5 cfsm and 81% WBA at 1.0 cfsm).

3.4.3.2 Habitat for fish

This site has a high amount of total suitable habitat (Figure 3.7). Total habitat is 40% WBA at 0.1 cfsm and increases steadily to peak of 59% WBA at 0.5 cfsm before dropping slightly to 56% WBA at 1.0 cfsm. Slimy sculpin has the most suitable habitat at low flows (37% WBA at 0.1 cfsm). Suitable habitat for slimy sculpin decreases as flow increases (7% WBA at 0.5 cfsm, 6% WBA at 1.0 cfsm). Habitat for blacknose dace starts at 0% WBA at 0.1 cfsm, but increases sharply until it peaks at 49% WBA at 0.6 cfsm. Suitable habitat for blacknose dace gradually decreases until it is about 42% WBA at 1.0 cfsm. Suitable habitat for brook trout is low (13% WBA at 0.1 cfsm) and drops to 0% WBA at flows of 0.4 cfsm and greater. White sucker has moderate levels of suitable habitat (1% WBA at 0.1 cfsm, 10% WBA at 0.5 and 1.0 cfsm). Longnose dace also has moderate levels of suitable habitat (2% WBA at 0.1 cfsm, 14% WBA at 0.5 cfsm, 13% WBA at 1.0 cfsm). Rainbow trout has 1% WBA suitable habitat at 0.1 cfsm and 0% WBA at all other flows. Brown trout habitat drops from 3% to under 1% WBA as flow increases from 0.1 to 0.2 cfsm. At higher flows, brown trout habitat gradually increases (4% WBA at 0.5 cfsm, 6% WBA at 1.0 cfsm). The habitat overlapping factor is highest at 0.3 cfsm (1.5 species per habitat unit). It is slightly lower at 0.1 and 0.2 cfsm (1.4) and at higher flows (1.4 at 0.5 cfsm, 1.2 at 1.0 cfsm).

3.4.4 Management Unit 3

This MU runs from 600 meters downstream of the Notch Inn Road bridge to 160 meters downstream of Ostrander Road. The first half of the 1125 meter unit contains several bedrock areas. There are also two short, eroded stretches (100-499 sq. m in size) downstream of two bridges located in the middle of the unit.

3.4.4.1 Hydro-morphology

This Management Unit is characterized by an abundance of boulders and shallow margins. It also contains moderate amounts of canopy cover shading, riprap, and woody debris. The substrate in this section is a combination of mega- and macro-lithal. At a flow of 0.4 cfsm, this site is shallow (AD= 30 cm, SD= 9), fast-flowing (AV= 33 cm/s, SD= 16), and has an average Froude number of 0.27 (SD= 0.14). At these flows, the site is composed of 67 HMUs, primarily runs (29.9%) (Appendix 2:4). Pools (11.5%), riffles (14.9%), ruffles (11.9%), cascades (10.5%), and rapids (10.5%) were also present in high quantities. Under higher flows (average flow = 2.1 cfsm), runs decrease significantly (5.2%). Riffles and cascades also decrease (10.3% and 5.2% respectively). Rapids (25.9%) and pools (19%) are present in the highest quantities. At lower flows (average flow = 0.14 cfsm), glides appear (7.6%). Runs and rapids both decrease in quantity (19.7% and 4.6%, respectively). Pools, on the other hand, increase in quantity (18.2%). Wetted area is 52% at 0.1 cfsm and increases steadily as flow increases (66% at 0.5 cfsm, 73% at 1.0 cfsm).

3.4.4.2 Habitat for fish

This site has a high amount of total suitable habitat (Figure 3.8). Total habitat increases with initial increases in flow and then remains fairly constant at flows of 0.5 cfsm and greater (44% at 0.1 cfsm, 60% at 0.5 and 1.0 cfsm). Slimy sculpin habitat is highest at 0.1 cfsm (37% WBA), dropping slightly before reaching a peak of 35% WBA at flows of 0.7 cfsm. Suitable habitat for slimy sculpin gradually decreases as flow increases further (32% WBA at 1.0 cfsm, 25% WBA at 1.5 cfsm). Suitable habitat for blacknose dace is relatively consistent, gradually increasing from 24% WBA to 35% WBA as the flow changes from 0.1 to 1.5 cfsm. Brook trout habitat is 6% WBA at 0.1 cfsm, and then drops to 0% WBA at 0.4 cfsm. As flow increases further, brook trout habitat increases slightly (1% WBA at 0.5 cfsm, 2% WBA at 1.0 cfsm). White sucker habitat gradually increases from 10% WBA at 0.1 cfsm to 14% WBA at 0.7 cfsm. As flow increases further, white sucker habitat decreases (12% WBA at 1.0 cfsm). Suitable habitat for longnose dace is lowest at 0.1 cfsm (1% WBA) and increases with increase in flow (6% WBA at 0.5 cfsm, 9% WBA at 1.0 cfsm). Suitable habitat for rainbow trout is low and increases slightly as flow increases (0% WBA at 0.1 cfsm, 3% WBA at 0.5 csfm, 4% WBA at 1.0 csfm). Suitable habitat for brown trout is also low and increases slightly as flow increases (1% WBA at 0.1 csfm and 0.5 csfm, 3% WBA at 1.0 csfm). The habitat overlapping factor is greatest at 0.1 cfsm (1.8 species per habitat unit), and is between 1.4 and 1.5 at all other flows.

3.4.5 Management Unit 4

This MU begins 162 meters downstream of Ostrander Road and stretches to roughly 100 meters upstream of the east-facing end of Mountain Road. This 1070-meter long stretch runs relatively close to Route 214 and contains four bridges. An eroded area (500-999 sq. m in size) and a clay exposure site are both located 200 m downstream from the top of the unit.

3.4.5.1 Hydro-morphology

This Management Unit is characterized by an abundance of boulders and overhanging vegetation, with shallow margins and woody debris also present in moderate amounts. The substrate is a combination of mega- and macro-lithal. At flows of 0.38 cfsm, this site is shallow (AD= 20 cm, SD= 9), fast-flowing (AV= 31 cm/s, SD= 16), and has an average Froude number of 0.26 (SD= 0.15). At these flows, the site is composed of 71 HMUs. Runs are most frequent (25.35%), followed by riffles (19.7%), rapids (16.9%) and cascades (12.7%) (Appendix 2:5). As flow increases from 0.38 to an average of 1.7 cfsm, all backwaters, pools and cascades (formerly 1.4%, 7.0% and 12.7%, respectively) disappear. Riffle and rapid presence increases under these high-flow conditions (38.8% and 42.1%, respectively). Under lower flow conditions (average flow=.13 cfsm), rapids decrease to 0%, while both riffles and ruffles increase (26.2% and 16.9%, respectively). Wetted area is high at .1 cfsm (68%) and increases further as flow increase (79% at .5 cfsm, 88% at 1 cfsm).

3.4.5.2 Habitat for fish

Overall, this Management Unit has a large amount of suitable habitat, especially for slimy sculpin and blacknose dace (Figure 3.9). Total habitat increases steadily as flow increases (53% WBA at 0.1 cfsm, 65% WBA at 0.5 cfsm, 74% WBA at 1.0 cfsm). Habitat for both slimy sculpin and blacknose dace is highest at 0.1 cfsm (approximately 49% WBA and 47% WBA, respectively). After this, habitat decreases in both cases, although blacknose dace habitat level levels out before 0.5 cfsm (at approximately 37% WBA), while slimy sculpin habitat continues to decrease until 0.5 cfsm (29% WBA). The amount of habitat remains fairly constant until 1.0 cfsm, when it begins to gradually increase to 37% WBA at 1.5 cfsm. White sucker and brook trout have very little suitable habitat at this site. White sucker habitat is greatest (approximately 6% WBA) at flows of 0.1 and 1.5 cfsm, and gradually drops to 2% WBA between these flows. Brook trout habitat remains almost completely constant (around 3% WBA) for all flows. Longnose dace habitat is lowest at 0.1 cfsm (2% WBA), but increases fairly quickly to its peak (16% WBA) at 0.5 cfsm. As flow increases from this point, habitat stays at approximately the same level, then slowly decreases to 10% WBA at 1.5 cfsm. Rainbow trout habitat is 0% WBA at low and middle flows, but increases slightly as flow further increases (3% WBA at 1.0 cfsm). Brown trout habitat is fairly constant at 3-4% WBA across all flows. The habitat overlapping factor is highest at 0.1 cfsm (2 species per habitat unit) and decreases as flow increases (1.4 at 0.5 cfsm, 1.2 at 1.0 cfsm).

3.4.6 Management Unit 5

This Management Unit runs between Route 214 and Mountain Road, and is further removed from both roads than the previous units were from Route 214. It reaches approximately 450 meters in either direction from the Wright Road bridge. The upstream half of this 900 m stretch contains an area of erosion 100-499 square meters in size, and the downstream section includes two clay exposure sites.

3.4.6.1 Hydro-morphology

This Management Unit is characterized by an abundance of boulders. Small amounts of woody debris, shallow margins, and canopy cover shading are also present. The substrate is largely macro-lithal. This site was mapped on two different days, with an average flow of 0.35 cfsm. Under this flow condition, the site is somewhat shallow (AD= 25 cm, SD= 8), fast-moving (AV= 35 cm/s, SD= 14), and has an average Froude number of 0.25 (SD= 0.11). The site is composed of 42 HMUs (at average flows of 0.35 cfsm), which are predominantly riffles (19.1%), glides (16.7%), rapids (16.7%), and runs (14.3%), (Appendix 2:6). Pools, plunge pools, and cascades are also present in moderate quantities (9.5% each). All glides, pools, plunge pools and cascades disappear under higher flow conditions (average flow = 1.64 cfsm). The abundance of runs more than doubles (40%) as flow decreases (average flow= 0.14 cfsm). Rapids, however, disappear entirely. Backwaters, sidearms, and fast runs are present at this site in small quantities (5.6%, 4.2% and 1.4%, respectively) under low-flow conditions. Wetted area is 45% at 0.1 cfsm and increases gradually as flow increases (49% at 0.5 cfsm, 55% at 1.0 cfsm).

3.4.6.2 Habitat for fish

This site has moderate levels of total suitable habitat, which increase gradually with flow (37% WBA at 0.1 cfsm, 38% WBA at 0.5 cfsm, 42% WBA at 1.0 cfsm) (Figure 3.10). Slimy sculpin habitat is the most plentiful at approximately 30%; habitat for all other species is almost always less than 10% WBA. The availability of slimy sculpin habitat remains fairly constant (26% WBA at 0.1 cfsm, 30% WBA at 0.5 cfsm, 32% WBA at 1.0 cfsm). Blacknose dace habitat is also approximately 27% WBA at 0.1 cfsm, but then falls sharply to 10% WBA before flows reach 0.5 cfsm. As flows increase from this point, blacknose dace habitat decreases only slightly (8% WBA at 1.0 cfsm). Brook trout has no habitat at 0.1 cfsm, but suitability increases with flow (to 6% WBA at 0.5 cfsm) before falling to 4% WBA at 1.0 cfsm. Habitat for white sucker is initially low (5% WBA at 0.1 cfsm) and then decreases further as flow increases (1% at 1.0 cfsm). At 0.1 cfsm, longnose dace has no suitable habitat. Its habitat initially increases with flow (to 11% WBA) before falling to 8% WBA at 1.5 cfsm. No suitable habitat is available in this Management Unit for either rainbow trout or brown trout. The habitat overlapping factor is highest between 0.1 and 0.7 cfsm (1.5 species per habitat unit) and then decreases as flow increases (1.3 at 1.0 cfsm).

3.4.7 Management Unit 6

This Management Unit stretches 300 m to either side of Neal Road. It has a length of 740 m, the first third of which runs very close to Route 214; the remaining downstream portion is considerably more removed. Two clay exposure sites are located near the base of the section, along with an area of erosion 0-99 square meters in size that sits between the road and the stream. The alignment of the stream in this unit is much different from its historical alignment.

3.4.7.1 Hydro-morphology

This Management Unit contains moderate amounts of boulders and canopy cover shading. Woody debris and shallow margins are also present, but to a lesser extent. The substrate is primarily macro-lithal in character. At flows of 0.33 cfsm, this site is shallow (AD= 23, SD= 8), fast-flowing (AV= 35 cm/s, SD= 12), and has an average Froude number of 0.29 (SD= 0.12). Under these flow conditions, the site is composed of 32 HMUs, which are predominantly riffles (28.1%) and rapids (25.0%) (Appendix 2:7). Pools and runs are also present in moderate quantities (12.5% each), along with glides (9.4%). Fast runs are not present at these flows, but have an abundance of 24% under high-flow conditions (2.1 cfsm). The presence of ruffles also increases as flow increases, from 3.1% to 16%. In contrast, all plunge pools disappear and rapids decrease to 8% as flow increases. At a flow of 0.13 cfsm, the proportion of runs increases significantly (27.3%). Ruffles also increase, changing from 3.1% at moderate flows to 16.7% at low flows. Riffles decrease (16.7%), while rapids completely disappear. Wetted area is 39% at 0.1 cfsm and increases steeply to 67% at 0.5 cfsm; as flows increase to 1.0 cfsm, wetted area increases more gradually (74%).

3.4.7.2 Habitat for fish

This site has a reasonably high amount of suitable habitat, especially for slimy sculpins (Figure 3.11). Total habitat is 37% WBA at 0.1 cfsm and peaks at 62% WBA at 0.5 cfsm. As flow increases further, total habitat decreases gradually (56% at 1.0 cfsm). Slimy sculpin habitat is 31% WBA at 0.1 cfsm and increases quickly to 53% WBA at 0.5 cfsm before declining in response to increasing flow (to 40% WBA at 1.5 cfsm). Habitat suitability for blacknose dace is 5% WBA at 0.1 cfsm and increases to 24% WBA at 0.5 cfsm. At higher flows, however, blacknose dace habitat increases slightly (30% WBA at 1.0 cfsm). Brook trout habitat is low, but remains reasonably constant (6% WBA at 0.1 cfsm, 10% WBA at 0.5 cfsm, 11% WBA at 1.0 cfsm). Habitat for white sucker is 5% WBA at 0.1 cfsm and then increases to 24% WBA at 0.5 cfsm. At higher flows, white sucker habitat decreases (19% WBA at 1.0 cfsm). Longnose dace habitat increases from 3% WBA to 16% WBA as flow increases from 0.1 to 1.0 cfsm. No habitat is available for rainbow trout at 0.1 cfsm and 0.5 cfsm, but suitability increases gradually as flow increases (5% WBA at 1.0 cfsm). Brown trout habitat is also 0% WBA at 0.1 cfsm and increases as flow increases (1% WBA at 0.5 cfsm, 4% WBA at 1.0 cfsm). The habitat overlapping factor is lowest at 0.1 cfsm (1.3 species per habitat unit), and increases as flow increases (1.9 at 0.5 cfsm, 2.0 at 1.0 cfsm).

3.4.8 Management Unit 7

This MU stretches from 300 m downstream of Neil Road to the Jensen Road bridge. It is 480 m in length and flows between Route 214 and Meadow Brook Drive, maintaining a small to moderate distance between both roads. A clay exposure site is located 100 m from the top of the unit.

3.4.8.1 Hydro-morphology

This Management Unit is characterized by boulders, woody debris, and a large amount of shallow margin area. The dominant substrate is macro-lithal. At a flow of 0.31 cfsm, the site is fairly shallow (AD=21 cm, SD=8), fast-flowing (AV=37, SD=12), and has an average Froude number of 0.30 (SD=0.15). At flows of 0.31 cfsm, this site is composed of 16 HMUs, half of which are riffles and runs (25% each) (Appendix 2:8). Also present in moderate quantities are rapids (18.8%), pools (12.5%), and ruffles (12.5%). Under higher flows (flow=1.34 cfsm), fast runs emerge and are present in the highest quantities (27.3%). Ruffles also increase (18.2%), but runs decrease (19.2%) and riffles disappear entirely. Under lower flows (average flow=0.13 cfsm), riffles are present in the highest quantities (28.6%). Ruffles, glides, and sidearms are also present in relatively high quantities (21.4%, 14.3% and 14.3% respectively). Wetted area is 44% at 0.1 cfsm and increases steeply with initial increases in flow and then levels off (79% at 0.5 cfsm, 81% at 1.0 cfsm).

3.4.8.2 Habitat for fish

This site provides a great deal of suitable habitat, though much of this habitat is suitable for slimy sculpin alone (Figure 3.12). Total is 27% WBA at 0.1 cfsm but increases steeply to a peak of 75% WBA at 0.5 cfsm. As flow increases further, total habitat decreases gradually (64% WBA at 1.0 cfsm). Slimy sculpin habitat is 27% WBA at 0.1 cfsm, but rises sharply to its peak of 75% WBA before flows reach 0.5 cfsm. From this point, habitat declines slightly (to 64% WBA at 1.0 cfsm). Blacknose dace has about 14% WBA habitat at 0.1 cfsm. When the flow increases to 0.5 cfsm, habitat increases slightly to 16% WBA. At higher flows, blacknose dace habitat decreases (13% WBA at 1.0 cfsm). Brook trout habitat is 1% WBA at 0.1 cfsm and quickly falls to 0% WBA as flow increases. White sucker habitat is 14% WBA at 0.1 cfsm and peaks at 25% WBA at 0.3 cfsm. As flow increases further, white sucker habitat decreases (23% WBA at 0.5 cfsm, 10% WBA at 1.0 cfsm). Longnose dace habitat is 15% WBA and initially increases as flow increases (23% WBA at 0.5 cfsm). As flow increases further, longnose dace habitat decreases (13% WBA at 1.0 cfsm). Rainbow trout habitat is 0% WBA at 0.1 cfsm and increase to a peak of 9% WBA at 0.4 cfsm. As flows increase further, rainbow trout habitat decreases (7% at 0.5 cfsm, 2% at 1.0 cfsm). Brown trout habitat is low and constant at about 1-2% WBA across all flows. The habitat overlapping factor is highest at 0.1 cfsm (2 species per habitat unit) and decreases as flow increases (1.8 at 0.5 cfsm, 1.4 at 1.0 cfsm).

3.4.9 Management Unit 8

This MU runs between the Jensen Road bridge and the east-facing end of Stony Road. It is 1425 meters long and maintains a sizeable distance (no less than 100 m) from the roads at all times. The unit contains two clay exposure sites, one located 225 meters from the upstream end and one located 450 meters from the downstream end, and an area of erosion 1000-2757 square meters in size.

3.4.9.1 Hydro-morphology

This Management Unit contains moderate amounts of woody debris, shallow margins, and overhanging vegetation. Riprap is present to a lesser extent. The substrate is largely meso-lithal in character. This site was mapped on two different days, with an average flow of 0.36 cfsm. Under these flow conditions, the site is relatively shallow (AD= 22 cm, SD=9), fast-flowing (AV= 36, SD= 13) and has an average Froude number of 0.29 (SD= 0.14). It is composed of 72 HMUs, which are predominantly riffles (31.9%) and runs (20.8%), (Appendix 2:9). Pools and sidearms are also present in moderate quantities (15.3% and 11.1%, respectively). All cascades and glides disappear under higher flow conditions (average flow = 1.17 cfsm). Under these flows, fast runs appear (10.9%), and rapid and ruffle presence increase considerably (from 6.9% to 28.26% and 2.8% to 13.0%, respectively). At lower flows (average flow=0.13 cfsm), the abundance of backwaters increases significantly (from 4.2% to 21.9%) and the abundance of runs also increases (28.1%). Pools and riffles both decrease (6.3% and 25% respectively). Wetted area is 34% 0.1 cfsm and increases steadily as flow increases (52% at 0.5 cfsm, 59% at 1.0 cfsm).

3.4.9.2 Habitat for fish

This Management Unit has moderate amounts of habitat (Figure 3.13). Total habitat increases from 34% WBA at 0.1 cfsm to a peak of 45% WBA at 0.5 cfsm. As flow increase further, total habitat slightly decreases (39% WBA at 1.0 cfsm). Slimy sculpin has the most habitat, which, after an initial increase fom 21% to 30% WBA (between flows of 0.1 and 0.5 cfsm), drops to 27% WBA and remains constant with increasing flow rate. Blacknose dace habitat is also 21% WBA at 0.1 cfsm, but falls to 17% WBA by 1.0 cfsm. Brook trout habitat is 6% WBA at 0.1 cfsm, but then quickly drops to almost 0% WBA. White sucker habitat is 3% WBA at 0.1 cfsm and increases to 18% WBA at 0.5 cfsm. As flow increases further, white sucker habitat decreases (11% WBA at 1.0 cfsm, 2% WBA at 1.5 cfsm). Longnose dace habitat is highest at 0.1 cfsm (19% WBA), and fairly constant around 10% at flows of 0.3 cfsm and greater. Brown trout has moderate levels of suitable habitat, which increases as flow increases (2% WBA at 0.1 cfsm, 6% WBA at 0.5 cfsm, 14% WBA at 1.0 cfsm). Rainbow trout habitat is lower, but also increases as flow increases (1% WBA at 0.1 and 0.5 cfsm, 7% WBA at 1.0 cfsm). The habitat overlapping factor is highest at 0.1 cfsm (2.1 species per habitat unit) and decreases as flow increases (1.9 at 0.5 cfsm, 1.7 at 1.0 cfsm).

3.4.10 Management Unit 9

This Management Unit stretches from the east-facing end of Stony Road to 100 meters downstream of the west-facing end. It has a length of 325 meters and multiple clay exposure sites located near its base.

3.4.10.1 Hydro-morphology

This Management Unit contains boulders, as well as a small amount of overhanging vegetation. The substrate is largely meso-lithal in character. At flows of 0.34 cfsm, this site is somewhat shallow (AD= 24 cm, SD= 10), fast-flowing (AV= 36, SD= 14), and has an average Froude number of 0.25 (SD= 0.11). At these flows, the site contains 12 HMUs, which are primarily riffles (41.7%), followed by backwaters (16.7%) (Appendix 2:10). Glides, pools, runs, ruffles, and cascades are also present (8.3% each). Under higher flow conditions (1.08 cfsm), the entire site is composed of only two HMUs: one ruffle and one fast run. Under lower flow conditions (0.13 cfsm), both cascades and pools disappear, backwaters and runs increase (21.7 and 17.4% respectively), and riffles decrease (30.4%). Interestingly, rapids are found to increase from 0% to 8.7% under low flows. Wetted area is 55% at 0.1 cfsm and increases gradually as flow increases (60% at 0.5 cfsm, 68% at 1.0 cfsm).

3.4.10.2 Habitat for fish

This site has a moderate amount of suitable habitat (Figure 3.14). Total habiat is highest at the lowest flow and gradually decreases as flow increases (53% at 0.1 cfsm, 52% at 0.5 cfsm, 47% at 1.0 cfsm). Slimy sculpin habitat is highest (about 45% WBA) at flows of 0.1 and 1.0 cfsm and reaches a minimum level around 0.5 cfsm (26% WBA). Habitat for blacknose dace and brook trout is near 14% WBA. At intermediate flows, however, habitat for blacknose dace peaks to 35% WBA at 0.4 cfsm before declining, while brook trout habitat declines immediately, reaching 0% WBA at 1.0 cfsm. White sucker habitat is 0% WBA at 0.1 cfsm, but reaches 14% WBA when flow increases to 0.5 cfsm. Available habitat for white sucker then drops to 2% WBA at 1.1 cfsm. Long nose dace habitat is 17% WBA at 0.1 cfsm and increases slightly to 20% WBA at 0.4 cfsm. As flow increases further, long nose dace habitat decreases (19% WBA at 0.5 cfsm, 4% WBA at 1.0 cfsm). Rainbow trout has no suitable habitat at low flows, but as flow increases, habitat becomes more abundant (6% WBA at 0.5 cfsm, 38% WBA at 1.0 cfsm). Brown trout habitat is 4% WBA at 0.1 cfsm and 0% WBA at flows greater than 0.4 csfm. The habitat overlapping factor is highest at flows of 0.3 cfsm to 0.5 cfsm (1.8 species per habitat unit), and then decreases at lower and higher flows (1.6 at 0.1 cfsm, 1.1 at 1.0 cfsm).

3.4.11 Management Unit 10

This MU begins 100 meters downstream of Stony Road and spans a distance of 575 meters, which runs adjacent to the Stony Clove Rod and Gun club. The first half of this stretch is located relatively far away from roads, but the downstream portion is in very close proximity with Route 214. This is in sharp contrast to the 1959 stream alignment, which maintained a sizeable distance from Route 214 throughout the entire stretch. Even in comparison to the 1980 alignment, the stream is now noticeably channelized.

3.4.11.1 Hydro-morphology

This Management Unit is characterized by an abundance of shallow margin area and contains small amounts of woody debris and canopy cover shading. The substrate is a combination of meso- and micro-lithal. This site was mapped on two different days, with an average flow of 0.33 cfsm. Under these flow conditions, the site is shallow (AD= 20 cm, SD= 8), fast-flowing (AV= 33 cm/s, SD= 14), and has an average Froude number of 0.26 (SD= 0.12). It is composed of 32 HMUs, which are predominantly riffles (37.5%), followed by runs and glides (15.6% and 12.5%, respectively) (Appendix 2:11). Backwaters, pools and ruffles are also present in moderate quantities (9.4% each). All riffles disappear under higher flow conditions (1.08 cfsm). Another dramatic change that occurrs as flow increases is a significant increase in rapids (from 3.1 to 33.3%). Under lower flow conditions (average flow=0.14 cfsm), the predominant meso-habitat becomes runs, which increase to 25.9%. Glides also increase (22.2%), while riffles decrease (also 22.2%). Both ruffles and cascades disappear at low flows. Wetted area is 49% at 0.1 cfsm; it increases rapidly with initial increase in flow and then increase more gradually as flow increase beyond 0.5 cfsm (70% at 0.5 cfsm, 71% at 1.0 cfsm).

3.4.11.2 Habitat for fish

This site has a large amount of suitable habitat, especially for slimy sculpin (Figure 3.15). Total habitat increases as flow increases to 0.5 cfsm (45% WBA at 0.1 cfsm, 62% WBA at 0.5 cfsm), and remains constant at approximately 64% WBA at higher flows. Slimy sculpin habitat is 31% WBA at 0.1 cfsm and increases to about 62% WBA at 1.0 cfsm. Blacknose dace habitat is 23% WBA at 0.1 cfsm and peaks at 0.4 cfsm (30% WBA) before dropping to 13% WBA by 1.1 cfsm. Brook trout habitat is very low, and is highest (under 2% WBA) at 0.1 cfsm. At 0.1 cfsm, white sucker habitat is 6% WBA; it peaks around 0.5 cfsm (24% WBA) and then declines gradually (15% WBA at 1.0 cfsm). Longnose dace habitat is highest at 0.1 cfsm (22% WBA) and decreases as flow increases (3% WBA at 0.5 cfsm, 0% WBA at 1.0). Rainbow trout has a moderate level of habitat, which increases as flow increases (0% WBA at 0.1 cfsm, 2% WBA at 0.5 cfsm, 16% WBA at 1.0 cfsm). Brown trout has less than 2% WBA suitable habitat in this Management Unit. The habitat overlapping factor is highest at flows in the range of 0.2 to 0.5 cfsm (1.9 species per habitat unit). It is lower at 0.1 cfsm (1.8) and at higher flows (1.4 at 1.0 cfsm).

3.4.12 Management Unit 11

This Management Unit has a length of 750 meters, beginning roughly 850 meters downstream of Stony Road. This stretch runs in very close proximity to Route 214 for the first three-fourths of its length, before a noticeable stream-to-road distance arises. A single bridge is located near this point of divergence, downstream of which is located an area of erosion, 100-499 square meters in size.

3.4.12.1 Hydro-morphology

This Management Unit is characterized by an abundance of shallow margin area, and also contains moderate amounts of boulders and riprap. The substrate is a combination of macro- and micro-lithal. At flows of 0.31 cfsm, this site was shallow (AD= 21 cm, SD 8), fast-flowing (AV= 34, SD= 14), and had an average Froude number of 0.27 (SD= 0.13). Under these flow conditions, the site was composed of 34 HMUs, which were primarily riffles (32.4%), followed by pools and runs (17.7% each) (Appendix 2:12). Glides were also present in moderate quantities (11.8%). Pools and sidearms disappeared under higher flow conditions (1.08 cfsm), while rapid and run presence increased (29.41% each). Under lower flow conditions (average flow=0.15), the biggest changes were an increase in ruffles (from 2.9% to 15%), and a decrease in glides and pools (5 and 12.5%, respectively). Wetted area is 53% at 0.1 cfsm and increases gradually as flow increases (60% at 0.5 cfsm, 63% at 1.0 cfsm).

3.4.12.2 Habitat for fish

This site has a fairly high level of suitable habitat (Figure 3.16). Total habitat is 47% WBA at 0.1 cfsm and remains fairly constant at 54% at flows of 0.5 cfsm and higher. Slimy sculpins have fairly constant levels of suitable habitat (36% WBA at 0.1 cfsm, 32% WBA at 0.5, 25% WBA at 1.0 cfsm). Blacknose dace has the largest amount of suitable habitat at moderate flows, starting at 30% WBA at 0.1 cfsm and peaking at 37% WBA at 0.5 cfsm. Suitable habitat gradually decreases as flow increases (27% WBA at 1.0 cfsm). Brook trout has 8% WBA suitable habitat at 0.1 cfsm, which decreases to 0% WBA at flows of 0.5 cfsm and higher. White sucker habitat is highest at low and moderate flows, and begins to decrease as flow increases (17% WBA at 0.1 cfsm, 18% WBA at 0.5 cfsm, 10% WBA at 1.0 cfsm). Longnose dace habitat is highest at mid-level flows (4% WBA at 0.1 cfsm, 12% WBA at 0.5 cfsm, 8% WBA at 1.0 cfsm). Brown trout has a small amount of suitable habitat at all flows (2% WBA at 0.1 cfsm, 3% WBA at 0.5 cfsm, 1% WBA at 1.0 csfm). Rainbow trout has no suitable habitat in this Management Unit. The habitat overlapping factor is highest at flows of 0.1 cfsm and 0.2 cfsm (2 species per habitat unit) and decreases as flow increases (1.8 at 0.5 cfsm, 1.5 at 1.0 cfsm).

3.4.13 Management Unit 12

This Management Unit has a length of 270 meters, beginning approximately 500 meters upstream of Stony Clove Lane. It maintains a sizeable distance from roads at all times, moving further away from Route 214 in its middle. This contrasts the 1959 stream alignment, which maintained a nearly constant distance from Route 214.

3.4.13.1 Hydro-morphology

This Management Unit contains shallow margins, as well as boulders to a lesser degree. The substrate is a combination of meso- and macro-lithal. At flows of 0.29 cfsm, this site was shallow (AD=24 cm, SD= 10), fast-flowing (AV= 34 cm/s, SD= 16), and had an average Froude number of 0.27 (SD= 0.16). Under these flow conditions, the site was composed of 15 HMUs, which were primarily riffles and runs (26.7% each) (Appendix 2:13). Pools, rapids and ruffles were also present in moderate quantities (13.3% each). Under higher flow conditions (1.08 cfsm), this site was comprised of only 4 HMUs, one glide, run, rapid and ruffle. Under lower flow conditions (0.13 cfsm), backwaters increased from 0% to 15.4%. Ruffles also increased significantly (30.8%), becoming the most abundant mesohabitat. Riffles and runs decreased (7.7 and 15.4%, respectively) and rapids disappeared. Wetted area is 34% at 0.1 cfsm and increases sharply to 57% at 0.3 cfsm. Wetted area increases more gradually with further increases in flow (59% at 0.5 cfsm, 60% at 1.0 cfsm).

3.4.13.2 Habitat for fish

This Management Unit has moderate levels of suitable habitat for slimy sculpins, blacknose dace, and white suckers (Figure 3.17). Total habitat increases gradually as flow increases (32% WBA at 0.1 cfsm, 38% WBA at 0.5 cfsm, 46% WBA at 1.0 cfsm). Slimy sculpin habitat is lowest at moderate flows, and highest at high flows (22% WBA at 0.1 cfsm, 11% WBA at 0.5 cfsm, 27% WBA at 1.0 cfsm). Blacknose dace, on the other hand, has the greatest amount of suitable habitat at moderate flows. Blacknose dace habitat is low at 0.1 cfsm (4% WBA) and increases as flow reaches 0.6 cfsm 26% WBA). Suitable habitat gradually decreases with increasing flow at flows greater than 0.6 cfsm (19% at 1.0 cfsm). Brook trout has a small amount of suitable habitat; it is 4% WBA at 0.1 cfsm and decreases to 0% WBA at flows of 0.3 cfsm and higher. Suitable habitat for white suckers starts out low (7% WBA at 0.1 cfsm) and peaks at 0.4 cfsm (28% WBA). After that, suitable habitat decreases as flow increases (27% WBA at 0.5 cfsm, 2% WBA at 1.0 cfsm). Longnose habitat is 10% WBA at 0.1 cfsm and decreases to 0% WBA at flows of 0.5 cfsm and higher. Brown trout habitat is highest at 0.5 cfsm (2% WBA) and decreases at lower and higher flows. Rainbow trout has no suitable habitat in this Management Unit. The habitat overlapping factor is 1.5 species per habitat unit at 0.1 cfsm, 1.7 at 0.5 cfsm, and 1.1 at 1.0 cfsm.

3.4.14 Management Unit 13

This Management Unit stretches from roughly 225 meters upstream of Stony Clove Road to 150 meters upstream of Willow Lane. This unit is 425 meters long and is located a reasonable distance away from Route 214. Stony Clove Road, however, intersects Route 214 perpendicularly and crosses over the unit near the downstream end.

3.4.14.1 Hydro-morphology

This Management Unit is characterized by an abundance of riprap and shallow margin area, with a small amount of boulders. The substrate is a combination of macro- and meso-lithal. At flows of 0.27 cfsm, this site is shallow (AD= 17 cm, SD= 7), fast-flowing (AV= 32 cm/s, SD= 13), and has an average Froude number of 0.28 (SD=0.14). Under these flow conditions, this site is composed of 21 HMUs, which are primarily riffles (28.6%), glides (19.1%), and runs (14.3%) (Appendix 2:14). Pools, sidearms, and rapids are also present in moderate quantities (9.5% each). Under higher flow conditions (1.08 cfsm), this site includes only 5 HMUs: two riffles, two ruffles, and a single section of rapids. Under lower flow conditions (0.13 cfsm), backwaters increase significantly (from 4.8 to 16.7%). Both pools and sidearms disappear under these conditions. Wetted area is 53% at 0.1 cfsm and increases sharply to 78% at 0.3 cfsm. Wetted area increases steadily with further increases in flow (82% at 0.5 cfsm, 87% at 1.0 cfsm).

3.4.14.2 Habitat for fish

This Management Unit has a great deal of suitable habitat at flows below 1.0 cfsm (Figure 3.18). Total habitat is 49% WBA at 0.1 cfsm and peaks at 63% WBA at 0.4 cfsm. As flow increases further, total habitat decreases (61% at 0.5 cfsm, 19% at 1.0 cfsm). Slimy sculpin has the most suitable habitat, which is 28% WBA at 0.1 cfsm and reaches the highest level at 0.4 cfsm (52% WBA). At flows greater than 0.4 cfsm, habitat gradually decreases (46% WBA at 0.5 cfsm, 8% WBA at 1.0 cfsm). Suitable habitat for blacknose dace is 32% WBA at 0.1 cfsm and then gradually decreases (25% WBA at 0.5 cfsm, 0% WBA at 1.0 cfsm). Suitable habitat for brook trout is highest at moderate flows (1% WBA at 0.1 cfsm, 9% WBA at 0.5 cfsm, 2% WBA at 1.0 cfsm). White sucker habitat starts out at 18% WBA at 0.1 cfsm and then slowly decreases with increasing flow (17% WBA at 0.5 cfsm, 4% WBA at 1.0 cfsm). Longnose dace habitat is fairly constant (15% WBA at 0.1 cfsm, 12% WBA at 0.5 cfsm, 11% WBA at 1.0 cfsm). Brown trout has low levels of suitable habitat in this Management Unit (under 1% WBA) and rainbow trout has no suitable habitat. The habitat overlapping factor is highest at flows in the range of 0.2 cfsm to 0.4 cfsm (2 species per habitat unit). It is 1.9 at 0.1 cfsm and keeps declining to 1.6 at 1.0 cfsm.

3.4.15 Management Unit 14

This MU stretches 150 meters to either side of Willow Lane. It is 350 meters long and runs between Route 214 and Stony Clove Lane, maintaining a moderate distance from both. This unit contains a single bridge at its downstream end.

3.4.15.1 Hydro-morphology

This Management Unit is characterized by an abundance of shallow margin area, with overhanging vegetation and woody debris present in small quantities. The substrate is a combination of meso- and macro-lithal. At flows of 0.27, this site is somewhat shallow (AD= 25 cm, SD= 10), fast-flowing (AV= 36 cm/s, SD= 15), and has an average Froude number of 0.28 (SD= 0.14). Under these flow conditions, the site is composed of 13 HMUs, which are primarily runs (30.8%), pools, riffles, and rapids (15.4% each) (Appendix 2:15). Under higher flow conditions (1.08 cfsm), this site is comprised of only 5 HMUs: two runs, two ruffles and a riffle. Under lower flow conditions (0.12 cfsm), pools double in proportion (31.3%) and ruffles also increased significantly (from

7.7% to 25%). Riffles and runs decrease (6.3 and 18.8%, respectively), while plunge pools and rapids both disappear entirely. Wetted area is fairly low at 0.1 cfsm (27%), but more than doubles as flow increases to 0.3 cfsm (59%). Wetted area steadily increases with as flow increases further (65% at 0.5 cfsm, 76% at 1.0 cfsm).

3.4.15.2 Habitat for fish

This Management Unit has a fairly level of suitable habitat (Figure 3.19). Total habitat increases fairly steeply as flows increases from 0.1 to 0.7 cfsm (26% WBA at 0.1 cfsm, 63% WBA at 0.5 cfsm, 66% WBA at 0.7 cfsm). As flow increase further, total habitat slightly decreases (60% WBA at 1.0 cfsm). Slimy sculpin habitat starts out fairly low, but increases quickly as flow increases (9% WBA at 0.1 cfsm, 41% WBA at 0.5 cfsm). At flows greater than 0.5 cfsm, suitable habitat gradually decreases (34% WBA at 1.0 cfsm). Blacknose dace habitat is lowest at 0.1 cfsm (14% WBA) and peaks at 0.3 cfsm (40% WBA). Suitable habitat slowly decreases at flows greater than 0.3 cfsm (36% WBA at 0.5 cfsm, 25% WBA at 1.0 cfsm). Brook trout has no suitable habitat in this Management Unit. Suitable habitat for white sucker is 12% WBA at 0.1 cfsm, and peaks at 16% WBA at 0.5 cfsm. White sucker habitat then decreases as flow increases (4% WBA at 1.0 cfsm, 0% WBA at 1.5 cfsm). Longnose dace habitat is low at 0.1 cfsm (4% WBA) and rapidly increases as flow increases to 0.4 cfsm (34% WBA). As flow increases beyond 0.4 cfsm, suitable habitat decreases to 4% at 1.0 cfsm. There is no suitable habitat for rainbow trout or brown trout in this Management Unit. The habitat overlapping factor is highest at 0.3 cfsm (2 species per habitat unit) and reaches a low point of 1.0 at 1.1 cfsm. It is 1.4 species per habitat unit at 0.1 cfsm, 1.8 at 0.5 cfsm, and 1.1 at 1.0 cfsm.

3.4.16 Management Unit 15

This 345 m Management Unit runs from 150 meters downstream of Willow Lane to the merge of Stony Clove Creek with Warner Creek.

3.4.16.1 Hydro-morphology

This Management Unit is characterized by an abundance of boulders and canopy cover shading, with shallow margins also occurring on a relatively frequent basis. Riprap is also present, but only in small quantities. The substrate is largely macro-lithal. At flows of 0.25 cfsm, this site is somewhat shallow (AD= 25 cm, SD= 14), fast-flowing (AV= 32 cm/s, SD= 17), and has an average Froude number of 0.25 (SD= 0.16). Under these flow conditions, the site is composed of 20 HMUs, which are primarily runs (30%) and pools (20%) (Appendix 2:16). Riffles, sidearms, rapids, and fast runs are also present in moderate quantities (10% each). Under higher flow conditions (1.08 cfsm), this site is composed of only two HMUs, both of which are rapids. Under lower flow conditions (0.11 cfsm), backwaters increase from 0% to 10.3%. The proportion of ruffles also increases from 5% to 13.8%. Pools decrease significantly (10.3%) in low-flow conditions, while rapids and fast runs decrease entirely. Wetted area is 37% at 0.1 cfsm and increases fairly steeply as flow increases (63% at 0.5 cfsm, 77% at 1.0 cfsm).

3.4.16.2 Habitat for fish

This Management Unit has a moderate level of total suitable habitat, especially at middle flows (Figure 3.20). Total habitat increases from 0.1 cfsm to a peak at 0.4 cfsm (29% WBA at 0.1 cfsm, 46% WBA 0.4 cfsm, 44% WBA at 0.5 cfsm, 7% WBA at 1.0 cfsm). Slimy sculpin has the highest amount of suitable habitat, starting at 4% at 0.1 cfsm and reaching the highest point at 0.4 cfsm (30% WBA). At flows greater than 0.4 cfsm, suitable habitat gradually decreases (28% WBA at 0.5 cfsm, 4% WBA at 1.0 cfsm) until it reaches 0% WBA at 1.1 cfsm. Blacknose dace habitat is highest at 0.1 cfsm (26% WBA) and then steadily decreases as flow increases (15% WBA at 0.5 cfsm, 2% WBA at 1.0 cfsm). Brook trout habitat starts out at 0% WBA at 0.1 cfsm and then increases as flow increases until it peaks at 0.5 cfsm (7% WBA), where habitat levels decrease until it reaches 0% WBA at 1.1 cfsm. White sucker habitat is very low, starting out at 4% WBA at 0.1 cfsm and then decreasing to 0% WBA at flows higher than 0.3 cfsm. Longnose dace habitat is low (2% WBA at 0.1 cfsm, 5% WBA at 0.5 cfsm, 1% WBA at 1.0 cfsm). Brown trout habitat first increases as flow increases until it reaches a high point at 0.5 cfsm, where it then decreases (1% WBA at 0.1 cfsm, 12% WBA at 0.5 csfm, 5% WBA at 1.0 csfm). Rainbow trout habitat also increases at first and then decreases (0% WBA at 0.1 csfm, 7% WBA at 0.5 csfm, 2% WBA at 1.0 csfm). The habitat overlapping factor is between 1.2 and 1.5 species per habitat unit for flows of 0.1 to 1.0 csfm.

3.4.17 Management Unit 16

This Management Unit runs from where Stony Clove Creek and Warner Creek merge to the Silver Hollow Bridge. It is 400 meters long and runs between Silver Hollow Road and Route 214, within reasonable proximity to both. It includes several evenly distributed clay exposure sites and an area of erosion (500-999 sq. m in size).

3.4.17.1 Hydro-morphology

This Management Unit is characterized by an abundance of boulders, with riprap present to a lesser extent. The substrate is predominantly mega-lithal in character. At flows of 0.25 cfsm, this site is heterogeneous in depth (AD= 35.78 cm, SD= 17.50), fast-flowing (AV= 35.36 cm/s, SD= 17.50), and has an average Froude number of 0.24 (SD= 0.17). Under these flow conditions, the site is composed of 9 HMUs, which are primarily runs (33.3%) and rapids (22.2%) (Appendix 2:17). Glides, pools, fast runs, and cascades are also present in moderate quantities (11.1% each). Under higher flow conditions (1.08 cfsm), this site is composed of only three HMUs: one riffle, one plunge pool, and one rapid. Under lower flow conditions (0.10 cfsm), significant changes in mesohabitat composition is observed. Ruffles increase from 0% to 13.3% and both backwaters and plunge pools increase from 0% to 6.7%. Runs and cascades also increase (40 and 20%, respectively). Rapids and fast runs disappear under these conditions. Wetted area is 42% at 0.1 cfsm and increases consistently as flow increases (58% at 0.5 cfsm, 77% at 1.0 cfsm).

3.4.17.2 Habitat for fish

Total suitable habitat in this Management Unit is low, especially at higher flows (29% WBA at 0.1 cfsm, 20% WBA at 0.5 csm, 7% WBA at 1.0 cfsm) (Figure 3.21). Slimy sculpin habitat is low, and decreases as flow increases (6% WBA at 0.1 cfsm, 3% WBA at 0.5 cfsm, 0% WBA at 1.0 cfsm). Suitable habitat for blacknose dace is the highest. Blacknose dace habitat is most abundant at low flows and decreases as flow increases (24% WBA at 0.1 cfsm, 18% WBA at 0.5 cfsm, 6% WBA at 1.0 cfsm). Brook trout has no suitable habitat in this Management Unit. White suckers have only a small amount of suitable at 0.1 cfsm (3% WBA) and no suitable habitat at all other flows. Longnose dace and rainbow trout have no suitable habitat in this Management Unit. Brown trout habitat is fairly constant (around 5% WBA) at flows between 0.2 and 0.6 cfsm, but decreases at lower and higher flows (0% at 0.1 cfsm, 2% at 1.0 cfsm) 1.0 cfsm. The habitat overlapping factor is between 1.0 and 1.2 for flows up to 1.0 cfsm.

3.4.18 Management Unit 17

This Management Unit stretches between the Silver Hollow Bridge and 250 meters upstream of Park Road. It is 650 meters long and contains many clay exposure sites, especially in the downstream portion of the stretch. At least half of this unit is eroded (1000-2757 sq. m erosion areas); these erosion sites are located near the top and bottom 250 meters of the stretch.

3.4.18.1 Hydro-morphology

This Management Unit is characterized by an abundance of boulders and riprap, with shallow margins occurring on a relatively frequent basis. The substrate is predominantly mega-lithal. At flows of 0.27 cfsm, this site was heterogeneous in depth (AD= 30 cm, SD= 15), relatively fast-flowing (AV= 28 cm/s, SD= 16), and had an average Froude number of 0.2 (SD= 0.12). At these flows, the site was composed of 24 HMUs, which were primarily rapids (25%), followed by runs (20.8%), (Appendix 2:18). Fast runs and glides were also present in moderate quantities (16.7% and 12.5%, respectively), as were pools, sidearms and ruffles (8.3% each). Under higher flow conditions (2.08 cfsm), this site was composed of only two HMUs, both of which were ruffles. Under lower flow conditions (0.10 cfsm), both pools and ruffles increased from 8.3 to 14.8%, while fast runs disappeared. Wetted area is 57% at 0.1 cfsm and increases only slightly as flow increases (58% at 0.5 cfsm, 59% at 1.0 cfsm).

3.4.18.2 Habitat for fish

This Management Unit has a moderate level of total suitable habitat, which is highest at low flows (47% WBA at 0.1 cfsm, 33% WBA at 0.5 cfsm, 25% WBA at 1.0 cfsm) (Figure 3.22). Slimy sculpin habitat is highest at low flows, and quickly declines to 0% WBA (23% WBA at 0.1 cfsm, 0% WBA at 0.5 cfsm, 1.0 cfsm). Suitable habitat for blacknose dace is the most abundant. Blacknose dace habitat is highest at the lowest flow, and slowly decreases as flow increases (33% WBA at 0.1 cfsm, 32% WBA at 0.5 cfsm, 24% WBA at 1.0 cfsm). There is no suitable habitat for brook trout in this Management Unit. Suitable habitat for white suckers is fairly low at all flows (7% WBA at 0.1 cfsm, 2% WBA at 0.5 cfsm, 4% WBA at 1.0 cfsm). Longnose dace habitat is low at low flows and increases slightly as flow increases, and then decreases as flows increases further (2% WBA at 0.1 cfsm, 12% WBA at 0.5 cfsm, 9% WBA at 1.0 cfsm). Brown trout habitat increases as flow increases (4% WBA at 0.1 csfm, 18% WBA at 0.5 csfm, 20% WBA at 1.0 csfm). Rainbow trout habitat also increases as flow increases (0% WBA at 0.1 csfm, 15% WBA at 0.5 csfm, 16% WBA at 1.0 csfm). The habitat overlapping factor is relatively similar across many flows; it is 1.4 species per habitat unit at 0.1 and 0.5 cfsm and 1.5 at 1.0 cfsm.

3.4.19 Management Unit 18

This Management Unit stretches from 250 upstream of Park Road to the Chichester Bridge. It has a length of 385 meters, the first half of which is eroded (1000-2757 sq. m in area). This stretch maintains a relatively constant and sizeable distance from Route 214, in contrast to the 1959 stream alignment, which curved much closer to the road towards the middle of the stretch. This unit contains a single clay exposure site at the beginning.

3.4.19.1 Hydro-morphology

This Management Unit is characterized by an abundance of boulders, with shallow margins occurring occasionally. The substrate is largely mega-lithal in character. At flows of 0.27 cfsm, this site was heterogeneous in depth (AD= 28.11 cm, SD= 10.60), fast-flowing (AV= 36.85 cm/s, SD= 17.08), and had an average Froude number of 0.25 (SD= 0.12). At these flows, the site was composed of 10 HMUs, which were primarily runs, rapids and fast runs (20% each) (Appendix 2:19). Glides, pools, sidearms and ruffles were also present in moderate quantities (10% each). Under higher flow conditions (average flow= 1.71 cfsm), this site was composed primarily of ruffles (50%), followed by rapids and sidearms (25% each). Under lower flow conditions (0.10 cfsm), backwaters increased from 0% to 18.8%, and runs more than doubled (from 20 to 43.8%). Pools, sidearms, and fast runs all disappeared under these conditions. Wetted area is 56% at 0.1 cfsm and increases more quickly as with initial increases in flow, but then increases more gradually with further increases in flow (66% at 0.5 cfsm, 68% at 1.0 cfsm).

3.4.19.2 Habitat for fish

This Management Unit has fairly high levels of total suitable habitat (Figure 3.23). Total habitat increase from 38% WBA at 0.1 cfsm to 62% WBA at 0.4 cfsm. As flow increases further, total habitat decreases (61% WBA at 0.5 cfsm, 43% WBA at 1.0 cfsm). Slimy sculpin habitat decreases from 19% WBA at 0.1 cfsm to 6% WBA at 0.2 cfsm, and remains fairly constant as flow increases further. Blacknose dace habitat increases slightly with initial increases in flow, and then decreases as flow increases further (24% WBA at 0.1 cfsm, 32% WBA at 0.5 cfsm, 22% WBA at 1.0 cfsm). There is no suitable habitat for brook trout or white suckers in this Management Unit. Longnose dace habitat is 0% WBA at 0.1 cfsm but rises rapidly to 43% WBA as flow increases to 0.5 cfsm. As flow increases above 0.5 cfsm, suitable habitat levels gradually decrease (31% WBA at 1.0 cfsm). Habitat for brown trout is 0% WBA at 0.1 csfm, but constant at 5-6% WBA at all other flows. Habitat for rainbow trout increases a small amount as flow increases (0% WBA at 0.1 csfm, 3% WBA at 0.5 csfm) and then decreases to 1% WBA at 1.0 cfsm. The habitat overlapping factor is highest at flows of 0.8 and 0.9 cfsm (1.4 species per habitat unit). It is slightly lower at other flows (1.1 at 0.1 cfsm, 1.3 at 0.5 and 1.0 cfsm).

3.4.20 Management Unit 19

This Management Uni stretches from the Chichester Bridge to the upstream end of School Lane. It has a length of 1170 meters, the majority of which runs very close to Route 214, especially for the last 500 meters. One hundred and fifty meters of stream near the upper-middle portion of the stretch is eroded (1000-2757 sq. m erosion area), as is a smaller segment (100-499 sq. m) in the lower-middle portion. A single clay exposure site is located in the same area as the smaller eroded segment; bedrock is abundant throughout the downstream half of the unit.

3.4.20.1 Hydro-morphology

This Management Unit is characterized by an abundance of boulders and shallow margin area, with riprap present in moderate amounts. The substrate is largely mega-lithal in character. This site was mapped on two different days, with an average flow of 0.24 cfsm. Under these flow conditions, the site is heterogeneous in depth (AD= 28 cm, SD= 13) and velocity (AV= 33 cm/s, SD= 17), with an average Froude number of 0.25 (SD= 0.16). It is composed of 60 HMUs, which are predominantly cascades (23.3%), plunge pools (18.3%), and runs (15%) (Appendix 2:20). Glides and pools are also present in moderate quantities (11.7% and 8.3%, respectively). All backwaters disappear under higher flow conditions (average flow = 1.21 cfsm) and cascade presence drops to 3.3%. Under these flows, fast runs appear (3.3%), and rapid and ruffle presence increase considerably (from 6.7 to 20% and 3.3 to 23.3%, respectively). Under lower flow conditions (average flow = 0.12 cfsm), runs almost doubled (29.7%), while both plunge pools and cascades decrease significantly (1.4% and 5.4%, respectively). Wetted area is 57% at 0.1 cfsm and increases steadily as flow increases (68% at 0.5 cfsm, 73% at 1.0 cfsm).

3.4.20.2 Habitat for fish

Total suitable habitat in this Management Unit is fairly constant at slightly greater than 40% WBA at all flows (Figure 3.24). Habitat for slimy sculpin initially decreases as flow increases (23% WBA at 0.1 cfsm, 12% WBA at 0.5 cfsm) and then gradually increases as flow increases further (19% WBA at 1.0 cfsm). The greatest amount of suitable habitat is for blacknose dace, which is highest at low flows and gradually decreases as flow increases (34% WBA at 0.1 cfsm, 28% WBA at 0.5 cfsm, 15% WBA at 1.0 cfsm). There is no suitable habitat for brook trout in this Management Unit. White sucker habitat decreases to 0% WBA at flows between 0.2 cfsm and 0.6 cfsm, and then increases as flow increases (5% WBA at 1.0 cfsm). Longnose dace habitat is slightly higher at moderate flows than at low and high flows (5% WBA at 0.1 cfsm, 14% WBA at 0.5 cfsm, 7% WBA at 1.0 cfsm). Suitable habitat for rainbow trout is minimal (under 1% WBA). Brown trout habitat decreases from 5% WBA at 0.1 csfm to 3% WBA at 0.2 csfm, and then increases slightly as flow increases (3% WBA at 0.5 csfm, 4% WBA at 1.0 csfm). The habitat overlapping factor is highest at lower flows and decreases as flow increases (1.5 at 0.1 cfsm, 1.2 at 0.5 cfsm, 1.1 at 1.0 cfsm).

3.4.21 Management Unit 20

This Management Unit stretches 400 meters, starting at the upstream end of School Lane. The first 100 meters of this unit are in close proximity to Route 214; the remainder of the stretch is considerably further away from the road. The current stream alignment is considerably different from the historical stream alignment for this unit, especially that of 1959; it is now more channelized.

3.4.21.1 Hydro-morphology

This Management Unit contains a large amount of shallow margin area, with boulders and riprap present in moderate amounts. The substrate is a combination of macro- and meso-lithal. At flows of 0.23 cfsm, this site is shallow (AD= 20 cm, SD= 8), fast-moving (AV= 30 cm/s, SD= 10), and has a Froude number of 0.24 (SD= 0.09). At these flows, the site is composed of 13 HMUs, which are primarily riffles and runs (30.8% each), followed by pools (15.4%) (Appendix 2:21). Backwaters, glides, and rapids also occur (7.7% each). Under higher flow conditions (1.08 cfsm), this site is composed of only four HMUs: one glide, one run, one rapid and one ruffle. Under lower flow conditions (0.11 cfsm), ruffles are the dominant mesohabitat (increasing from 0% to 25%), with glides and rapids increasing in relative abundance (16.8% each). Riffle presence, however, decreases (8.3%), while pools completely disappear. Wetted area is 30% at 0.1 cfsm and increases steeply as flow increases (65% at 0.5 cfsm, 88% at 1.0 cfsm).

3.4.21.2 Habitat for fish

This Management Unit has high levels of suitable habitat, especially at high flows (Figure 3.25). Total habitat increases steeply as flow increases (26% WBA at 0.1 cfsm, 65% WBA at 0.5 cfsm, 86% WBA at 1.0 cfsm). Slimy sculpin habitat is abundant, and increases as flow increases (24% WBA at 0.1 cfsm, 25% WBA at 0.5 cfsm, 58% WBA at 1.0 cfsm). Blacknose dace habitat is highest at the middle level flows and lowest at the extreme flows (4% WBA at 0.1 cfsm, 43% WBA at 0.5 cfsm, 7% WBA at 1.0 cfsm). There is no suitable habitat for brook trout in this Management Unit. White sucker habitat is quite high, especially at high flows (1% WBA at 0.1 cfsm, 30% WBA at 0.5 cfsm, 58% WBA at 1.0 cfsm). Longnose dace habitat is highest at the middle level flows (0% WBA at 0.1 cfsm, 20% WBA at 0.5 cfsm, 3% WBA at 1.0 cfsm). There is no suitable habitat for brown trout or rainbow trout in this Management Unit. The habitat overlapping factor is highest at 0.3-0.5 cfsm (1.8 species per habitat unit) and lowest at 0.1 cfsm (1.1 species per habitat unit); it decreases slightly at flows higher than 0.5 cfsm (1.5 at 1.0 cfsm).

3.4.22 Management Unit 21

This Management Unit begins 500 meters upstream of School Lane and continues to the watershed boundary. It is 1375 meters long and runs very close to Route 214 for the majority of its length. Some bedrock is present near the top of the stretch, and a bridge is present near the bottom, where the creek is crossed by Main Street.

3.4.22.1 Hydro-morphology

This site is characterized by an abundance of boulders and shallow margin area, with overhanging vegetation and canopy cover shading present in small amounts. The substrate is a combination of macro- and mega-lithal. At flows of 0.23 cfsm, this site is shallow (AD= 22 cm, SD= 10), and somewhat fast-flowing (AV= 30 cm/s, SD= 19) with an average Froude number of 0.23 (SD= 0.16). At these flows, the site is composed of 34

HMUs, which are primarily runs (23.5%), ruffles (17.7%), and rapids (14.7%) (Appendix 2:22). Pools and rapids are also present in moderate quantities (8.8% each). Under higher flow conditions (1.08 cfsm), this site is composed primarily of riffles and ruffles (25% each), followed by rapids (16.7%). All backwaters, pools, and cascades disappear. Under lower flow conditions (0.10 cfsm), backwaters become the dominant mesohabitat, increasing from 5.9% to 21.6%. Runs, however, decrease slightly (17.7%) and fast runs disappear. Wetted area is 35% at 0.1 cfsm and increases gradually as flow increases (42% at 0.5 cfsm, 43% at 1.0 cfsm).

3.4.22.2 Habitat for fish

This Management Unit has low levels of total suitable habitat at middle flows, but habitat levels gradually increase as flows decrease or increase (28% WBA at 0.1 cfsm, 16% WBA at 0.5 cfsm, 32% WBA at 1.0 cfsm), (Figure 3.26). Slimy sculpin has the largest amount of suitable habitat, especially at high flows (18% WBA at 0.1 cfsm, 8% WBA at 0.5 cfsm, 29% WBA at 1.0 cfsm). Blacknose dace habitat is highest at low and high flows and decreases at moderate flows (18% WBA at 0.1 cfsm, 5% WBA at 0.5 cfsm and 1.0 cfsm). Brook trout habitat is only available at 0.1 cfsm and is present in very low quantities (3% WBA). White sucker habitat is minimal at low and middle flows, but increases at higher flows (1% WBA at 0.1 cfsm, 0% WBA at 0.5 cfsm, 11% WBA at 1.0 cfsm). Habitat for longnose dace is highest at 0.1 cfsm (11%) and is fairly low and constant at all other flows (about 3% WBA). Habitat for brown trout and rainbow trout is 0% WBA at 0.1 csfm and is constant at about 3% WBA at higher flows. The habitat overlapping is highest at 0.1 (1.8 species per habitat unit). It fluctuates between 1.4 and 1.7 at other flows.

4 DISCUSSION

4.1 Target Community

We evaluated three possible target fish community structures for the Stony Clove: one based on historical data from seven streams in the Hudson River watershed, another based upon 2002 data collection in 28 Beaver Kill tributaries, and a third drawn from historical data collected from Stony Clove Creek. Due to the Catskill Region's long history of management and human use, available fish data does not date back early enough to describe a period when the Stony Clove and/or surrounding streams were unimpaired. We therefore initially considered all three of the possible target communities to be equally viable options.

The target community based on the Hudson watershed has the highest affinity to that observed during the 2002 Stony Clove fishing survey (73%). Both communities have abundant populations of slimy sculpin. The largest population difference is in longnose dace abundance; the Stony Clove had three times the proportion of this species in comparison to the target community. Furthermore, the Hudson River watershed community suggests that brook trout should be twice as abundant as was observed in the Stony Clove. White sucker are also underrepresented in the Stony Clove.

Current Stony Clove data has only a 52% affinity to the target community established from the Beaver Kill watershed data. The target community structure calls for high brook trout abundance (34%), but brook trout comprise only 3% of the observed Stony Clove community. Similarly, slimy sculpin comprises 17% of the total Beaver Kill community, yet this is half the population size found in the Stony Clove (32%). Longnose dace proportion in the Stony Clove is also more than twice that of the target community.

The target community established with the historic and current Stony Clove data are quite different from present fauna composition (56% affinity). Slimy sculpin, which is currently the most common species in the Stony Clove, should only comprise in 8% of the fish community, according the historic model. In contrast, white sucker is the most common species in the model (31%), but it has an abundance of only a tenth of that (3 %). The expected values for brook trout are very low, although still twice the size of what was observed (5%).

In comparisons to all of the target communities, the present-day Stony Clove consistently shows an under representation in brook trout (less than half the size of the target communities). White sucker are also slightly underrepresented, while longnose dace are slightly overrepresented.

4.2 Fish Abundance

Slimy sculpin is currently most common fish species in the Stony Clove, comprising one third of the fish community. This is followed by brown trout and both dace species. Of the 1839 fish collected, however, only 46 were brook trout or white sucker, indicating that both species make up only a small percentage (3%) of the community.

The historical data from the Stony Clove (from 1957, 1959 and 1989) sharply contrast that observed during our 2002 fishing survey. White sucker, rainbow trout, blacknose dace, and brown trout were the most common species the historic Stony Clove. Slimy sculpin, which is the most frequently occurring fish in the Stony Clove today, comprised less than 0.2% of the historic population. These differences could quite possibly be due to differences in sampling methods and equipment, as the historic data suggests a focus on large fish and sport fish. Even with these differences, however, historic records also contain very few brook trout.

The data we collected from the Stony Clove is similar to the data collected from the five streams within the Beaver Kill watershed (Round Out, Stewart Brook, Spring Brook, Trout Brook, and Willowemoc); although, fish density in the Stony Clove was only half of the density found in the other streams. Both surveys identified slimy sculpin as the most abundant species and showed low abundances for both brook trout and white sucker. We collected more blacknose dace than longnose dace in the Beaver Kill tributaries, however, which was the opposite of what we observed in the Stony Clove. This could be due to the fact that longnose dace is well-adapted to high flow velocities and typically inhabits the more central regions of rivers, and that the Stony clove has more run type habitats with higher flow velocities.

Under the investigated conditions, the Stony Clove has a large amount of shallow margins, which should provide good nursery habitat. This is reflected by the high numbers of juvenile fish (especially trout) recorded during the survey.

We also compared our data to that obtained from another electro-fishing study conducted on the Stony Clove by Bary Baldigo of the USGS (See Appendix 5).

4.3 Trout Analysis

We compared the age structures of brook, rainbow, and brown trout to investigate possible reasons for the under-representation of brook trout and the high abundances of brown and rainbow trout in the Stony Clove (Figure 4.1a & 4.1b). When divided into age classes, brook trout is the only species that follows a normal population distribution; brook trout numbers decrease with increasing age while rainbow and brown trout peak at an age level of 1-2 years. The further delineation of age classes indicates an abundance of brown and rainbow trout between 120 mm and 180 mm long. This population peak is most likely due to the stocking of fish for commercial purposes, thus explaining their high levels. The scarcity of individuals older than two years suggests that the majority of these fish do not survive the winter. This is supported by other studies that have investigated stockfish survivals (Weiss and Schmutz, 1999).

In order to investigate competition between brown and rainbow trout and brook trout, we created an additional logistic regression model for brook trout, entering presence of both introduced species as an independent variable. While brook trout are unaffected by rainbow trout, the model selected brown trout as a significant attribute and associated a negative regression value with the presence of this species (Table 2.5). The model has a high predictive value. Considering that brown trout is known to be a more aggressive species than brook trout, it is reasonable to conclude that brown trout out-competes brook trout (Fausch and White, 1981).

4.4 Habitat Assessment

4.4.1 Management Unit 1

This Management Unit is dominated by riffles and rapids and is shallow with relatively fast, diverse flow velocities. At very low flows, the wetted area is only a third of the bankfull area, but then increases steadily with flow to almost bankfull. At the lowest flow, almost the entire wetted area is suitable for the target community. This proportion then declines with increasing flows to a little over half. Slimy sculpin habitat fills the entire wetted area at 0.1 cfsm and then declines slowly. Blacknose dace habitat is about half as large as slimy sculpin habitat for low flows, but then increases toward the same level as slimy sculpin at higher flow. White sucker follow the same trend as blacknose dace, with a minimum around 0.5 cfsm. Brook trout habitat steadily declines with increasing flows and longnose dace has barely any habitat. Overall, the habitat conditions are relatively stable. Of all the investigated species, brook trout has the greatest disadvantage; it is one of the largest and most mobile species and also has very low levels of suitable habitat present, which decline with flow. Even at very low flows that could provide more habitat, the rising temperature poses serious limitations for brook trout. Interestingly, brown and rainbow trout do not have much prime habitat ($p>50\%$), but the amount of low quality habitat ($p= 20\%-50\%$) is still substantial (Appendix 4:1).

4.4.2 Management Unit 2

This unit is comprised largely of cascades and has some riprap, woody debris, and canopy cover. It is a shallow area with relatively fast, but varying velocities. At very low flows, the wetted area is half the size of the bankfull area and increases steadily to 90% of bankfull at 1.5 cfsm. At the highest measured flows, the size of the management unit increases only laterally, not lengthwise. The overall habitat increases gradually until mid-flows, when it then declines. The largest amount of habitat is available for blacknose dace, whose rating curve increases steeply at low flows and then gradually declines. The amount of habitat considered to be excellent for slimy sculpin declines sharply with flow. White sucker and longnose dace have relatively stable, moderate levels of habitat available. With the exception of lowest flows, no habitat is available for brook trout. Rainbow and brown trout have only low levels of habitat available (Appendix 4:2).

4.4.3 Management Unit 3

This unit is dominated by runs and contains several bedrock areas with boulders, large substrate, and some woody debris. It is slightly deeper and faster than Unit 2. At very low flows, the wetted area is half the size of bankfull; this proportion increases steadily to 80% of bankfull at higher flows. At all flows, 80% of the wetted area is prime habitat. The habitat level for all species peaks between 0.5 cfsm and 1.0 cfsm and is relatively stable. The unit has a medium amount of habitat available for slimy sculpin and blaknose dace. The other three species from the target community have habitat levels that comprise less than 15% of the bankfull area. Brown and rainbow trout have more habitat at higher flow levels (Appendix 4:3).

4.4.4 Management Unit 4

This unit runs close to Route 214 and is dominated by shallow runs, riffles, and rapids that include an abundance of boulders. At all flows, the wetted area covers a large portion of bankfull width and has a steadily increasing trend towards 95%. Around 80% of the wetted area is highly suitable for fish. The habitat conditions for all species are relatively stable across the investigated range. The majority of the area is suitable for slimy sculpin and blacknose dace. The habitat levels for brook trout and white sucker are constantly very low. Again, brown and rainbow trout do not have much prime habitat ($p>50\%$), but the amount of low quality habitat ($p= 20\%-50\%$) is still substantial (Appendix 4:4).

4.4.5 Management Unit 5

This unit runs between two roads and consists mostly of fast flowing, shallow habitats (riffles, glides and rapids) with lots of boulders, but almost no woody debris. It is only about half of bankfull across all measured flows, with a slight increase with flow. Therefore, as flow increases, it becomes mostly deeper and faster, turning into runs. The hydro-morphological units are also larger than those in Unit 4. Nevertheless, the overall habitat (as well as habitat for slimy sculpin) stays at a constant level, covering the majority of wetted area. As flows get faster, the habitat becomes less suitable for blacknose dace. White sucker and brook trout habitat stay at very low levels, though the latter’s habitat increases slightly at flows close to 0.6 cfsm. Similar to previous sections, brown and rainbow trout have very little prime habitat, but plenty of low quality habitat available (Appendix 4:5).

4.4.6 Management Unit 6

The upper portion of this unit runs very close to the road, but then veers away in the lower half. Since the creek moves away from the road, the impact of road stabilization cannot be determined. The *unit* consists mostly of fast-flowing, shallow habitats (riffles and rapids) with boulders, shading, and woody debris. The wetted area increases from 40% to 80% of bankfull with an inflection point near 0.5 cfsm. The majority of wetted area is highly suitable for fish. The overall suitable habitat level increases strongly before flows reach 0.7 cfsm and then gradually declines. For the majority of species, the habitat increases strongly between flows of 0.2 and 0.4 cfsm, though white sucker and slimy sculpin habitat has a peak a little after 0.45 cfsm. Brook trout habitat stays relatively constant at a 10% level. Brown and rainbow trout habitat strongly increases at higher flows (Appendix 4:6).

4.4.7 Management Unit 7

This unit runs between two roads. It is shallow and slightly faster than Unit 6, consisting mostly of fast-flowing habitats (riffles and runs) with numerous shallow margins. The habitat changes into mostly fast runs when flow increases. At flows between 0.1 cfsm and 0.4 cfsm, the wetted area increases dramatically from about 40% to 80% of the bankfull area. Following this increase, the wetted area remains constant. Almost the entire wetted area is suitable for the target fauna, but mainly for slimy sculpin. Again, sculpin habitat emulates the overall habitat-rating curve and declines above 0.6 cfsm. With the exception of brook trout, other species' habitat levels are moderate, peaking around 0.5 cfsm, then declining toward zero at 1.0 cfsm. There is no prime habitat for brook trout in this unit. Even brown and rainbow trout do not have much habitat available (Appendix 4:7).

4.4.8 Management Unit 8

This unit runs between two roads and is shallow and faster than the unit upstream. It consists mostly of fast-flowing shallow habitats (riffles and runs) with many shallow margins. The dominant substrate in this unit is smaller in size than that in Unit 7. It changes into mostly fast runs and ruffles when flow increases. At mapped flows, the wetted area increases from 30% to 70% of the bankfull area, with an inflection point between 0.4 cfsm and 0.8 cfsm. At this point, the overall habitat begins to decline. Almost the entire wetted area is suitable for the target fauna at low flow. Slimy sculpin, blacknose dace, and longnose dace have the best habitat conditions under these circumstances. Interestingly, the levels of suitable habitat for blacknose and longnose dace cross at higher flows. White sucker habitat peaks between 0.4 cfsm and 0.8 cfsm and then proceeds to decline towards zero. Again, brook trout has very low habitat levels in this unit, even low quality habitat is scarce. Brown and rainbow trout have very low levels of excellent habitat and moderate levels of usable habitat (Appendix 4:8).

4.4.9 Management Unit 9

This unit contains boulders, a little overhanging vegetation, and substrate that is small in size. At investigated flows, the water covers from 55% to 80% of the bankfull area. Wetted area increases steadily as flow increases, but hydro-morphological units change dramatically. This is reflected in the strong habitat suitability changes for individual species across the flows, even though the overall amount of habitat stays constant. Slimy sculpin loses habitat and then gains it back at higher flows. Both dace species and white sucker species show habitat increases until 0.3 cfsm, and then a complete loss above 1.0 cfsm. Brook trout has very little habitat except at very low flows, however, this habitat is probably useless due to thermal reasons. The brown trout has low levels of poor habitat and only rainbow trout shows a significant increase in habitat suitability at higher flow levels. Overall, this unit has poor habitat conditions due to constant hydro-morphological fluctuations and a lack of permanent available habitat (Appendix 4:9).

4.4.10 Management Unit 10

Since this unit is channelized, increasing flow creates slight increases in wetted area and strong changes in hydro-morphology. The substrate found in this unit is smaller in size than that found upstream. Some debris and shallow margins are present. The wetted area increases sharply until 0.4 cfsm, where it stays constant at a 70% level. The fluctuations in habitat levels are less dramatic than those found in Unit 9, excluding flows at 1.2 cfsm. HMU's are fewer and bigger. Both dace species and white sucker lose their habitat with increasing flow. Brook trout habitat is very low whereas the remaining two trout species have some usable habitat available (Appendix 4:10).

4.4.11 Management Unit 11

This Management Unit is located very close to the road. The habitat pattern is somewhat similar to Management Units 9 and 10, along with extensive shallow margin areas and some riprap. At the lowest flows, a little more than half of the bankfull area is covered with water. The rating curve increases steadily to 70%, with an inflection point around 0.3 cfsm. At 1.2 cfsm, the HMU's are bigger, but the overall habitat stays relatively constant. Slimy sculpin habitat is abundant, with a little loss around 0.3 cfsm. Blacknose dace habitat, in contrast, peaks around 0.5 cfsm and then declines. Longnose dace habitat declines slowly and white sucker habitat stays constant, declines slowly, and then levels out again. Brook trout habitat is almost non existent, but the other two trout species have some usable habitat available (Appendix 4:11).

4.4.12 Management Unit 12

This Management Unit has the highest diversity of hydro-morphologic units at 0.3 cfsm. As flow changes, the size and location of the units change, but dominant types (ruffle, rapid run) stay the same. Shallow margins are abundant throughout the site, followed by boulders. The wetted area almost doubles between flows of 0.1 cfsm and 0.3 cfsm and then stays constant, though with less and faster units. Suitable habitat within this unit is relatively high. Slimy sculpin habitat lowers at around 0.3 cfsm, and then increases with flow. Blacknose dace and white sucker habitat peak before 1.0 cfsm and then declines. Longnose dace has some low quality habitat at low flows and then disappears by 1.0 cfsm. Habitat for trout species is either unavailable or very poor (Appendix 4:12).

4.4.13 Management Unit 13

This Management Unit is located very close to the road and has a habitat pattern somewhat similar to both Units 11 and 12, although more glides appear. At lower flows, a little more than half of the bankfull area is covered with water, with extensive shallow margin areas and some riprap. As the hydro-morpholgic units decrease in number and enlarge when approaching 1.0 cfsm, wetted area approaches bankfull area quickly, but then gradually increases after 0.3 cfsm. The proportion of suitable area reaches its peak around 0.35 cfsm and then declines substantially with increasing flows. The curve for slimy sculpin reflects the overall habitat-rating curve with a peak around 0.35 cfsm. Blacknose dace and white sucker start at stable habitat levels, but then lose all habitat by 1.0 cfsm. Longnose dace habitat is also at low levels, but declines much slower. Brook trout habitat increases to almost 10% around 0.5 cfsm, but then also declines to zero. The other two trout species have a negligible amount of usable habitat available (Appendix 4:13).

4.4.14 Management Unit 14

This Management Unit has an abundance of shallow margins and should therefore offer good nursery habitat. It also offers some glides along with faster types of units at flows under 1.0 cfsm. With a flow increase above 1.0 cfsm, however, it turns into sizeable ruffle-run sequences only. The wetted area covers from one-third to two-thirds of bankfull, but the largest increase in wetted area is between flows of 0.1 cfsm and 0.3 cfsm. This causes a quick increase in suitable habitat area for low flows with a gradual decline afterward. Slimy sculpin and blacknose dace have similar levels of habitat with a peak between 0.3 cfsm and 0.8 cfsm and then a gradual decline. Longnose dace and white sucker have half as much habitat available than the other two species with a decline above 0.3 cfsm. Brook trout has no habitat available and the other trout species only have low probability areas. Low flows create twice as many habitat overlaps as higher flows (Appendix 4:14).

4.4.15 Management Unit 15

This Management Unit has numerous boulders, shallow margins, good canopy cover shading, and some riprap. Like Unit 14, only two-thirds of bankfull area is covered with water and the wetted area increases quickly between 0.1 cfsm and 0.3 cfsm. Suitable habitat also increases in this range, but it then drops to zero after 1.0 cfsm for all species. This situation could indicate low-flow channel entrenchment. Slimy sculpin and blacknose dace have the highest habitat levels. Brook trout habitat is concentrated in one run and sidearm, with some small usable areas in cascade regions. Brown and rainbow trout also show higher amounts of habitat availability, especially at 0.3 cfsm. Nevertheless, strong habitat declines for these two species at higher flows make the habitat much less sustainable and could possibly suppress the population (Appendix 4:15).

4.4.16 Management Unit 16

This Management Unit is much deeper and somewhat faster than the other units, with highly diverse hydraulics. Boulders are abundant and no shallow margins exist. Wetted area covers 80% of bankfull area and increases constantly with flow. This unit, like Unit 15, possesses a steep, entrenched channel, where habitat becomes faster and more uniform in response to flow increases beginning at 0.1 cfsm. This is reflected in the habitat, which supports only blacknose dace and slimy sculpin at the lowest observed flows. Even habitat for these species falls to zero with increasing flows, however. Rainbow and brown trout have only minute amounts of suitable habitat. Barely any habitat overlaps exist in this unit. This unit represents the worst conditions in the entire study area (Appendix 4:16).

4.4.17 Management Unit 17

This Management Unit has an abundance of riprap and boulders with some shallow margins. It is slower and a little shallower than Unit 16. Wetted area covers only 60% of the bankfull area at all investigated flows. At higher flows, this unit turns mostly into rapids and ruffles. The amount of habitat is therefore low and favors blacknose dace, whose habitat declines as flow increases. Slimy sculpin has predominantly low-quality habitat, as is the case with longnose dace, which still has more habitat than in Unit 16. Habitat is very low for white sucker and non-existent for brook trout. Interestingly, rainbow and brown trout have the more high-quality habitat in this unit than anywhere else, owing perhaps to the presence of deep pools scoured into the clay subpavement (Appendix 4:17).

4.4.18 Management Unit 18

This Management Unit has many boulders and some shallow margins. It is a little shallower, but faster, than Unit 17. Wetted area covers only 55%-70% of the bankfull area at all investigated flows, with inflection point near 0.3 cfsm. This unit is comprised primarily of rapids and runs that turn into ruffles and rapids at higher flows. The overall habitat increases toward total wetted area until around 0.3 cfsm, from which point it declines steadily. The best habitat conditions are for longnose dace, followed by blacknose dace. This unit has the highest habitat levels for longnose dace. All other species have sparse suitable habitat. As is the case for other management units, brown and rainbow trout have some low-quality habitat available (Appendix 4:18).

4.4.19 Management Unit 19

This Management Unit runs close to the road and has large substrate with boulders, bedrock, some shallow margins, and riprap. Water here is somewhat slower than in Management Unit 18. Wetted area covers about 60% of bankfull area at low flows and increases to 80% at high flows in the lower portion of the unit. It has a variety of HMUs, which change frequently with flow. In comparison to Unit 18, the hydro-morphology here is not as uniform under higher investigated flows. This is reflected in the presence of relatively consistent levels of suitable habitat that vary for the species, but not for the community. Blacknose dace and slimy sculpin have the highest amounts of suitable habitat available, but at different flow conditions. The same opposing trend appears between longnose dace and white sucker. Of the trout species, habitat only exists for brown trout, and in minimal quantities. The overlapping factors are low (Appendix 4:19).

4.4.20 Management Unit 20

This Management Unit is channelized with riprap, boulders, and numerous shallow margins. It is much shallower than Unit 19 and is fast, with little hydraulic diversity. Wetted area increases from 30% to 90% of bankfull with increasing flow. Nevertheless, the HMU's become much larger above 1.0 cfsm. The habitat for slimy sculpin and white sucker increases rather constantly with flow. Similar to Unit 19, both dace species experience a reduction in habitat quality at higher flows, and have the best habitat between 0.3 cfsm and 0.6 cfsm. None of the salmonids have excellent habitat available, although brown and rainbow trout have some low-quality habitat available (Appendix 4:20).

4.4.21 Management Unit 21

This Management Unit has boulders and large amounts of shallow margins, but very little shading and overhanging vegetation. The substrate is large and the average hydraulic conditions are similar to those of Unit 20 but have a little higher velocity variability. Wetted area covers less than half of the bankfull area and stays relatively constant. The HMUs become much larger above 1.0 cfsm but are still highly variable. The community habitat-rating curve shows a trend that is unlike anywhere else upstream. This is attributed to the curve being dominated by slimy sculpin that, like in Unit 20, have their lowest habitat levels at around 0.3 cfsm. White sucker also contribute to the unique trend by having more habitat available at higher flows. As flow increases, blacknose dace habitat declines and longnose dace has only very low levels of habitat available. The introduced trout species have small amounts of excellent habitat available; no brook trout habitat is available at this site (Appendix 4:21).

4.4.22 Study area

The habitat conditions for the entire study area depict the river as, for most part, very shallow and fast. It is dominated by runs and riffles at low flows, which are then replaced by rapids and ruffles at flows in the higher end of the investigated range. Pools are found infrequently. Side arms, backwaters, islands, and plunge pools also have a very low occurrence. Though there is a significant presence of boulders, shading, and shallow margins, there is relatively little woody debris and overhanging vegetation.

At a large scale, the habitat conditions seem to be stable across the investigated flows, favoring slimy sculpin and blacknose dace. While blacknose dace habitat peaks at low flows, slimy sculpin habitat is high at both lower and higher flows; sculpins have the least amount of habitat at 0.5 cfsm. Longnose dace and white sucker have similar habitat curves with medium amounts of habitat. All trout species have a very low level of excellent habitat, although brown and rainbow trout have substantial amounts of moderate-quality habitat. The MesoHABSIM model evaluation performed on the Quinebaug River indicated that resilient species will use habitat with lower probabilities of presence if no better habitat is available, albeit in lower densities.

Although many of the sites provide a relatively constant amount of habitat across different flows, certain stretches exhibit a much higher flow-dependent variability in habitat levels. This situation is most frequently associated with high entrenchment, which does not allow wetted area to increase and leads to increased water velocities and depth (Figure 2.4). This phenomenon is manifested as a steady slope on wetted area curves. In these situations, habitat levels often decline dramatically with increases in flow, allowing for only a low-flow use of suitable areas. The analysis of management units from the habitat-fluctuations perspective reveals some general tendencies: 1) in the upper units, habitat conditions are the most stable, 2) wetted area increases steadily and habitat levels do not decline substantially. Beginning with Management Unit 6, it is common to see wetted areas increasing steadily only over a portion of the range of investigated flows.

Otherwise, wetted area remains almost constant at the higher end, causing a fluctuation and decline in habitat areas. In Units 19-21, the habitat pattern changes, offering more habitat area for slimy sculpin and white sucker at the higher flows.

A comparison of suitable area at various flows indicates that the habitat structure at 1.0 cfsm closely reflects the Hudson River target community (89% affinity). Furthermore, brook trout habitat is very low at this flow level (3%) as seen in Figure 4.2.

4.5 Modeling of brook trout habitat

One of the most apparent findings from this study is the overall deficit of suitable habitat for brook trout, which is one of the five target community species. Although the model target community indicates that brook trout should comprise 14% of the Stony Clove's fish population, our findings show that less than 5% of the wetted area is suitable for brook trout. To search for habitat conditions that support brook trout, we analyzed characteristics of all HMU's that were predicted to have excellent habitat for this species. Out of 1766 mapped units, 95 have probabilities of fish presence/abundance higher than 50%. Of these units, there are 39 riffles, 15 runs, 13 pools, 11 glides, 5 side arms, 3 plunge pools and ruffles, 2 fast runs, and one rapid. The most common characteristics of riffles are shallow margins and canopy shading. More than half of them also have woody debris and boulders. Depths are under 50 cm and velocities are under 45 cm/s. Runs have primarily shading and shallow margins, with some boulders and woody debris. Depth is below 50cm and velocity below 75 cm/s. Pools have abundant woody debris and shallow margins. Boulders, shading, undercut banks, and overhanging vegetation also occur sporadically. Depths are less than 60 cm. Glides have frequent shallow margins, woody debris, canopy shading, and boulders. Depths here are below 50 cm; velocities are less than 45 cm/s.

To further analyze brook trout habitat deficits, we compared habitat characteristics of areas in Management Unit 20 where no brook trout habitat existed to those of the areas with the same HMU type, where there was some expected brook trout habitat. A comparison of riffles shows that in contrast to HMUs with brook trout habitat, habitat without brook trout had higher velocities, no shading, and no woody debris. Runs without brook trout habitat did not contain shading, woody debris, or boulders. They were also shallower and faster that runs considered suitable for brook trout. Pools had no woody debris or shading, and were shallower and faster; glides lacked both woody debris and shading and were slower than the HMUs with brook trout habitat.

The results of these analyses can be useful in restoration planning and design. To analyze the extent to which these features affect the presence of brook trout habitat, we modified our data to simulate large amounts of woody debris, boulders, and shading. The graph in Figure 4.3 shows that habitat for brook trout would increase dramatically under these conditions, reaching almost 50% of WBA. Habitat levels would still decrease at flows above 1.0 cfsm, by which point all riffles and pools in the management unit would have turned into glides, runs, or ruffles. Brook trout habitat levels at this flow could be improved by adding pool and riffle sections (e.g. wider, irregular rock ramps, with substrate ranging from akal to macrolithal). The hydro-morphological criteria for these features are well defined and any hydrodynamic model can be applied to properly design the geometry of these HMUs. The brook trout response functions presented earlier in the report could be modeled iteratively to compare various design alternatives, and to target which management units will yield the greatest overall improvement to trout habitat with a specified management effort.

5 CONCLUSIONS

One of the primary conclusions we can make from the above analysis is that Stony Clove habitats are currently too shallow and fast-flowing to support the target community. Only about 10% of the mapped units were pools. Considering the highly dynamic hydro-morphological nature of the lower portion of the stream, one would expect to observe more sidearms and backwaters in this area. As flows increase, the occurrence of rapids increases disproportionally. The downstream-declining wetted-to-bankfull ratio could indicate system incision, producing sudden and dramatic flow fluctuations and the increasing entrenchment of the low-flow channel.

As some studies have shown, the availability and persistence of habitat over the course of a given season are important in maintaining healthy fauna (Freeman et al. 2001) In the Stony Clove, overall habitat area seems to be relatively stable across flows. Habitat conditions are best for slimy sculpin, followed by blacknose dace. White sucker and longnose dace habitat stays at similar levels. Excellent trout habitat is scarce at all flows, although brown trout and rainbow trout have substantial amounts of low-quality habitat at a wide range of flows. While brook trout habitat is extremely limited, regardless of flow, any brook trout habitat that does occur tends to be excellent. Generally speaking, the relative abundance of the species captured in Stony Clove corresponds well with the present habitat structure (Figure 5.1), although the fish densities we observed during our survey of the Stony Clove were much lower than those from our surveys of Beaver Kill watershed streams.

A more detailed analysis of the management units shows substantial flow-related habitat fluctuations, especially units downstream of Management Unit 9. In these areas, flows frequently increase to 1.0 cfsm (which is still in the range of low flows), which often reduces habitat availability to zero. This is most likely the consequence of river channelization and overall entrenchment, which cause fast-flowing, uniform hydromorphology at higher flows. These areas therefore have the highest restoration potential.

The relative distribution of habitat for each species corresponds relatively well with the structure of the target communities, except for in the case of brook trout, which shows clear habitat deficits. Additional simulations indicated that increased amounts of woody debris, shading as well as boulders, would improve brook trout habitat immensely.

The target community established using historical data collections from the seven tributaries in the Hudson River watershed most closely represents the fish fauna observed in Stony Clove creek. When used as a base line, it clearly distinguishes brook trout and white sucker as underrepresented species, and longnose dace as an overabundant species. Observed blacknose dace and slimy sculpin abundances are close to expected proportions.

In contrast to brook trout, brown trout and rainbow trout occur in high numbers, although the age structure of these species clearly indicates that the majority of the collected individuals are yearling stockfish. This age distribution indicates that the majority these fish do no survive the winter.[4] The age structure of brown trout also shows large numbers of young-of-the-year fish, which is likely the result of the great frequency of shallow margins.

Our model also shows that brown trout negatively influence the habitat availability for brook trout, a phenomenon which could serve to further suppress the native trout population. Although Weiss and Schmutz showed that hatchery fish tend to be temporary fixtures in a system, and therefore do not generally affect the resident population of same species in a stream, our study suggests that the stocking of one species may, in fact, affect the survival of other resident fish species. In the Stony Clove, habitat availability for brook trout is already limited; stocking aggressive exotics could therefore put additional strains on their population. The preferential restoration of brook trout habitat could increase the resilience of native fauna, however, thereby reducing the degree to which stocking damages the ecological integrity of the system and improving brook trout conditions while posing no threat to stocked sport fish.

[4] Whether this is because the generally low-quality habitat for trout species provide them with only enough area to survive the summer, or whether they are fished out is a question that might be answered through a kreel survey.

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HMU	**Description**
Riffle	Shallow stream reaches with moderate current velocity, some surface turbulence and higher gradient. Convex streambed shape.
Rapid	Higher gradient reaches with faster current velocity, coarser substrate, and more surface turbulence. Convex streambed shape.
Ruffle	Dewatered rapid in transition to either run or riffle.
Cascade	Stepped rapids with very small pools behind boulders and small waterfalls.
Glide	Moderately shallow stream channels with laminar flow, lacking pronounced turbulence. Flat streambed shape.
Run	Monotone stream channels with well determined thalweg. Streambed is longitudinally flat and laterally concave shaped.
Fast run	Uniform fast flowing stream channels.
Pool	Deep water impounded by a channel blockage or partial channel obstruction. Slow. Concave streambed shape.
Plunge pool	Where main flow passes over a complete channel obstruction and drops vertically to scour the streambed.
Backwater	Slack areas along channel margins, caused by eddies behind obstructions.
Side arm	Channels around the islands, smaller than half river width, frequently at different elevation than main channel.

Table 2.1 Definitions of hydromorphologic units (HMU) (mod. from Bisson & Montgomery 1996 and from Dolloff et al. 1993).

Attribute	Mapped (or measured) categories	Value in data base	Used for regression calculation
Hydro-morphological units	(see table 2.1)	(yes/no)	(see table 2.1)
Cover sources	broken water surface, undercut bank, woody debris, overhanging vegetation, submerged vegetation, boulder, riprap, canopy cover shading	(no/some/much)	undercut bank, woody debris, overhanging vegetation, submerged vegetation, boulder, riprap, canopy cover shading
Shore line	Land use, development, stabilization shallow margin	(yes/no)	shallow margin
Choriotop	Pelal, psamal, akal, micro-lithal, meso-lithal, macro-lithal, mega-lithal, phytal, xylal, sapropel, detritus (for exact definitions see Austrian Standard ON6232)	dominant type and type in seven random samples	% of random samples in each category
Depth	(cm)	seven random samples, mean, standard deviation	% of random samples in 6 classes in 25 cm increments (range 0 – 125 cm and above)
Mean column velocity	(cm/s)	seven random samples, mean, standard deviation	% of random samples in 8 classes in 15 cms^{-1} increments (range 0 – 105 cms^{-1} and above)
Froude number	calculated	seven random samples, average, standard deviation	average

Table 2.2 Physical attributes used to describe mesohabitat.

Nomenclature	grain size range	description of choriotope
Abiotic choriotopes		
megalithal	> 40 cm	upper sides of large cobbles and blocks, bedrock
macrolithal	> 20 cm to 40 cm	coarse blocks, head-sized cobbles, variable percentages of cobbles, gravel and sand
mesolithal	> 6.3 cm to 20 cm	fist to hand-sized cobbles with a variable percentage of gravel and sand
microlithal	> 2 cm to 6.3 cm	coarse gravel, (size of a pigeon egg to child's fist) with percentages of medium to fine gravel
akal	>0.2 cm to 2 cm	fine to medium-sized gravel
psammal	0.063 mm to 2 mm	sand
pelal	< 0.063 mm	silt, loam, clay, and sludge
Biotic choriotopes		
detritus		deposits of particulate organic matter; distinguished are: CPOM (coarse particulate organic matter), as eg fallen leaves, and FPOM (fine particulate organic matter)
xylal		tree trunks (dead wood), branches, roots, etc.
sapropel		sludge
phytal		submerged plants, floating stands or mats, lawns of bacteria or fungi, and tufts, often with aggregations of detritus, moss or algal mats (interphytal: habitat within a vegetation stand, plant mats or clumps)
debris		organic and inorganic matter deposited within the splash zone area by wave motion and changing water levels, eg mussel shells, snail shells

Table 2.3 Natural choriotop-types of the river bottom (modified from ON M6232).

Management Unit	Site	Date	DIS-CHARGE (cfs)	Avg Flow (cfsm)
mu1		9/3/2002	5.3	0.15
		8/28/2002	4.4	0.13
		7/3/2002	20	0.57
		5/14/2003	78	2.22
mu2	2a	9/3/2002	4.4	0.13
		9/3/2002	5.3	0.15
		5/14/2003	78	2.22
	2b	9/5/2002	5.6	0.16
		9/3/2002	4.4	0.13
		7/8/2002	14	0.40
		5/15/2003	76	2.17
mu3	3a	9/5/2002	5.6	0.16
		7/8/2003	14	0.40
		5/15/2003	76	2.17
	3b	8/16/2002	4.6	0.13
		10/1/2002	14	0.40
		6/18/2002	68	1.94
	3c	8/16/2002	4.6	0.13
		8/26/2002	4.8	0.14
		7/8/2003	14	0.40
		6/19/2002	73	2.08
mu4	4a	8/27/2002	4.5	0.13
		8/26/2002	4.8	0.14
		7/8/2002	14	0.40
		7/9/2002	13	0.37
		6/19/2002	73	2.08
	4b	9/13/2002	4.3	0.12
		7/9/2002	13	0.37
		7/10/2002	13	0.37
		6/20/2002	47	1.34

Management Unit	Site	Date	DIS-CHARGE (cfs)	Avg Flow (cfsm)
mu5	5a	9/17/2002	5.8	0.17
		9/13/2002	4.3	0.12
		7/11/2002	12	0.34
		7/10/2002	13	0.37
		6/20/2002	47	1.34
	5b	8/27/2002	4.5	0.13
		7/11/2002	12	0.34
		6/18/2002	68	1.94
mu6		9/13/2002	4.3	0.12
		9/9/2002	4.6	0.13
		7/11/2002	12	0.34
		7/12/2002	11	0.31
		6/19/2002	73	2.08
mu7	7a	7/12/2002	4.3	0.12
		6/19/2002	11	0.31
	7b	9/6/2002	5	0.14
		9/13/2002	4.3	0.12
		7/12/2002	11	0.31
		6/20/2002	47	1.34
mu8	8a	9/6/2002	5	0.14
		9/9/2002	4.6	0.13
		7/10/2002	13	0.37
		6/20/2002	47	1.34
	8b	9/9/2002	4.6	0.13
		7/11/2002	12	0.34
		7/10/2002	13	0.37
		6/21/2002	38	1.08
	8c	9/10/2002	4.5	0.13
		9/9/2002	4.6	0.13
		7/11/2002	12	0.34
		6/21/2002	38	1.08

Table 2.4 Flow table representing management units, sites, and corresponding flow values.

Management Unit	Site	Date	DIS-CHARGE (cfs)	Avg Flow (cfsm)
mu9		9/10/2002	4.5	0.13
		7/11/2002	12	0.34
		6/21/2002	38	1.08
mu10	10a	9/10/2002	4.5	0.13
		7/11/2002	12	0.34
		6/21/2002	38	1.08
	10b	9/17/2002	5.8	0.17
		9/10/2002	4.5	0.13
		7/12/2002	11	0.31
		7/12/2002	11	0.31
		4/28/2003	80	2.28
mu11	11a	9/17/2002	5.8	0.17
		7/12/2002	11	0.31
		7/12/2002	11	0.31
		4/28/2003	80	2.28
	11b	9/18/2002	4.7	0.13
		7/12/2002	11	0.31
		6/21/2002	38	1.08
mu12		9/18/2002	4.7	0.13
		7/12/2002	11	0.31
		7/15/2002	9.6	0.27
		6/21/2002	38	1.08
mu13		9/19/2002	4.1	0.12
		9/18/2002	4.7	0.13
		7/15/2002	9.6	0.27
		6/21/2002	38	1.08
mu14		9/19/2002	4.1	0.12
		7/15/2002	9.6	0.27
		6/21/2002	38	1.08
mu15		9/20/2002	3.5	0.10
		9/19/2002	4.1	0.12
		7/16/2002	8.7	0.25
		6/21/2002	38	1.08

Management Unit	Site	Date	DIS-CHARGE (cfs)	Avg Flow (cfsm)
mu16		9/20/2002	3.5	0.10
		7/16/2002	8.7	0.25
		6/21/2002	38	1.08
mu17		9/24/2002	3.6	0.10
		9/20/2002	3.5	0.10
		7/15/2002	9.6	0.27
		6/19/2002	73	2.08
mu18	18a	9/24/2002	3.6	0.10
		7/15/2002	9.6	0.27
		6/19/2002	73	2.08
	18b	9/24/2002	3.6	0.10
		7/15/2002	9.6	0.27
		6/20/2002	47	1.34
mu19	19a	9/25/2002	3.6	0.10
		9/24/2002	3.6	0.10
		9/18/2002	4.7	0.13
		7/16/2002	8.7	0.25
		6/20/2002	47	1.34
	19b	9/19/2002	4.1	0.12
		7/17/2002	8.2	0.23
		6/21/2002	38	1.08
mu20		9/20/2002	3.5	0.10
		9/19/2002	4.1	0.12
		7/17/2002	8.2	0.23
		6/21/2002	38	1.08
mu21		9/24/2002	3.6	0.10
		9/20/2002	3.5	0.10
		7/17/2002	8.2	0.23
		6/21/2002	38	1.08

Table 2.4 con't

Slimy Sculpin		**Long Nose Dace**		**Black Nose Dace**		**White Sucker**		**Brook Trout**	
Presence (80.9%)		Presence (79.6%)		Presence (77.2%)		Presence (94.3%)		Presence (78.9%)	
Variable	**Beta**	**Variable**	**Beta**	**Variable**	**Beta**	**Variable**	**Beta**	**Variable**	**Beta**
Boulders	-0.752	Overhanging Veg	0.802	Overhanging Veg	0.85	Riprap	0.701	Velocity (45-60)	-2.797
Overhanging Veg	-0.764	Submerged Veg	-1.944	Submerged Veg	-1.291	Clay	0.945	Velocity (60-75)	-4.24
Submerged Veg	1.529	Clay	1.026	Ruffle	-3.945	Pool	1.272	Macro	1.821
Canopy Cover		Backwater	5.167	Woody Debris	-0.432	Micro	3.303	Canopy Cover	
Shading	0.633	Velocity (less than 15)	-6.467	Clay	1.824			Shading	0.897
Clay	-1.308	Pelal	18.106	Rapid	-1.574	Constant	-3.804	Constant	-2.454
Run	1.041	Constant	-0.796	Constant	-1.009				
Macro	2.154								
Mega	-2.395								
Constant	0.556								
High Abundance (76.9%)		High Abundance (66.9%)		High Abundance (73%)		High Abundance (78.6%)		High Abundance (89.1%)	
Variable	**Beta**	**Variable**	**Beta**	**Variable**	**Beta**	**Variable**	**Beta**	**Variable**	**Beta**
Submerged Veg	1.623	Velocity (15-30)	2.158	Velocity (60-75)	-5.737	Boulders	-3.085	Woody Debris	2.305
Overhanging Veg	-0.471	Velocity (30-45)	3.377	Constant	1.105	Meso	-6.162	Riffle	3.139
Glide	1.167	Constant	-1.628			Constant	4.911	Depth (25-50cm)	-4.133
Ruffle	-1.136							Depth (75-100cm)	9.997
Depth (less than 25cm)	1.393							Velocity (15-30)	6.006
Constant	-1.81							Velocity (30-45)	-6.091
								Constant	-4.302

Table 2.5 Results of logistic regression analysis used to identify habitat requirements for the five target species.

Brown Trout		Rainbow Trout		Young of Year-Trout		Young of Year-Other	
Presence (72.1%)		Presence (76.7%)		Presence (70.6%)		Presence (89%)	
Variable	**Beta**	**Variable**	**Beta**	**Variable**	**Beta**	**Variable**	**Beta**
Boulders	0.337	Submerged Veg	-1.212	Overhanging Veg	0.752	Overhanging Veg	0.871
Submerged Veg	-0.76	Riffle	-0.885	Submerged Veg	-1.442	Clay	2.027
Fast Run	2.713	Constant	-0.712	Clay	-0.963	Backwater	3.257
Pool	0.73			Velocity (15-30)	1.546	Micro	4.838
Ruffle	0.819			Velocity (30-45)	2.543	Constant	-3.241
Depth (50-75 cm)	-2.51			Constant	-1.894		
Sidearm	2.829						
Constant	-1.039						
High Abundance (81.8%)		High Abundance (87%)		High Abundance (71.6%)		High Abundance (71.6%)	
Variable	**Beta**	**Variable**	**Beta**	**Variable**	**Beta**	**Variable**	**Beta**
Pool	1.341	Fast Run	2.113	Overhanging Veg	0.742	Depth (25-50cm)	-2.901
Constant	-1.782	Constant	-2.113	Constant	-1.467	Constant	0.519

Table 2.6 Results of logistic regression analysis used to identify habitat requirements for non-native species and young-of-the-year.

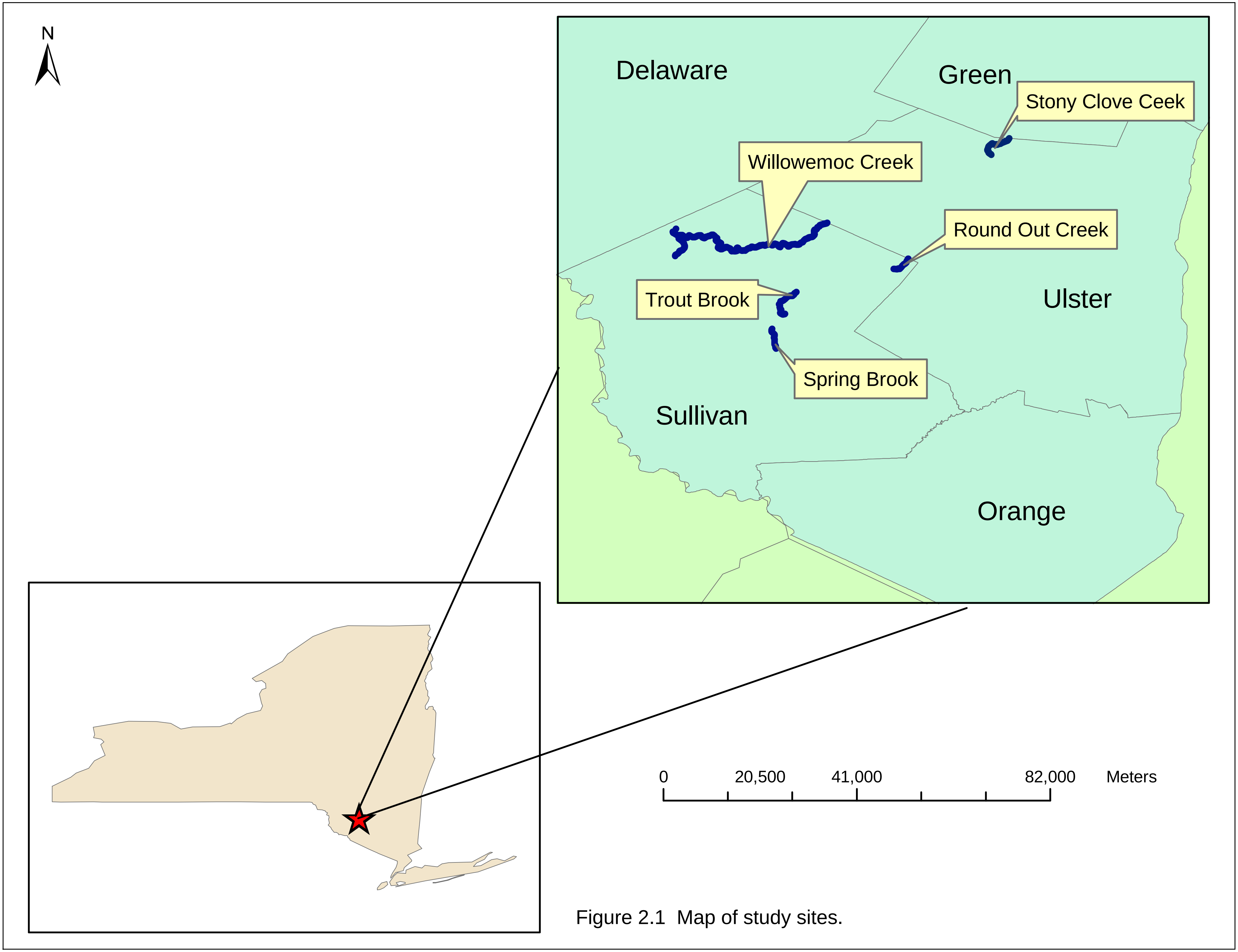

Figure 2.1 Map of study sites.

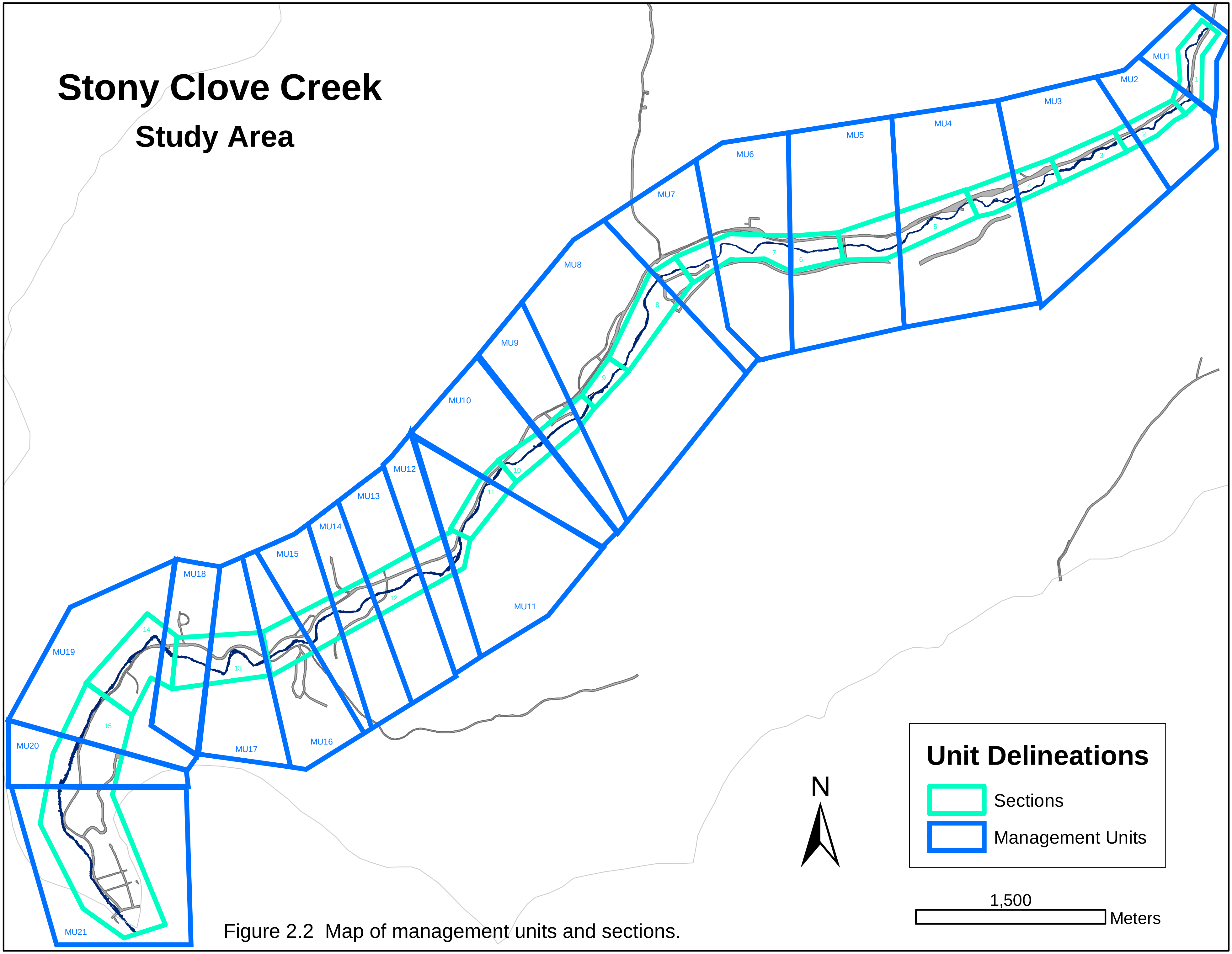

Figure 2.2 Map of management units and sections.

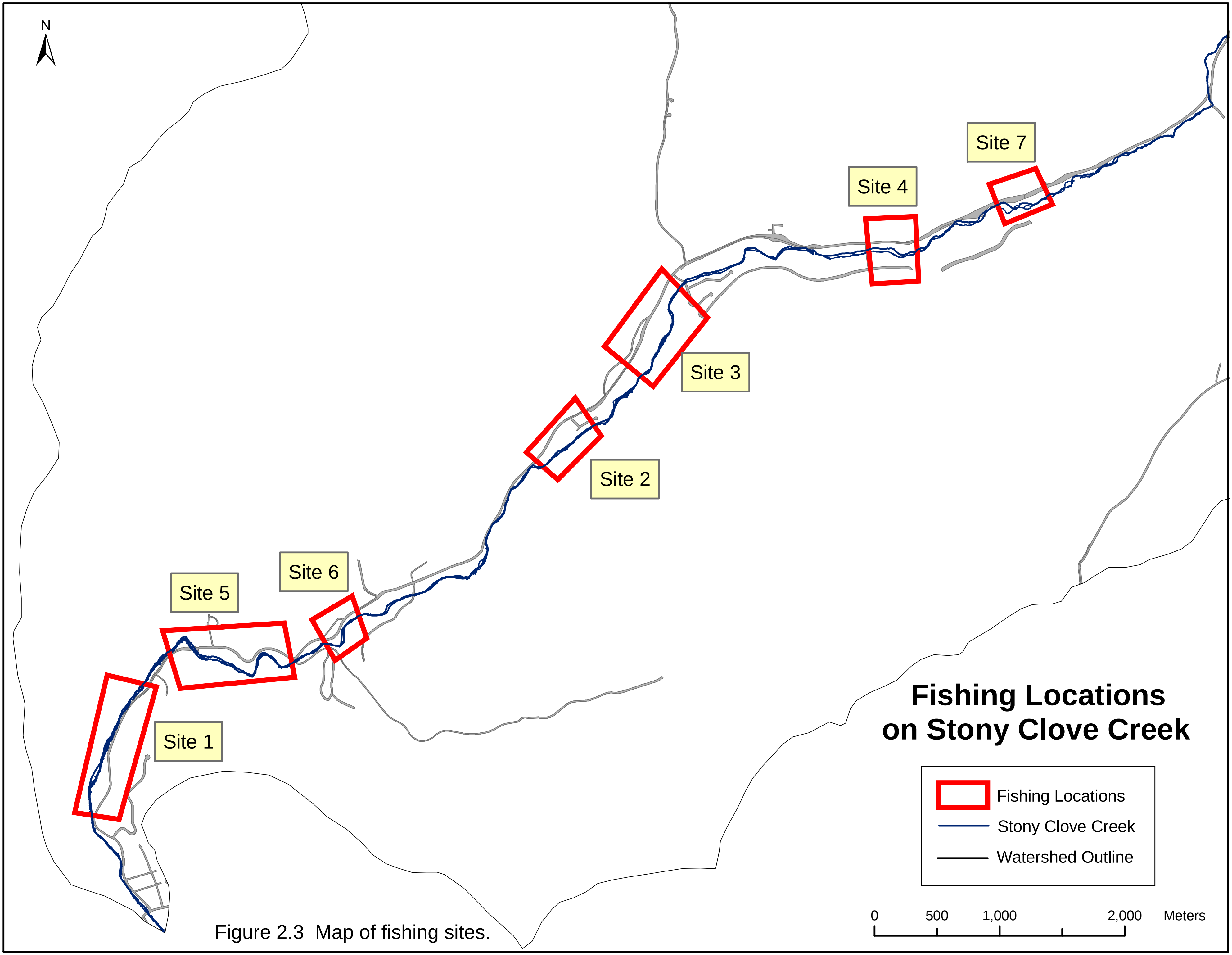

Figure 2.3 Map of fishing sites.

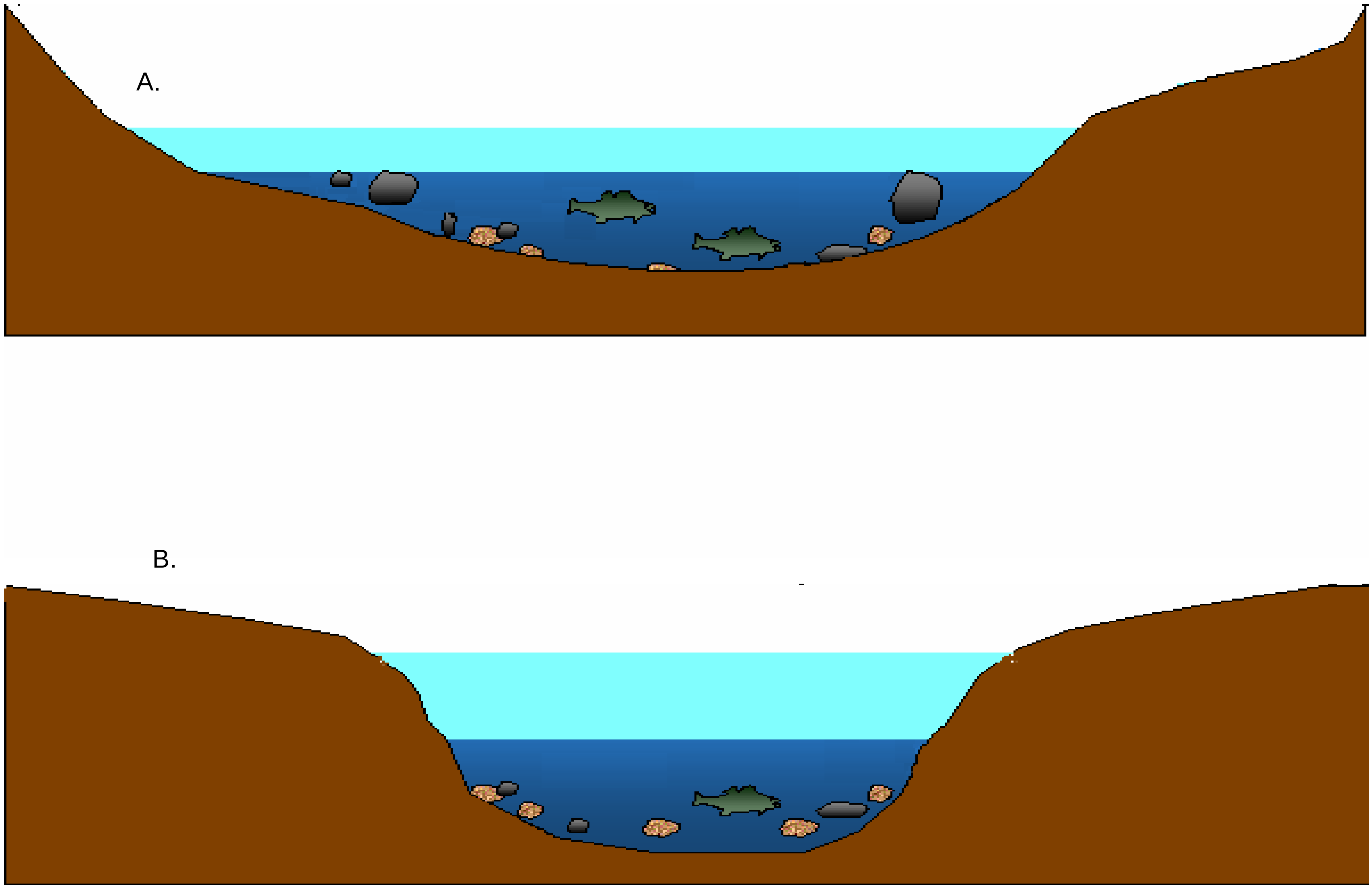

Figure 2.4 Non-entrenched (A.) versus entrenched (B.) channel.

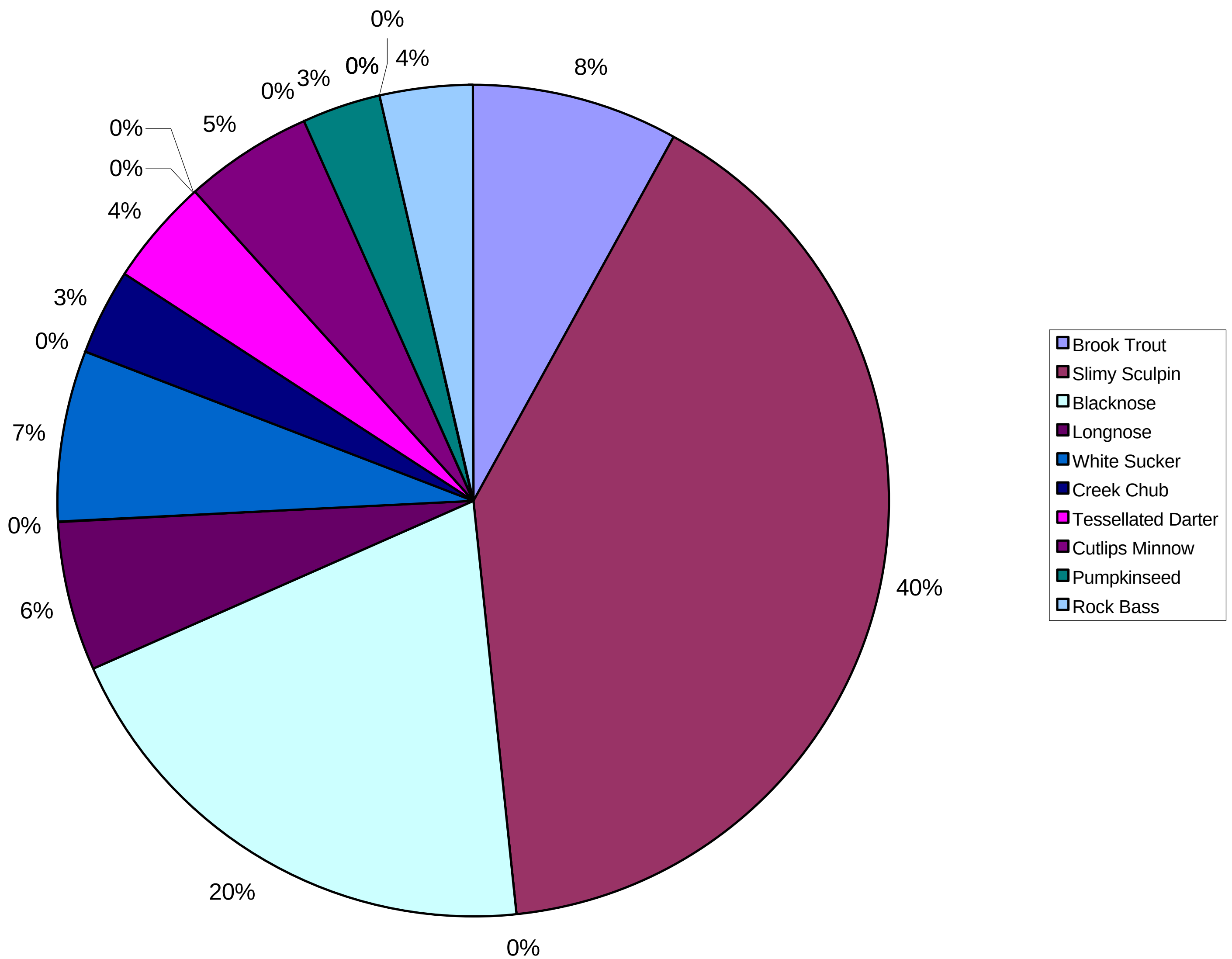

Figure 3.1 Target fish community for seven Hudson River watershed tributaries.

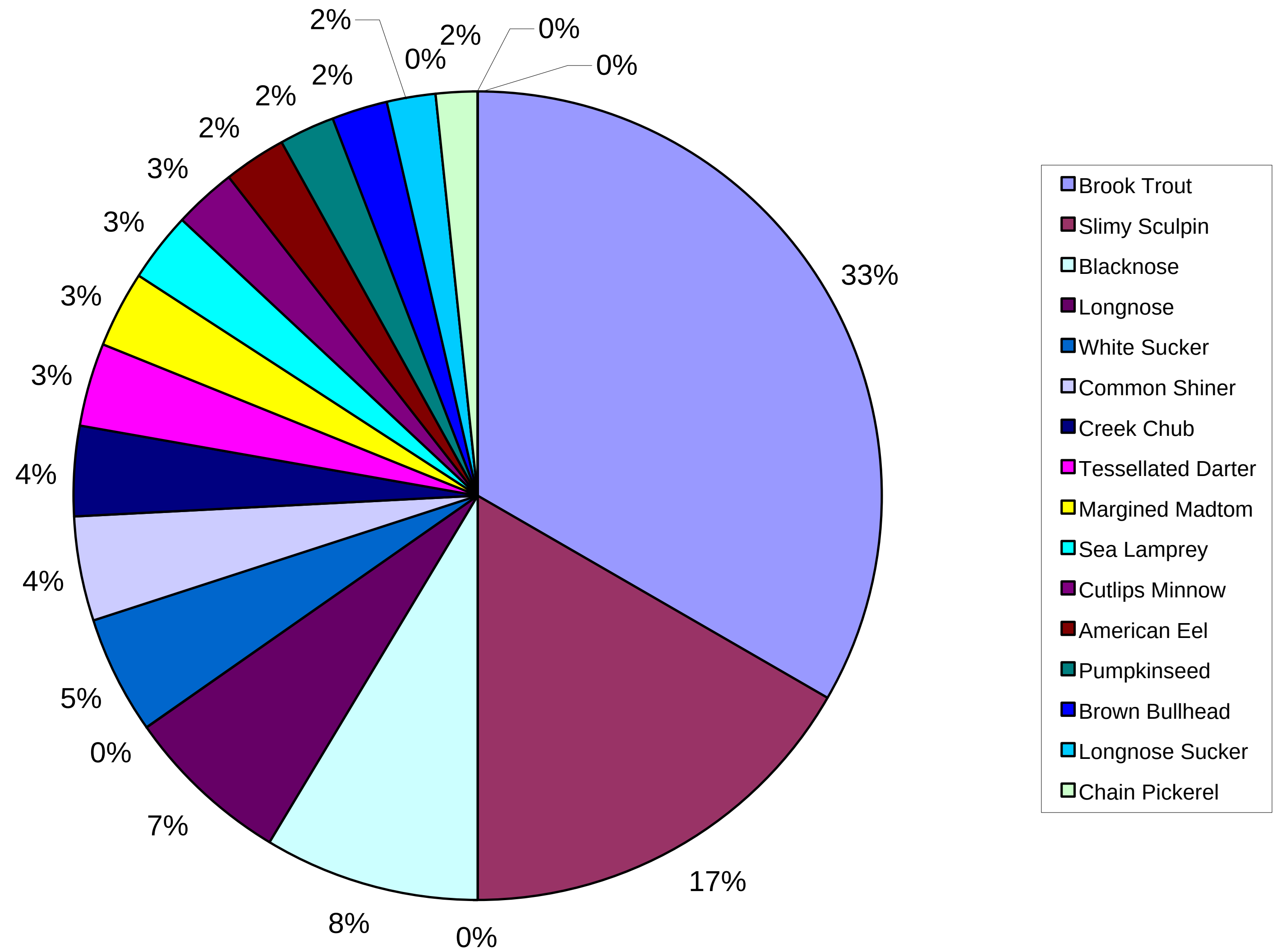

Figure 3.2 Target fish community for Beaver Kill watershed.

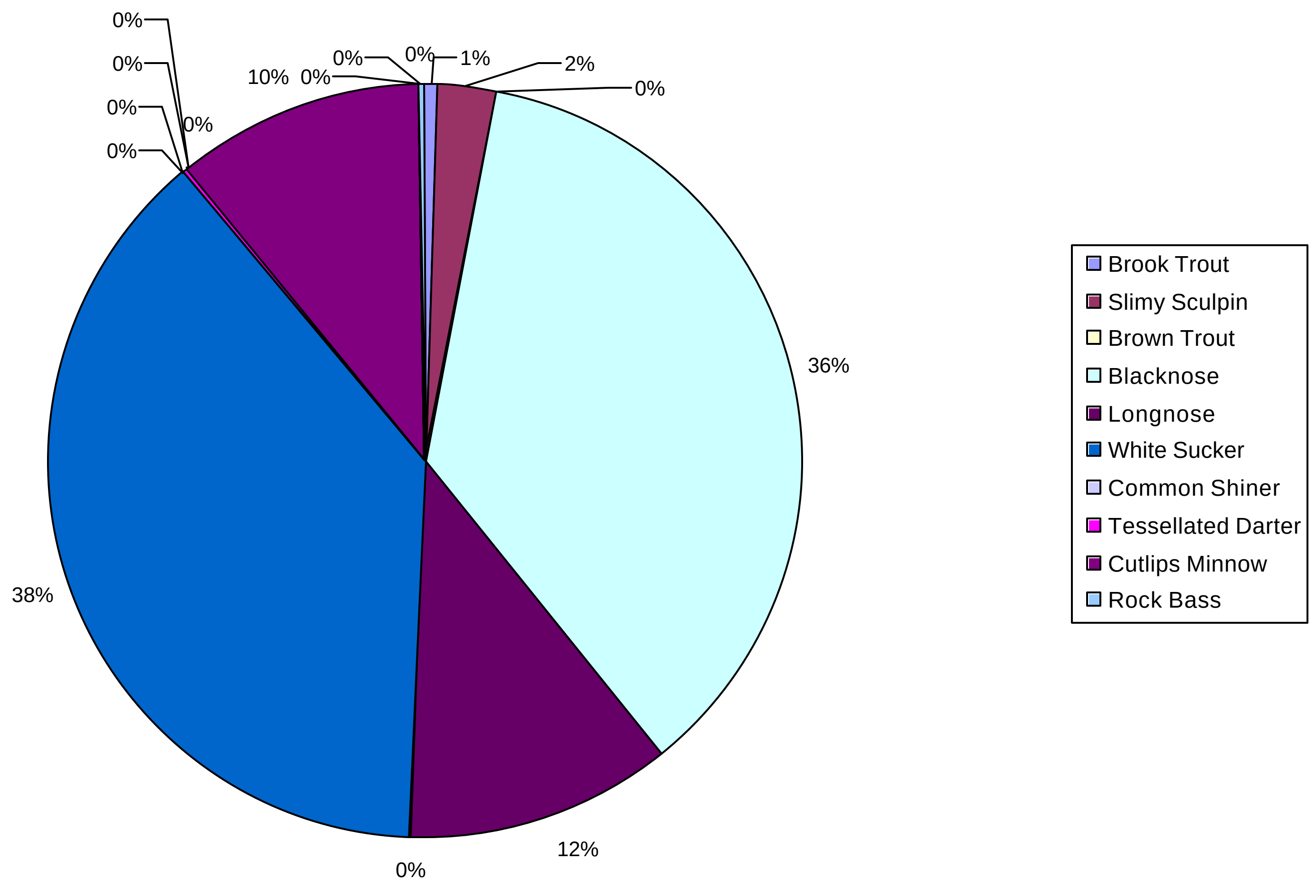

Figure 3.3 Relative abundances of target fish community for the historic Stony Clove Creek.

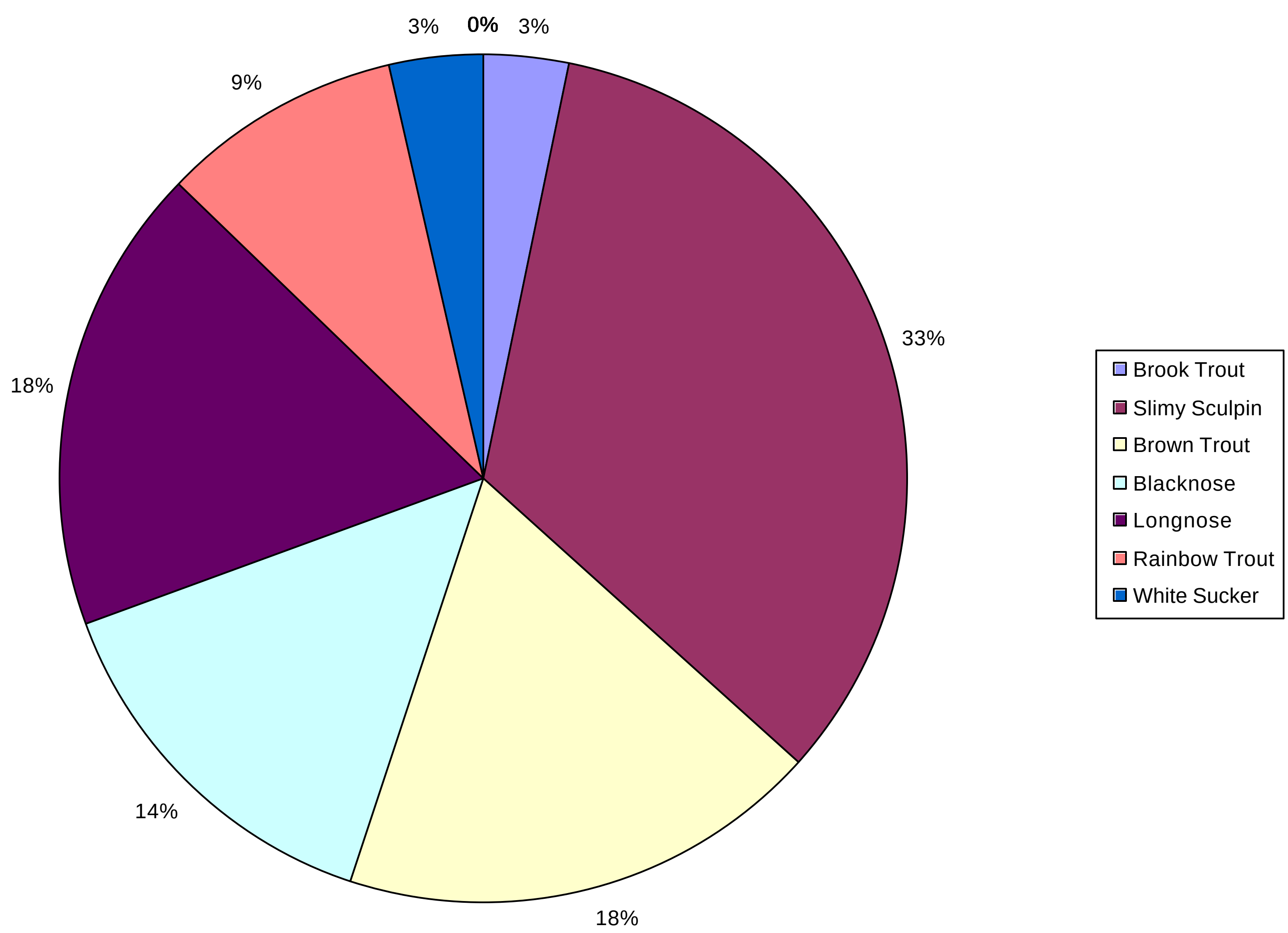

Figure 3.4 Target fish community for Stony Clove 2002.

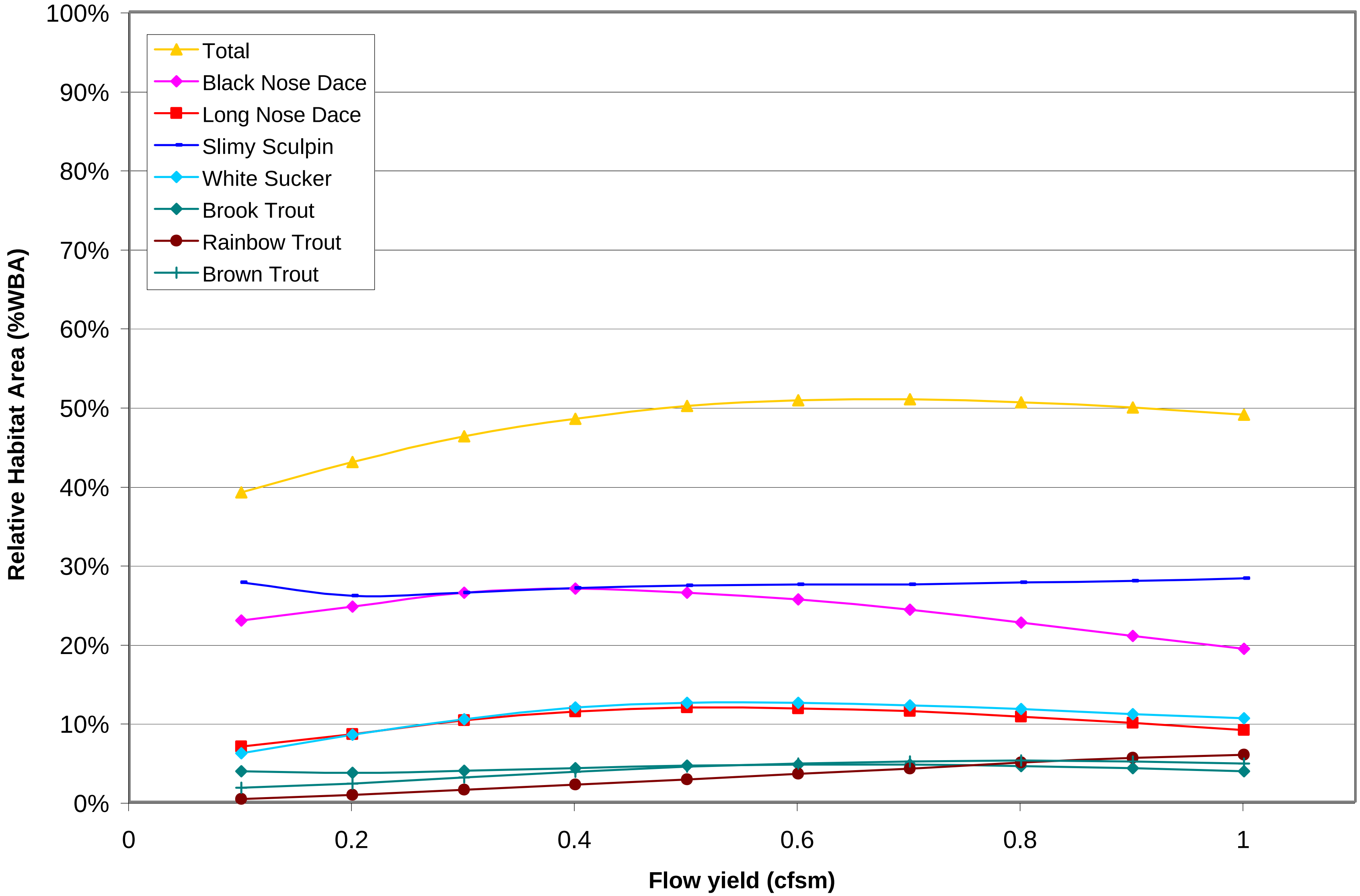

Figure 3.5 Rating curve for relative habitat area versus flow for Stony Clove study area.

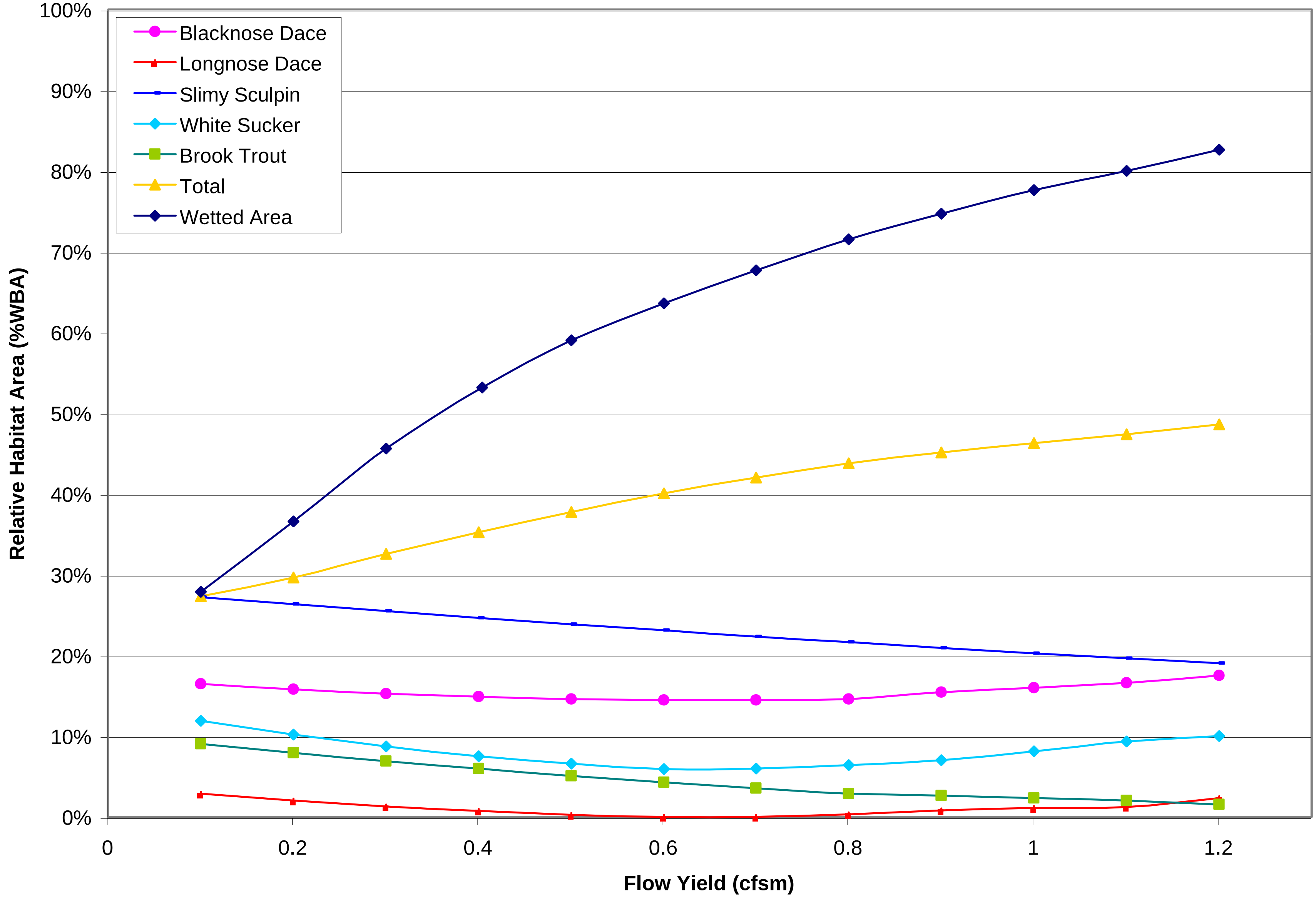

Figure 3.6 Rating curve for relative habitat area versus flow for Management Unit 1.

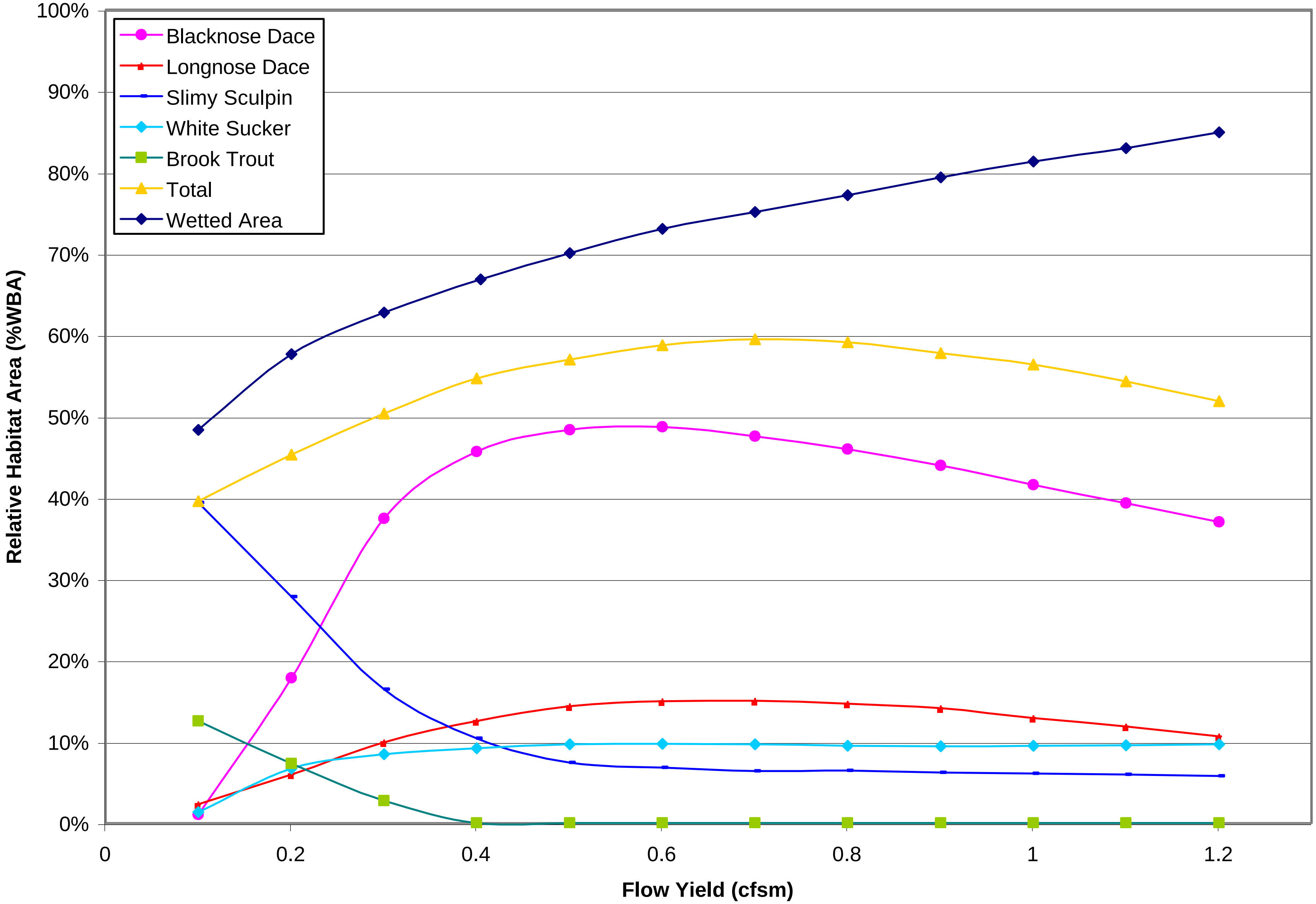

Figure 3.7 Rating curve for relative habitat area versus flow for Management Unit 2.

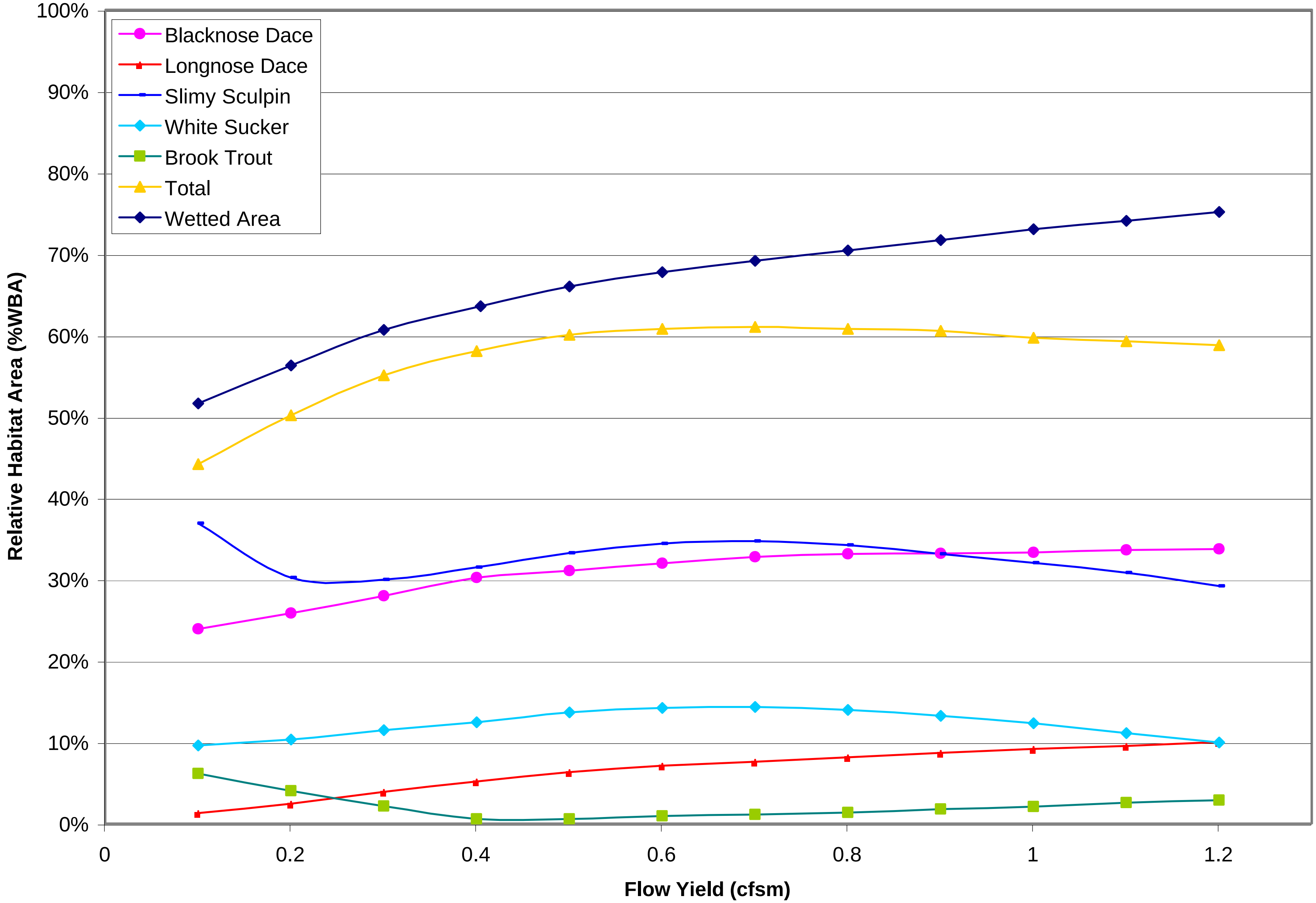

Figure 3.8 Rating curve for relative habitat area versus flow for Management Unit 3.

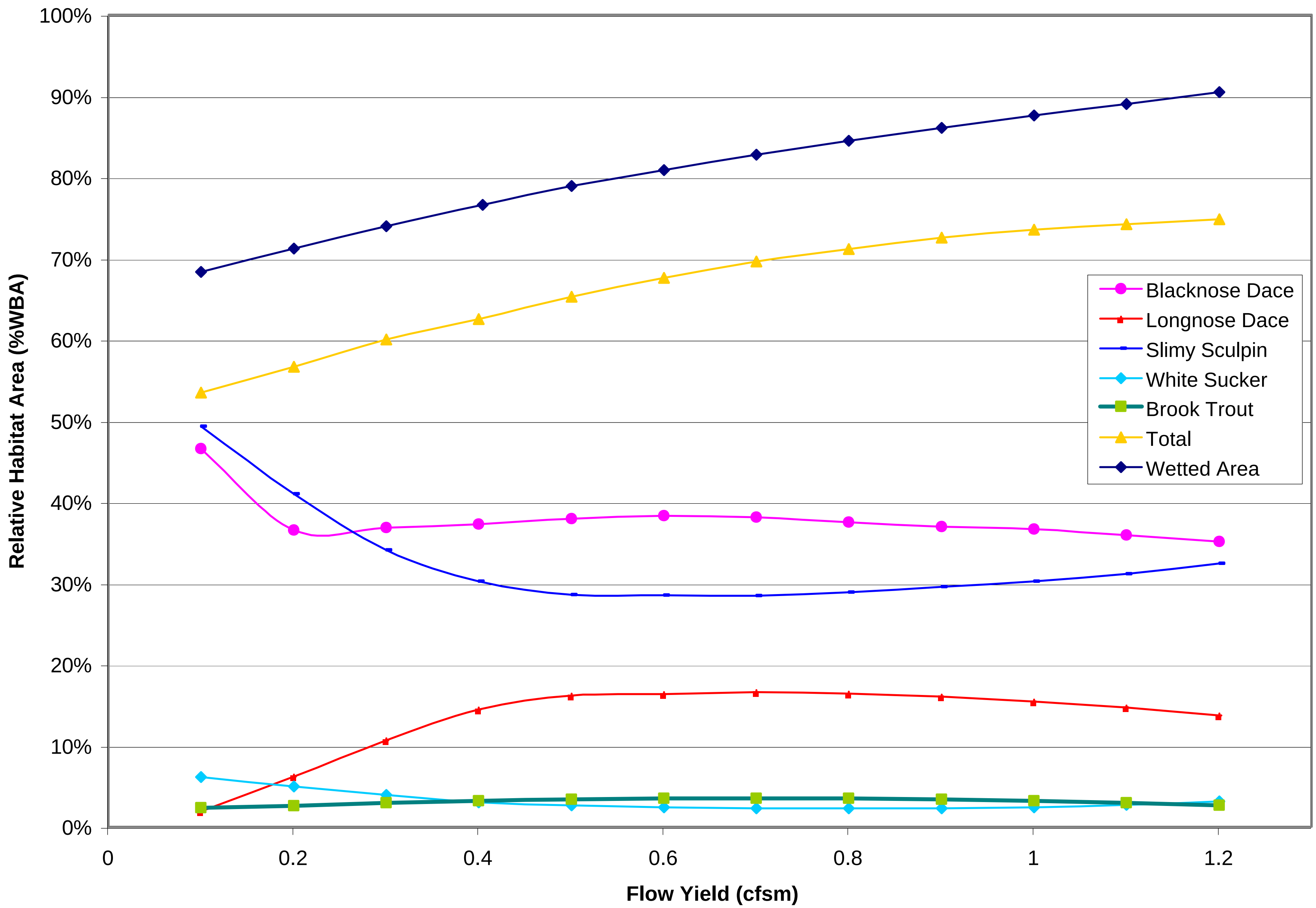

Figure 3.9 Rating curve for relative habitat area versus flow for Management Unit 4.

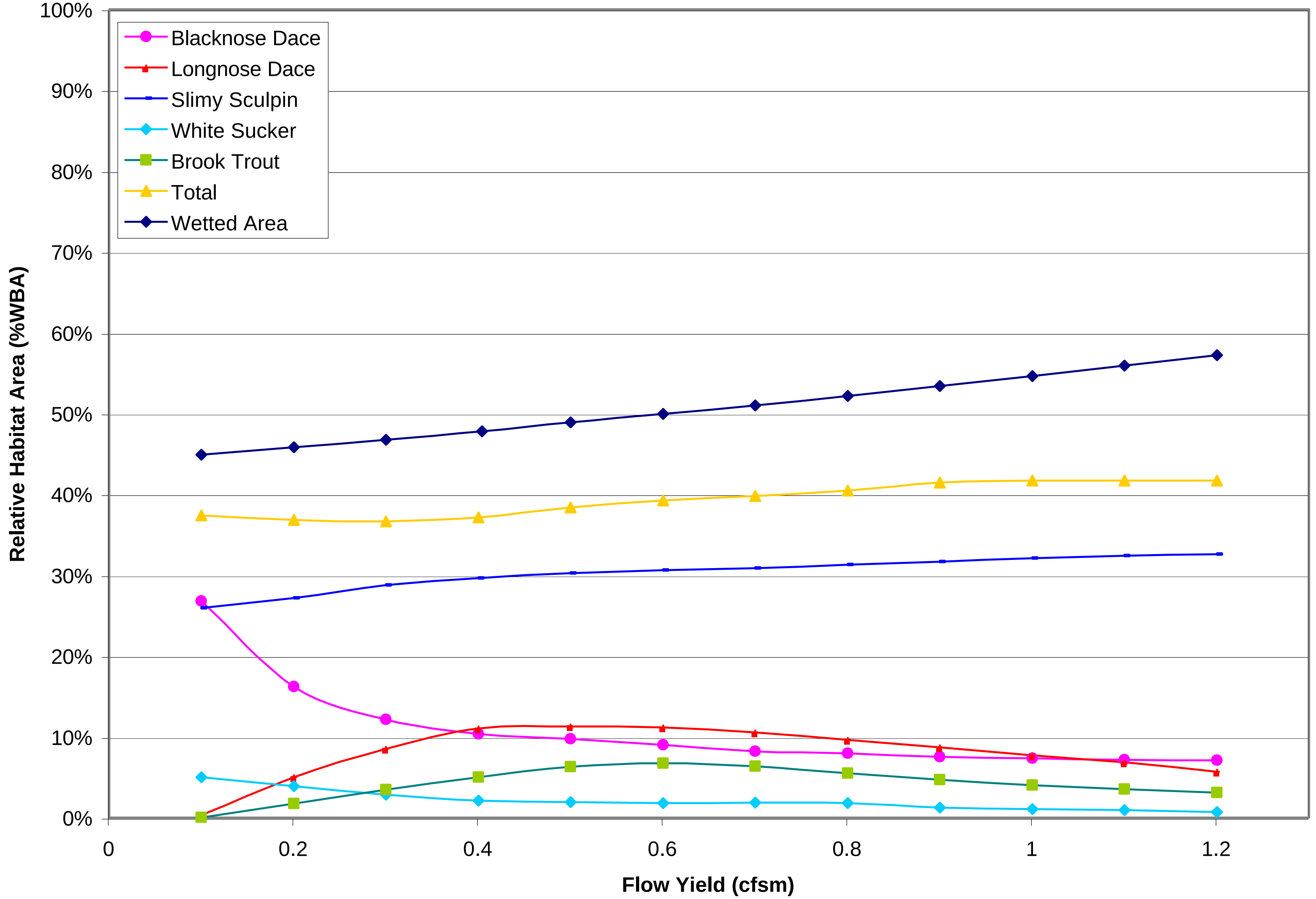

Figure 3.10 Rating curve for relative habitat area versus flow for Management Unit 5 .

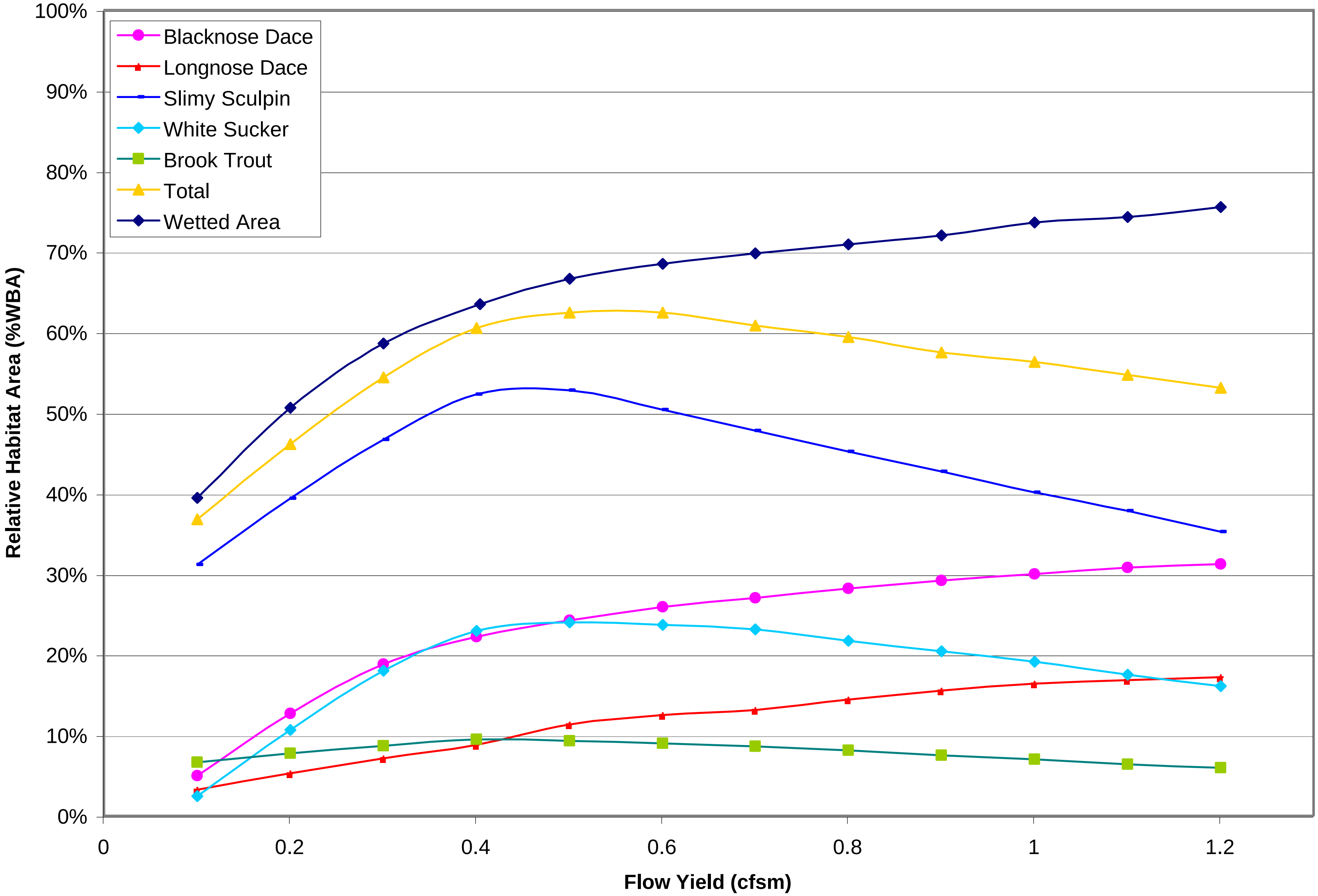

Figure 3.11 Rating curve for relative habitat area versus flow for Management Unit 6.

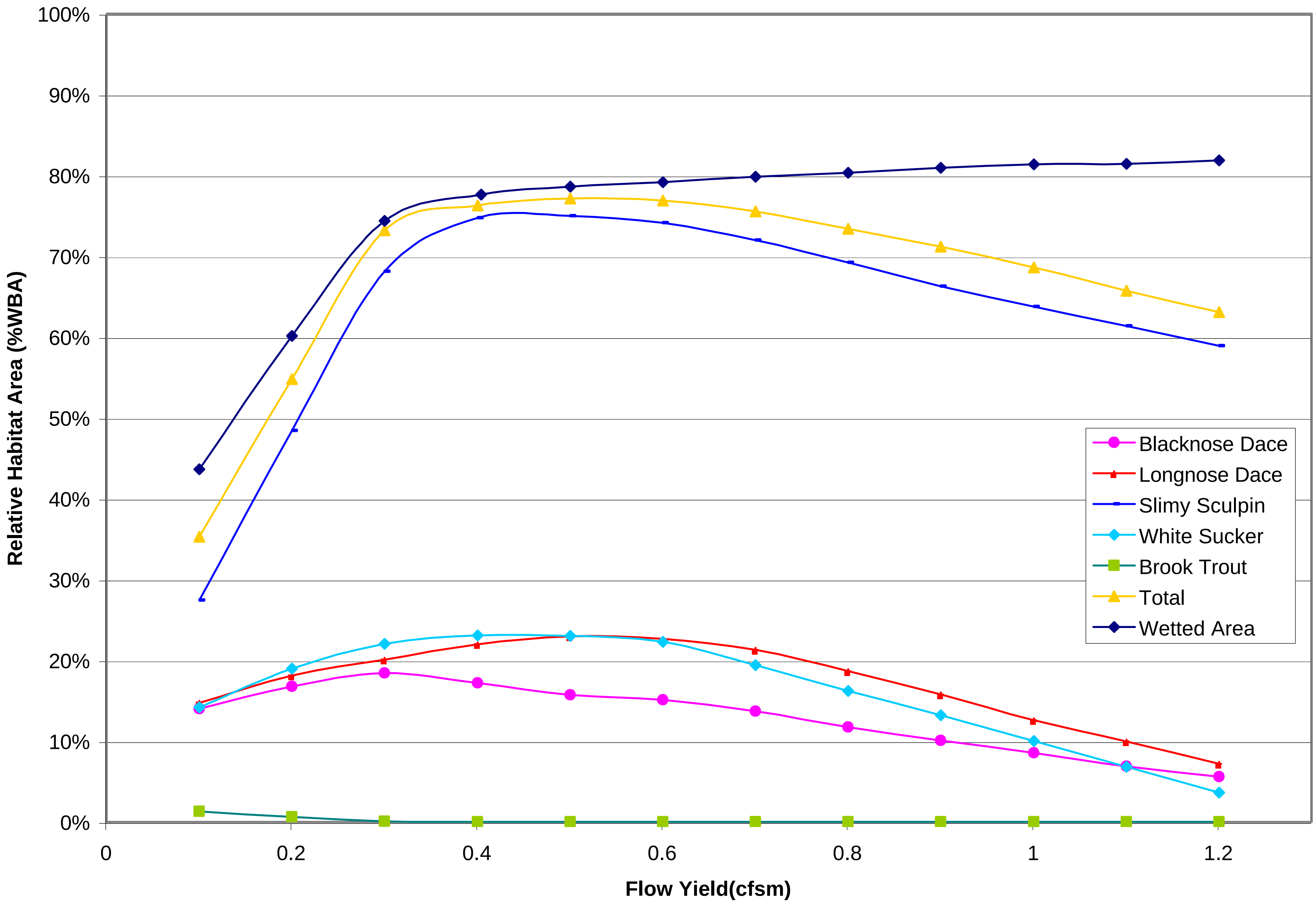

Figure 3.12 Rating curve for relative habitat area versus flow for Management Unit 7.

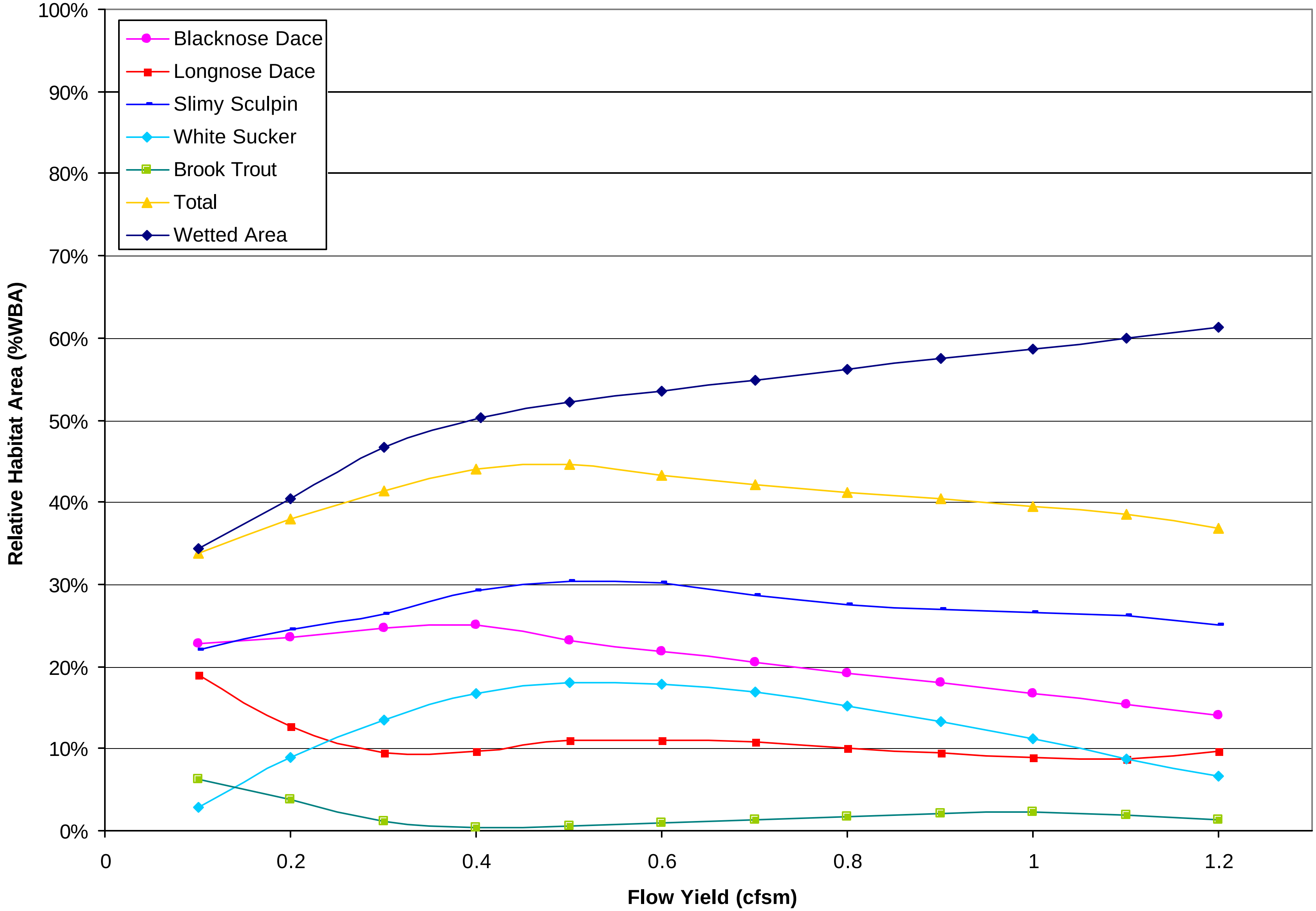

Figure 3.13 Rating curve for relative habitat area versus flow for Management Unit 8.

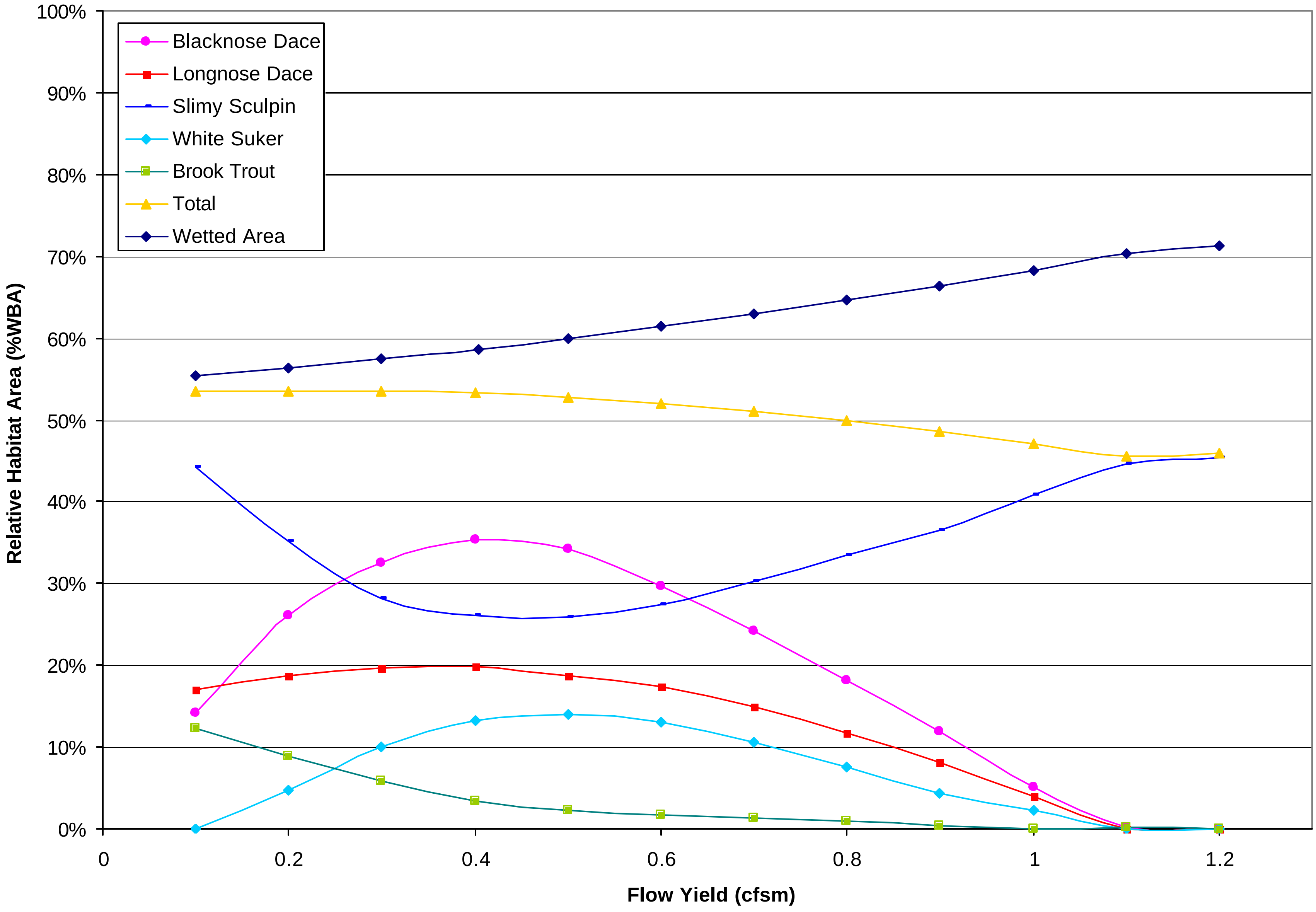

Figure 3.14 Rating curve for relative habitat area versus flow for Management Unit 9.

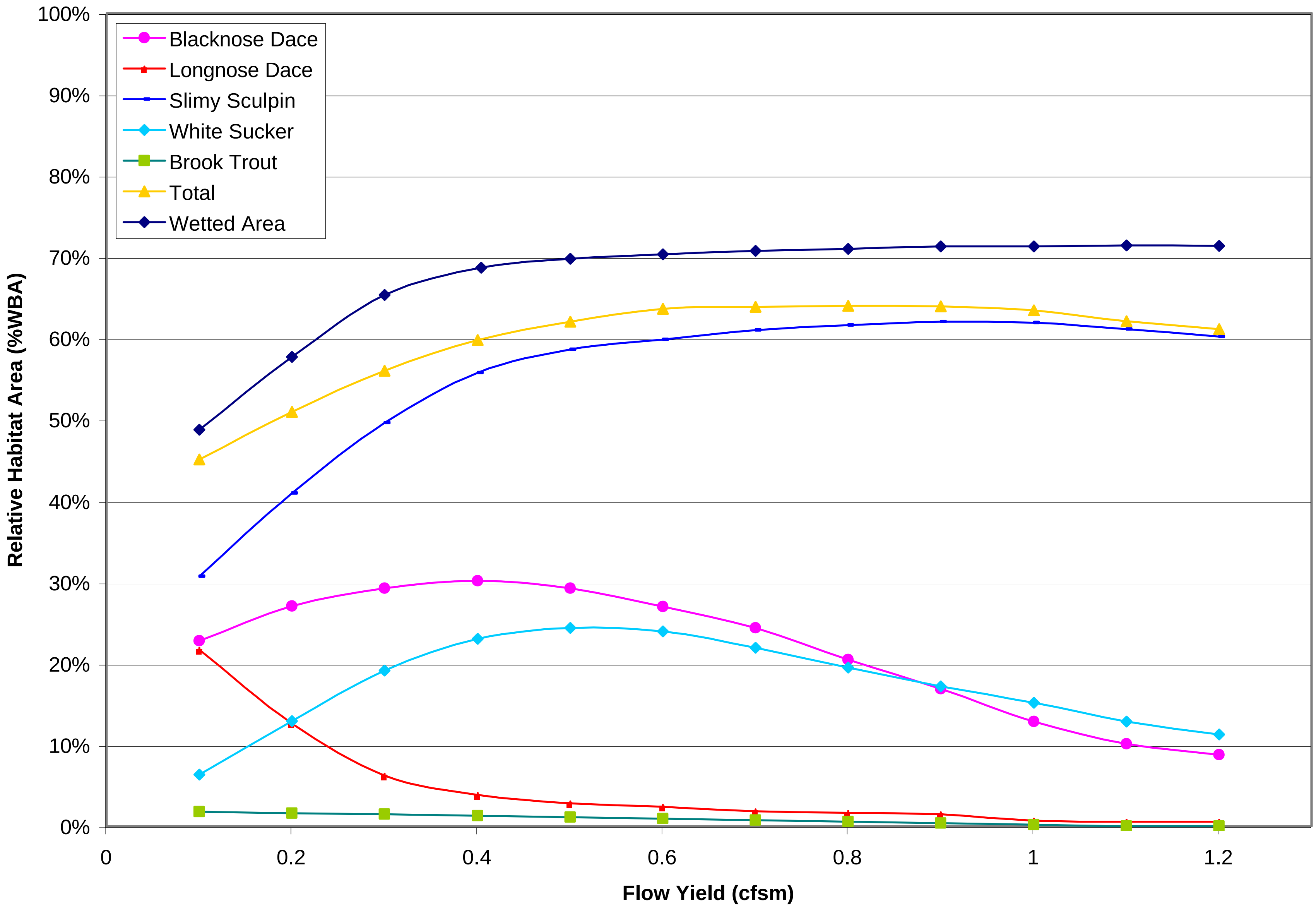

Figure 3.15 Rating curve for relative habitat area versus flow for Management Unit 10.

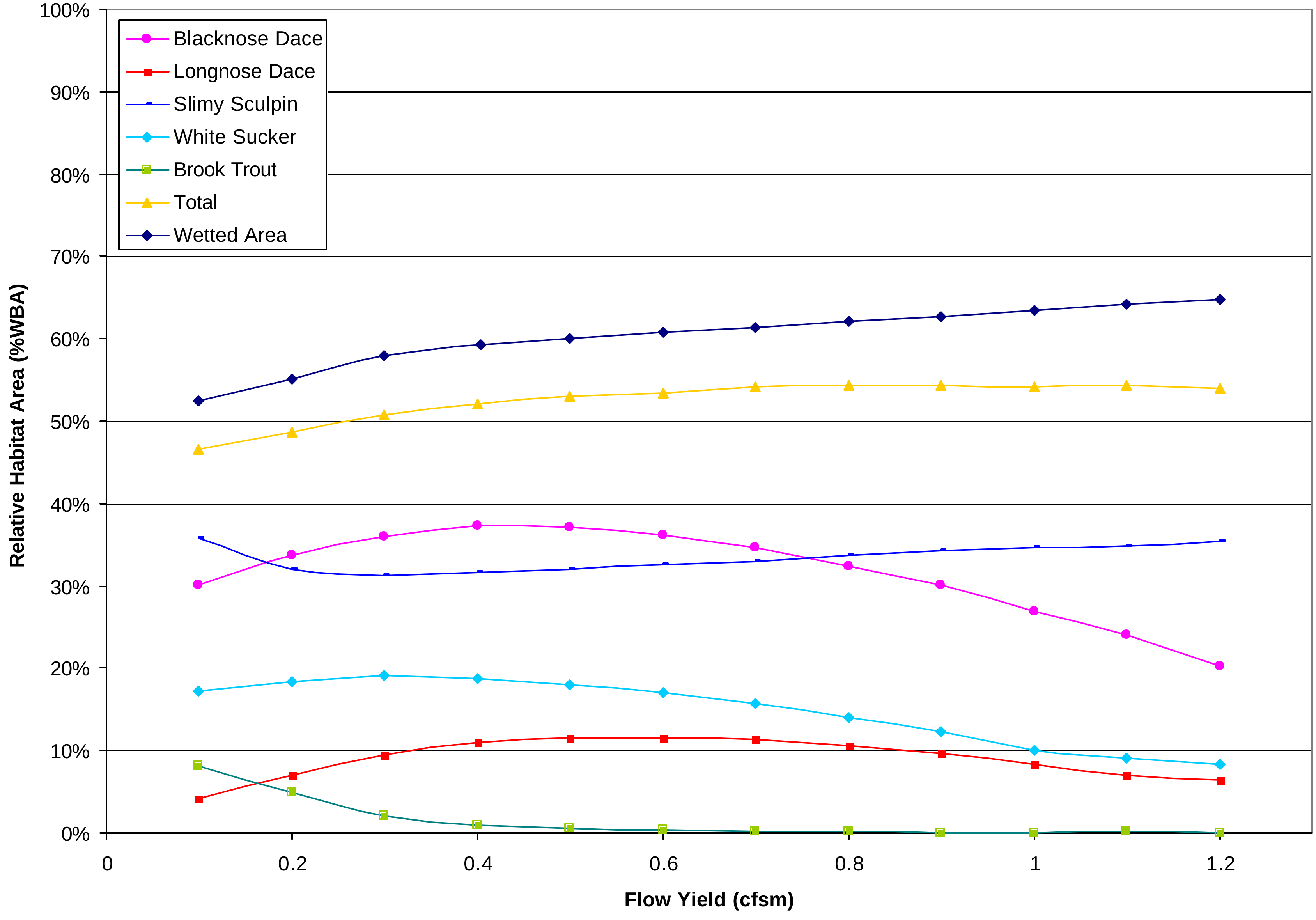

Figure 3.16 Rating curve for relative habitat area versus flow for Management Unit 11.

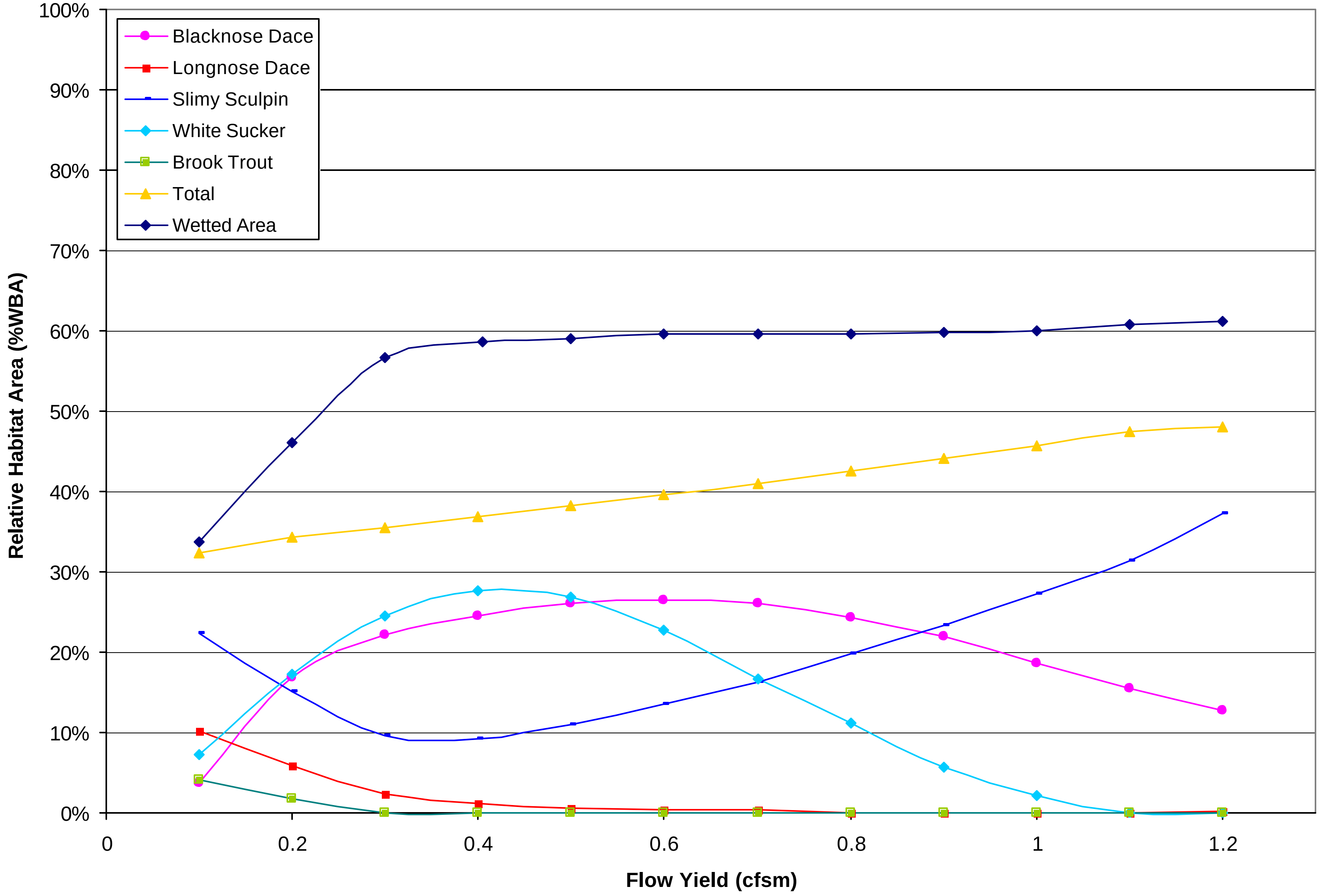

Figure 3.17 Rating curve for relative habitat area versus flow for Management Unit 12.

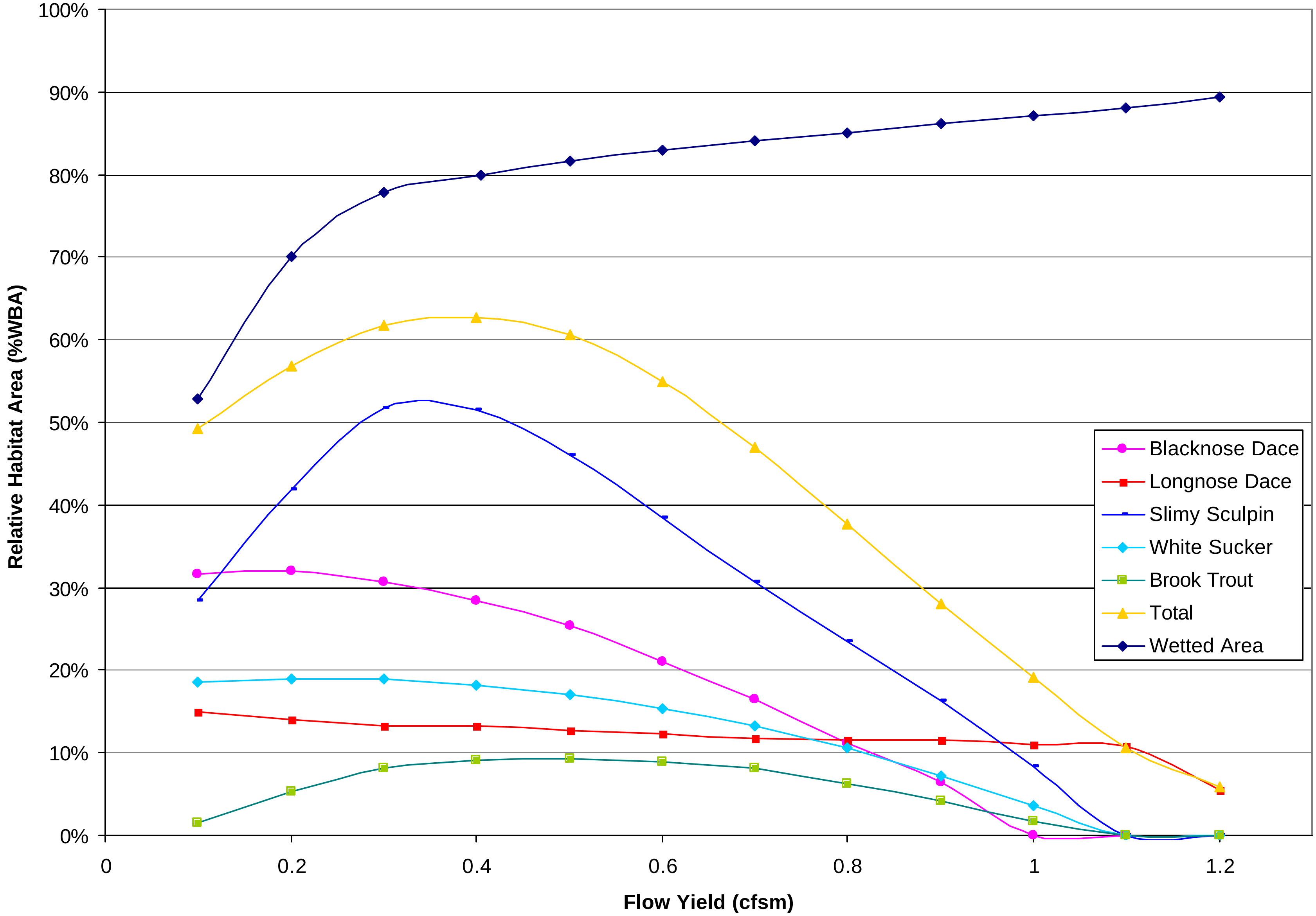

Figure 3.18 Rating curve for relative habitat area versus flow for Management Unit 13.

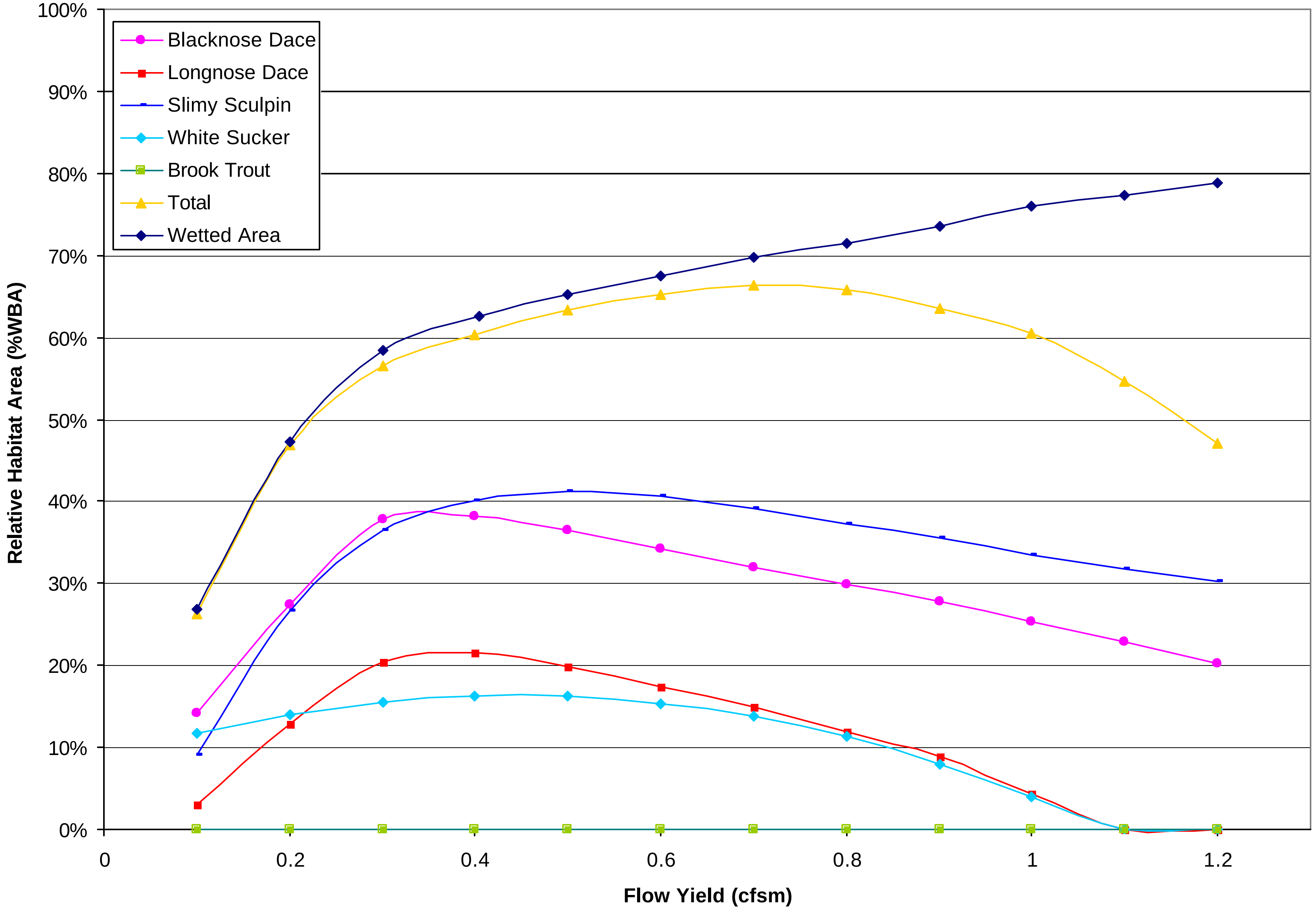

Figure 3.19 Rating curve for relative habitat area versus flow for Management Unit 14.

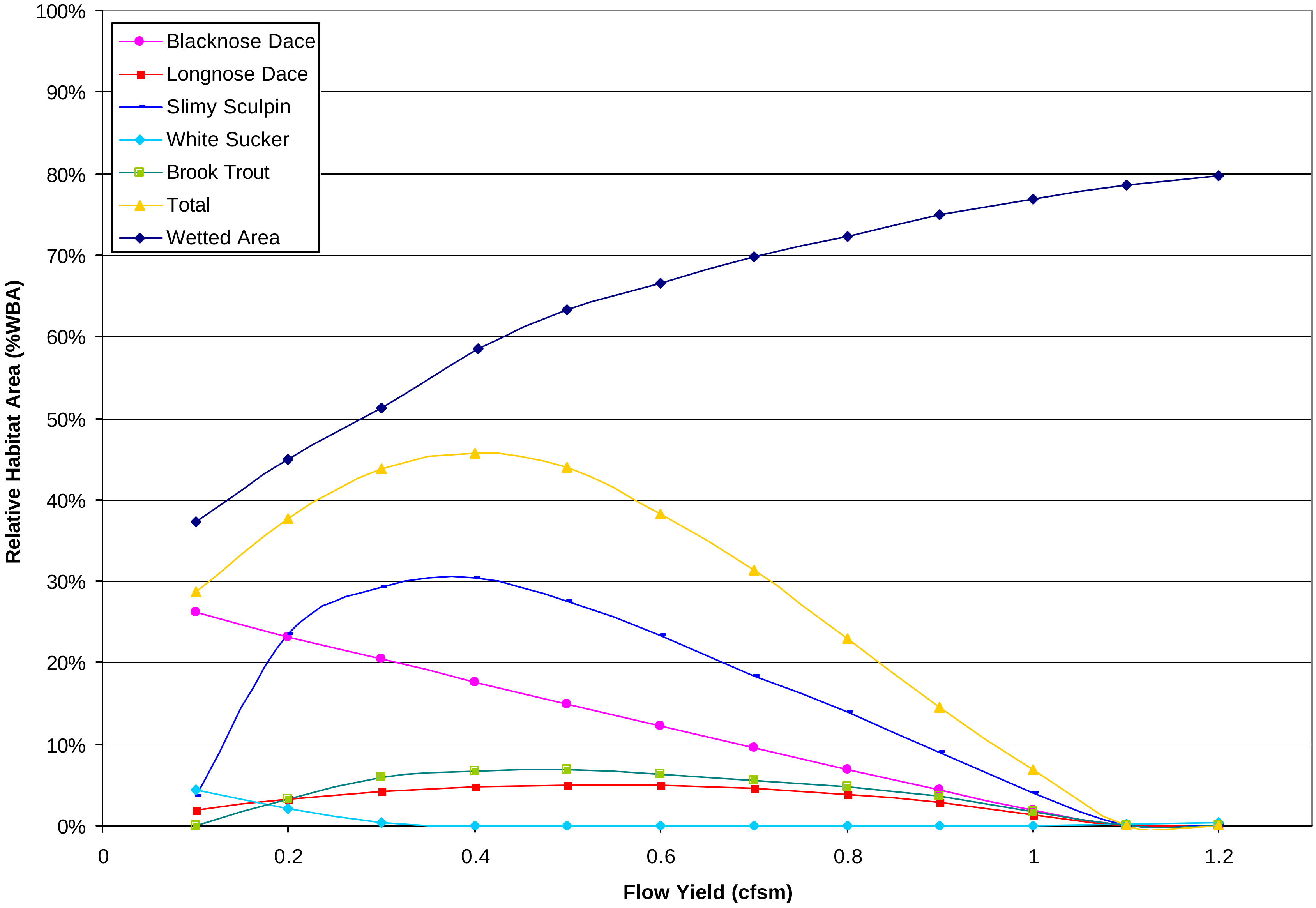

Figure 3.20 Rating curve for relative habitat area versus flow for Management Unit 15.

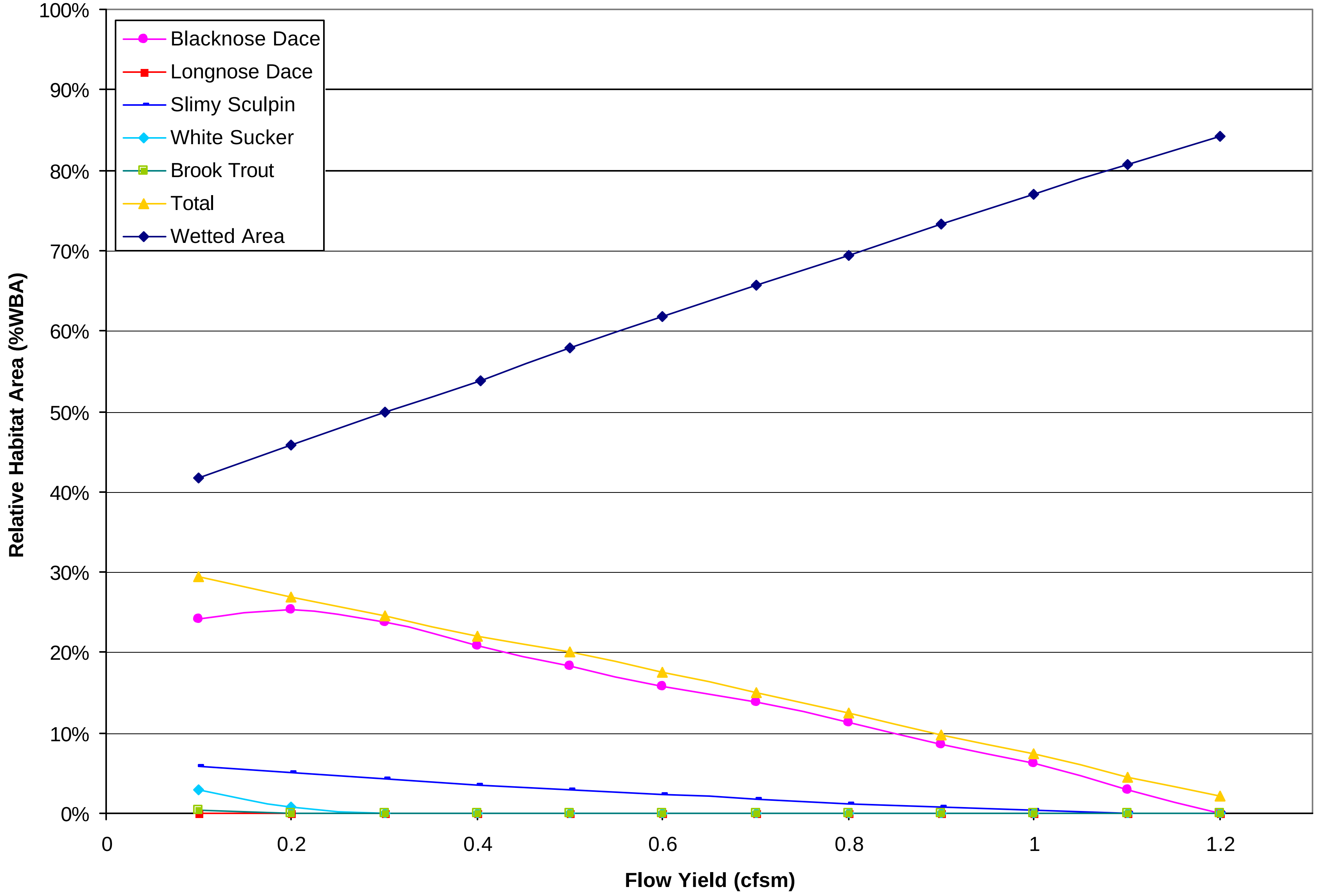

Figure 3.21 Rating curve for relative habitat area versus flow for Management Unit 16.

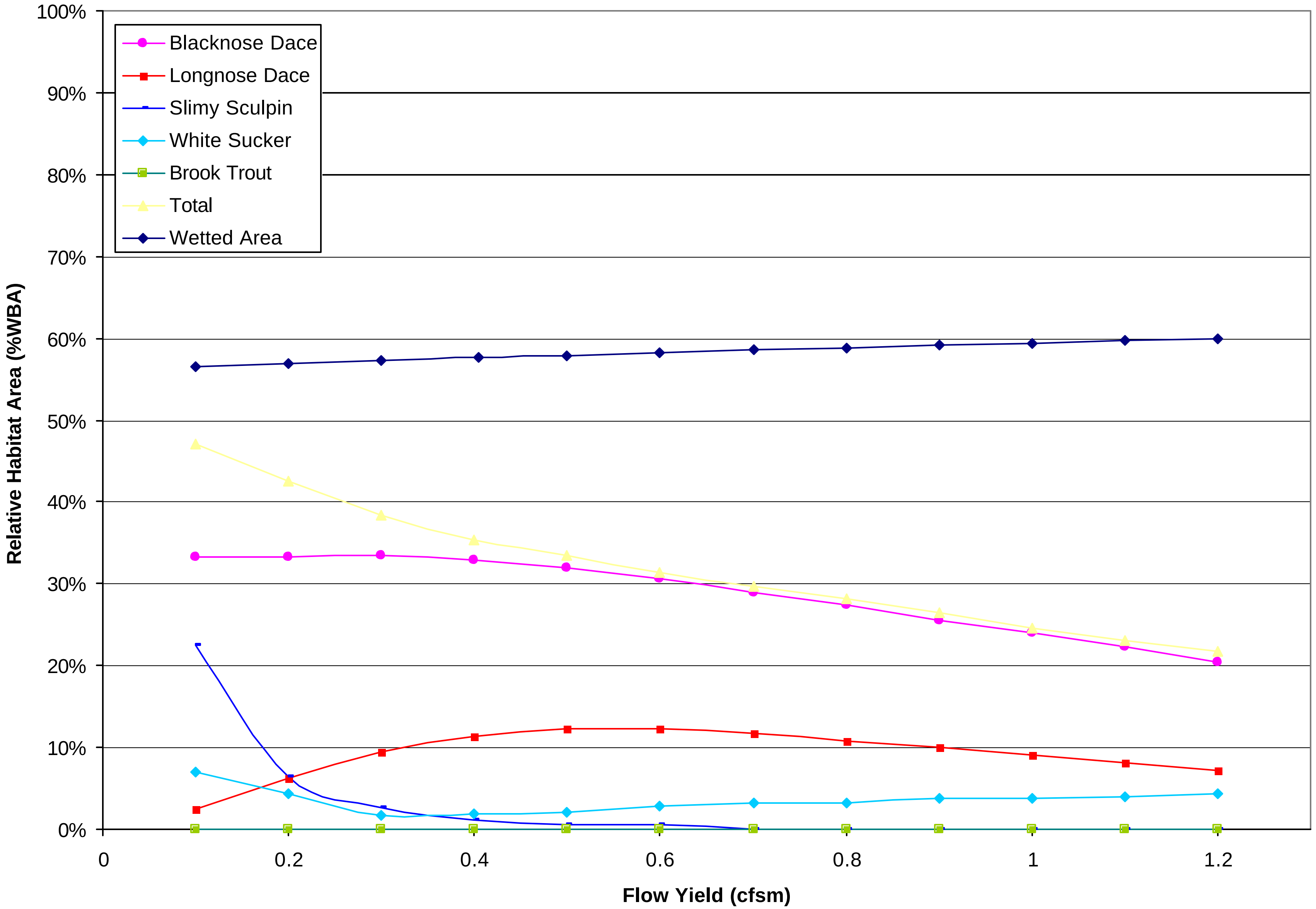

Figure 3.22 Rating curve for relative habitat area versus flow for Management Unit 17.

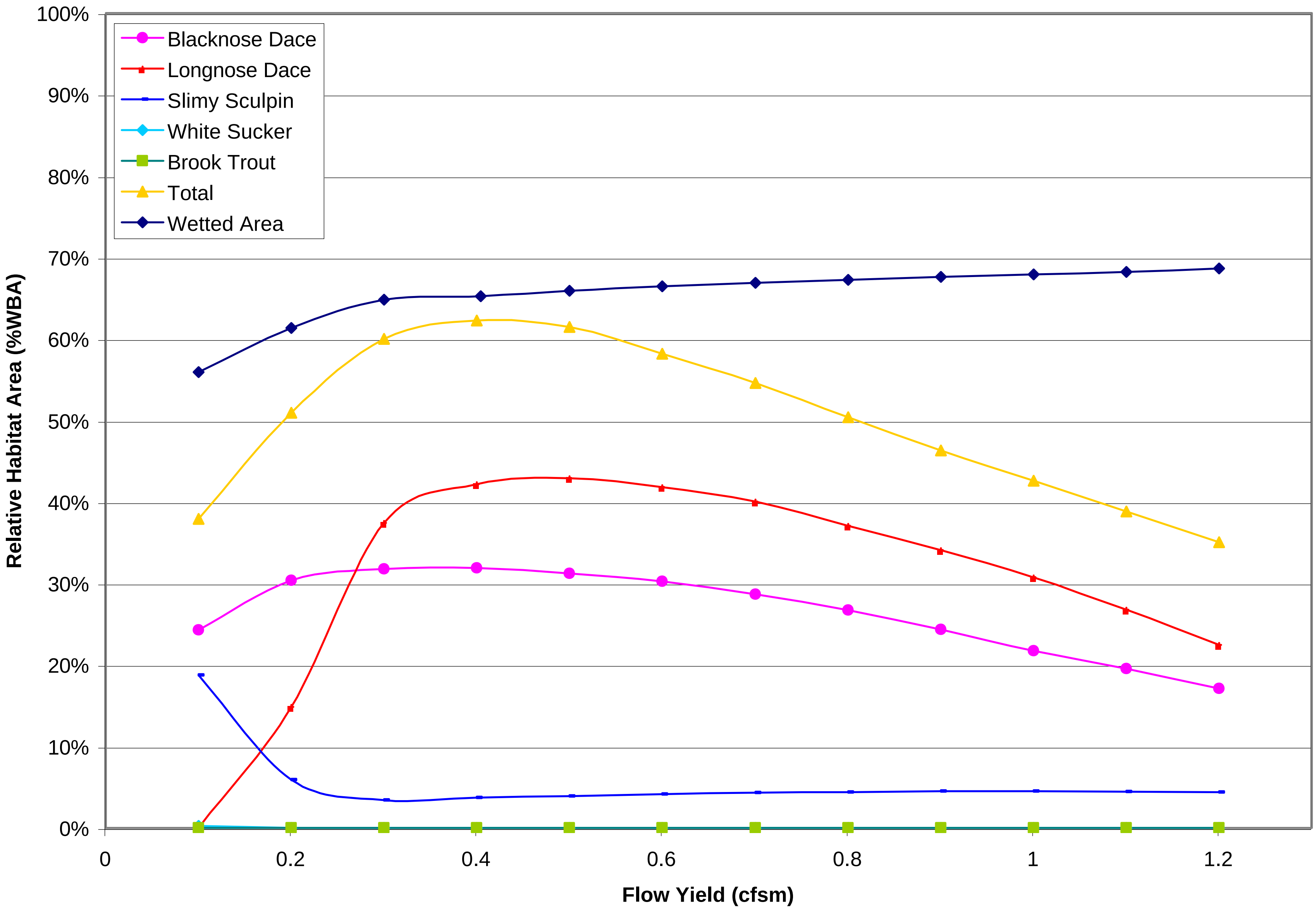

Figure 3.23 Rating curve for relative habitat area versus flow for Management Unit 18.

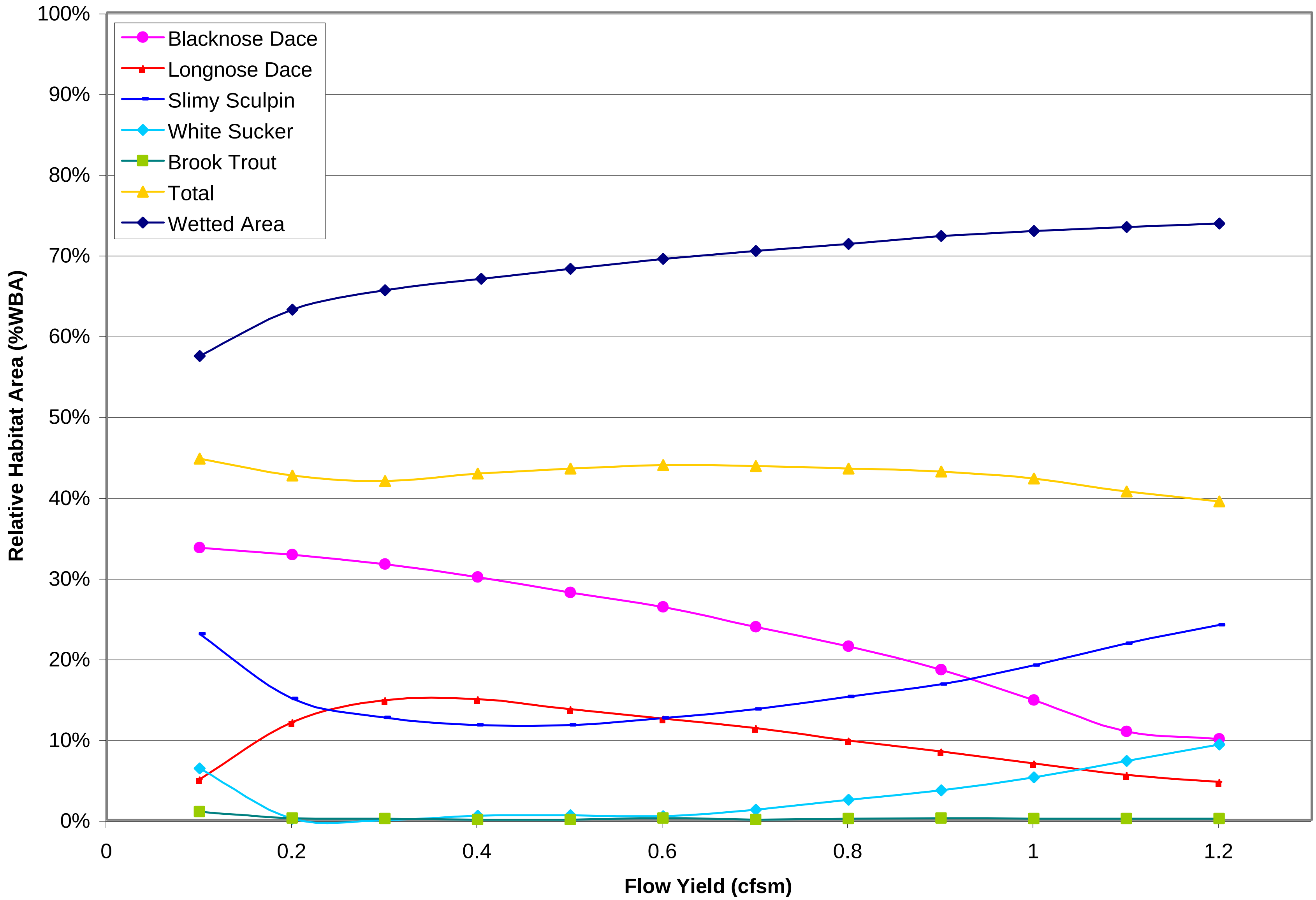

Figure 3.24 Rating curve for relative habitat area versus flow for Management Unit 19.

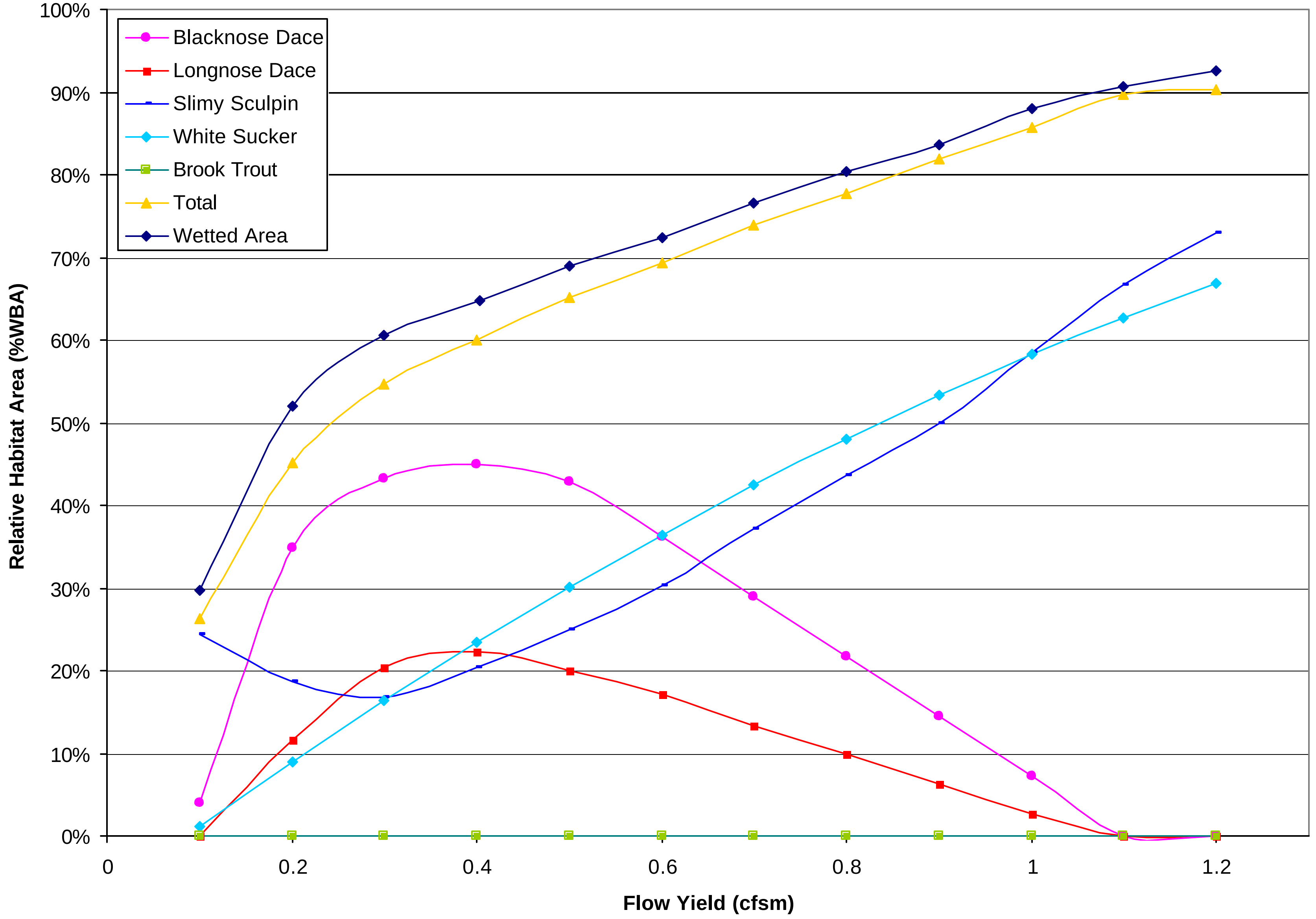

Figure 3.25 Rating curve for relative habitat area versus flow for Management Unit 20.

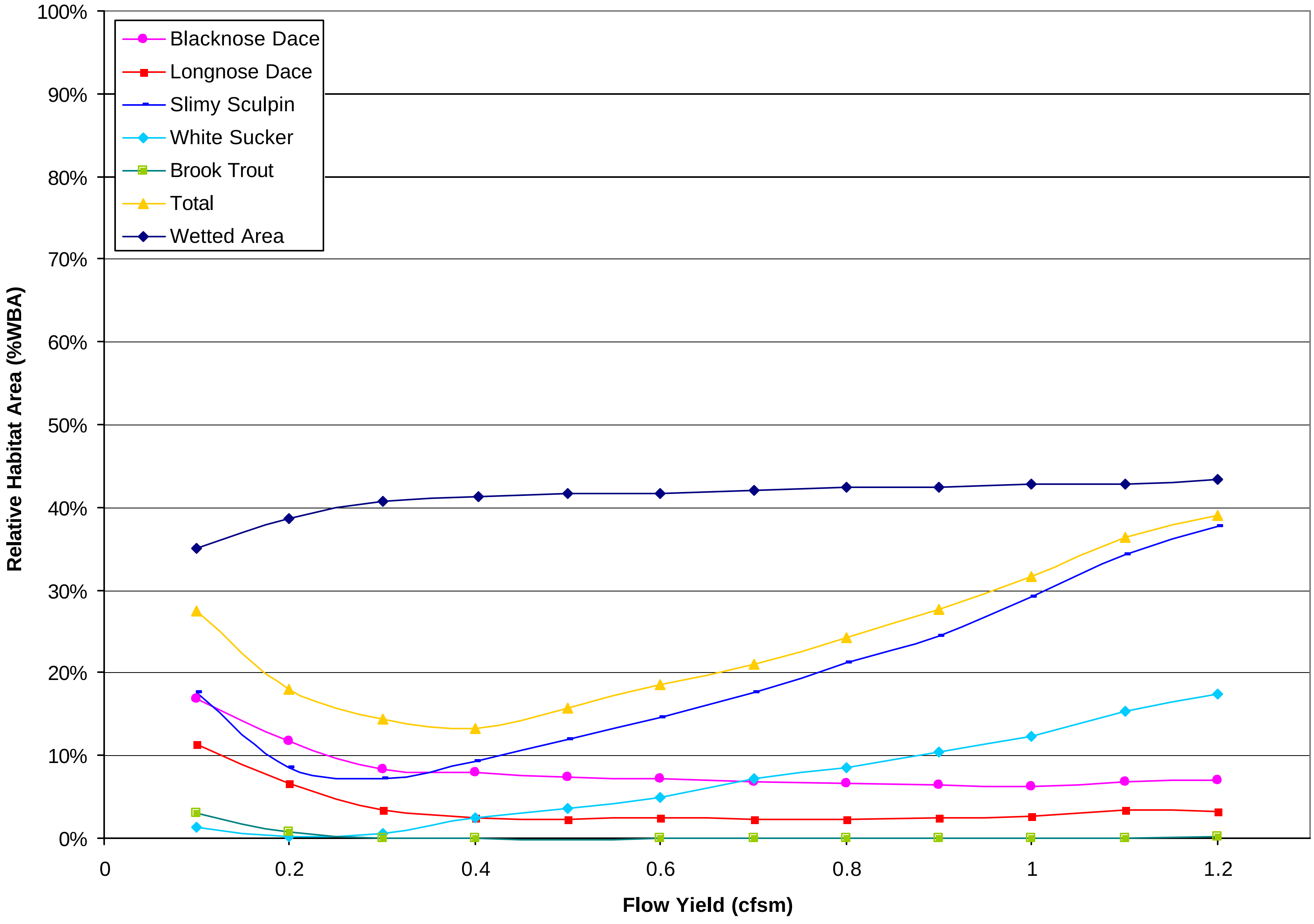

Figure 3.26 Rating curve for relative habitat area versus flow for Management Unit 21.

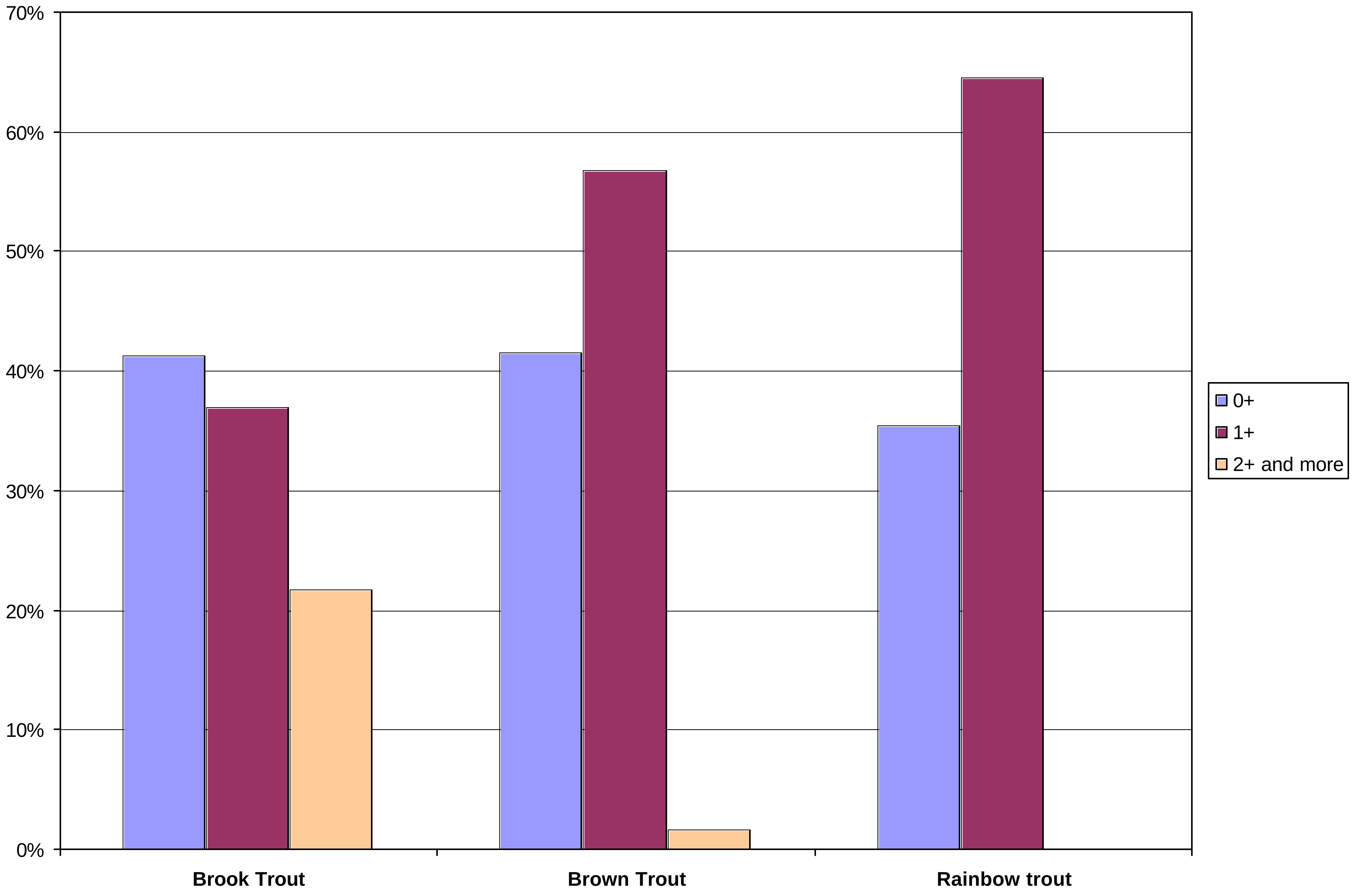

Figure 4.1a Comparison of age structure of brook, brown, and rainbow trout.

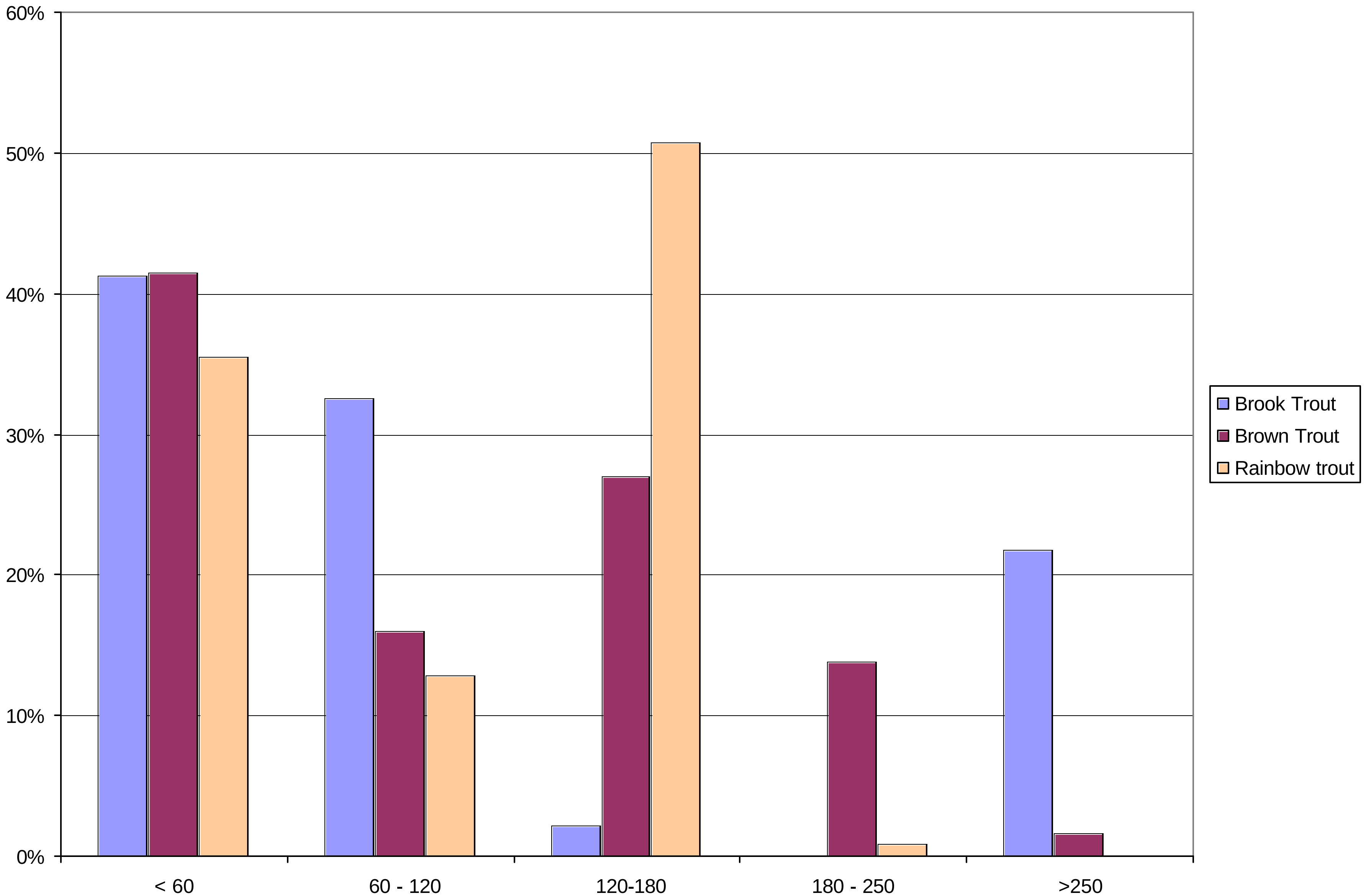

Figure 4.1b Comparison of age structure of brook, brown, and rainbow trout.

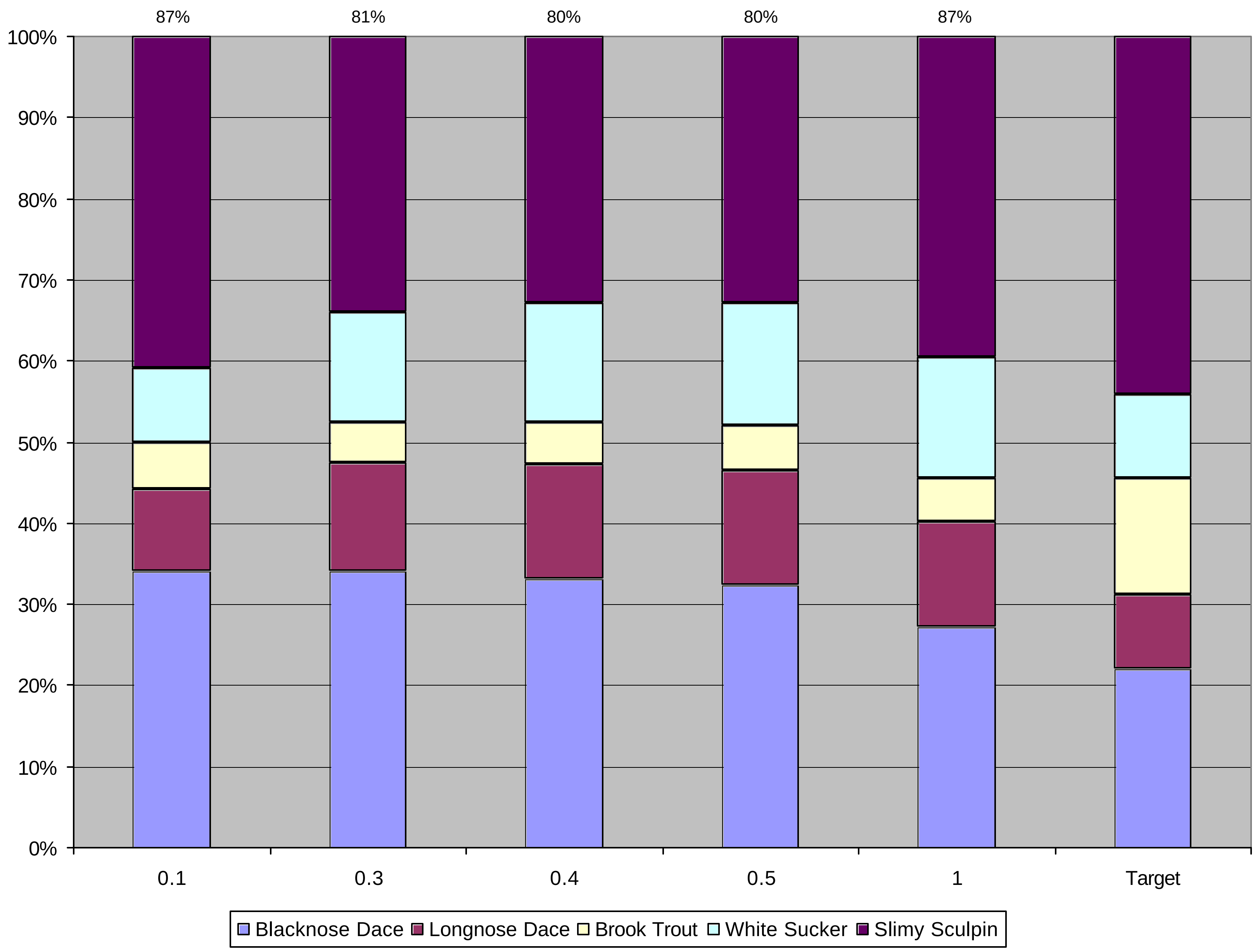

Figure 4.2 Fish habitat structure and corresponding affinity values shown at selected flows for target fish.

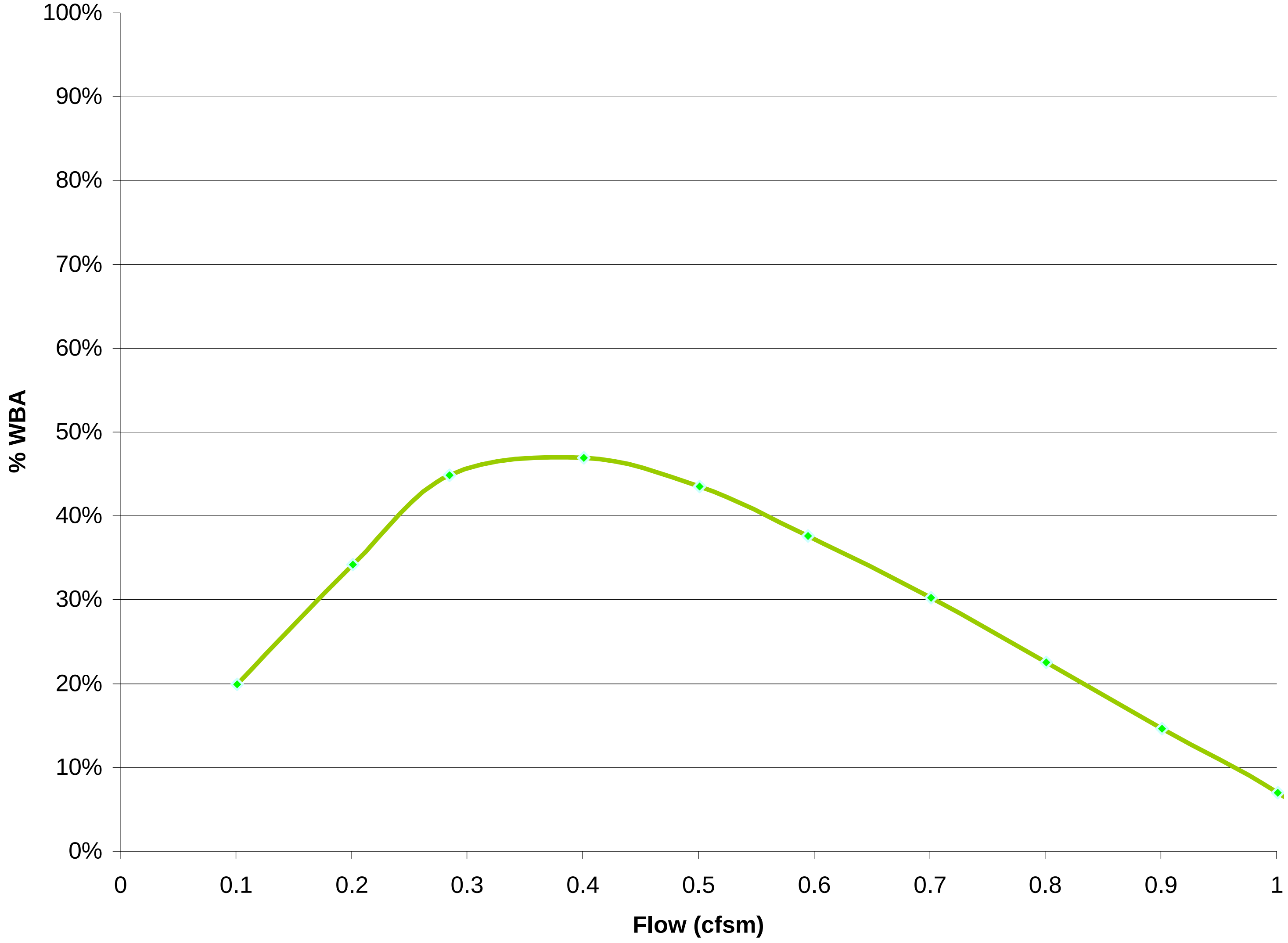

Figure 4.3 Simulation of brook trout habitat including increased woody debris, boulders, and shading.

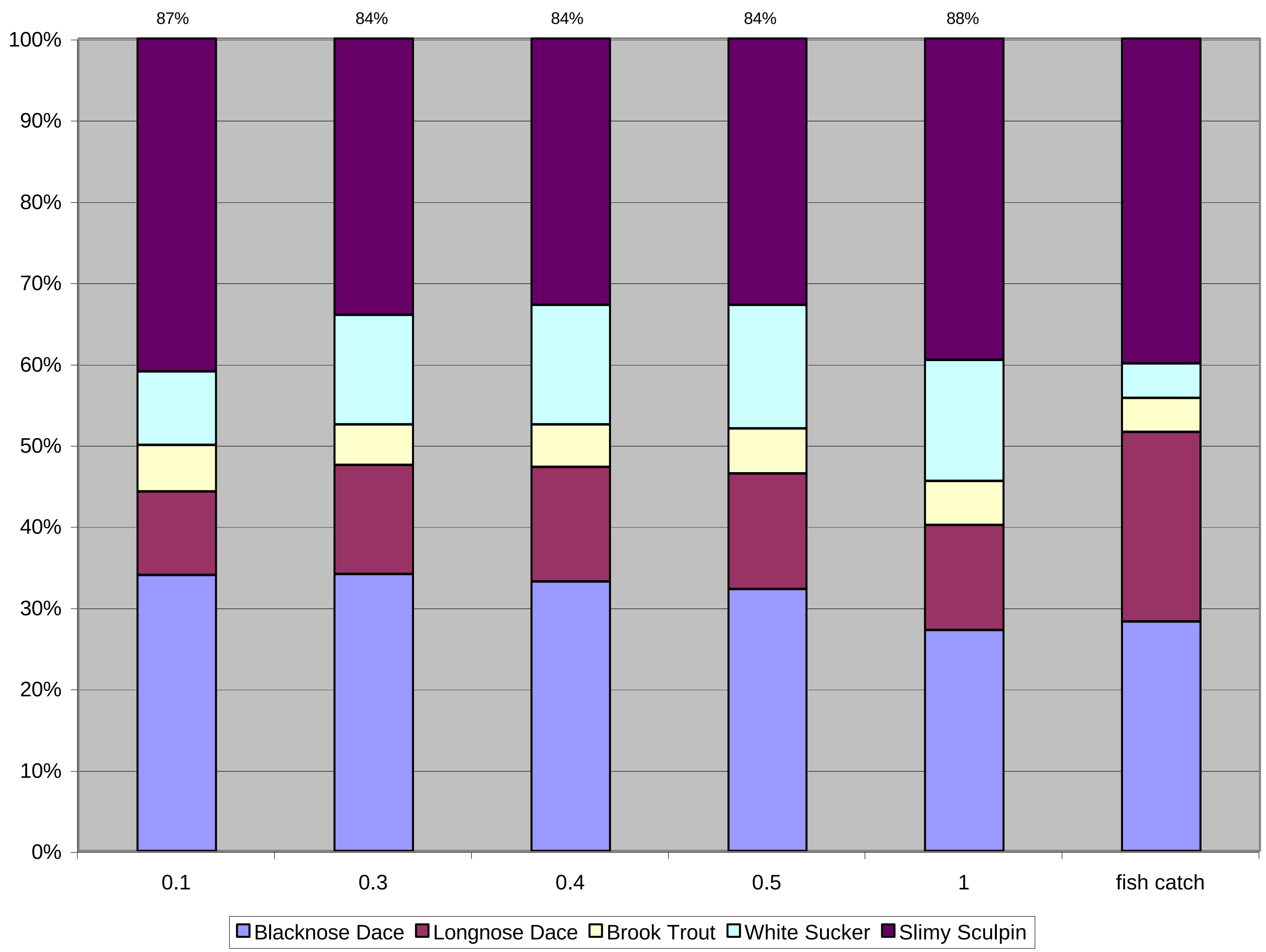

Figure 5.1 Fish habitat structure and corresponding affinity values shown at selected flows for fish catch.