Fish Survey Report

Bushkill Creek and Sober's Run

Northampton County, PA

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To the Bushkill Stream Conservancy

January 24, 2008

Summary

Fish surveys were conducted from July through October 2007 at seven sampling sites on two tributaries and the mainstem of the Bushkill Creek, and at six sampling sites on the east and west branches of Sober's Run, a tributary of Bushkill Creek, located in Northampton County, Pennsylvania. The purpose of the surveys was to confirm the presence of brook trout (*Salvelinus fontinalis*) in the Bushkill Creek Watershed and document the fish species assemblages at the sampling site locations.

A total of 35 brook trout individuals, ranging in total length from 60 to 245 mm (2.4-9.7 in.), were found at four sampling sites on Bushkill Creek. A total of 8 brook trout individuals, ranging in total length from 65 to 320 mm (2.5-13.0 in.), were found at two sampling sites on Sober's Run.

A total of 19 fish species were identified during the surveys on Bushkill Creek and Sober's Run, with 18 fish species identified at the sampling sites on Bushkill Creek, and 17 fish species identified at the sampling sites on Sober's Run.

Length-frequency distributions of brook trout individuals collected during the surveys indicate reproduction is occurring in small, self-sustaining brook trout populations in both Bushkill Creek and Sober's Run.

Introduction

The 80 square mile Bushkill Creek Watershed is located almost entirely within the Great Valley Section of the Ridge and Valley Physiographic Province, in Northampton County, Pennsylvania. Main watershed streams include the 21 mile Bushkill Creek, and its two main tributaries, Sober's Run and the Little Bushkill Creek.

The Bushkill Creek Watershed can be viewed as having an upper basin, of mainly non-carbonate shale bedrock, and a lower basin, of primarily limestone and dolomite bedrock. In the upper basin, water from springs on the southern slope of the Blue Mountain (Kittatinny Ridge) begin the headwaters that gather and flow south through the shales of the Ordovician-aged Martinsburg Formation. In this upper basin, with gently rolling terrain, stream pH ranges from 6.3 to 7.5, and stream flow varies considerably in response to precipitation, with rapid run-off and minimal underground drainage (Bradt 1974; Bradt 1999). By contrast, the lower basin, fed by numerous limestone springs, has less variable stream flow, and stream pH ranges from 7.2 to 8.9 (Bradt 1974; Bradt 1999).

Within the watershed, water temperatures are low enough (66^0F or about 19^0C in July and August) and dissolved oxygen levels high enough (minimum of 7 mg/l) for the Bushkill Creek and its tributaries to be designated as HQ-CWF (High Quality Waters and Cold Water Fish) in The Pennsylvania Code Title 25, Section 93.9c. Drainage List C**.**

Located in the upper basin of the watershed, the fish survey area included Bushkill Creek, from its headwaters to approximately 3 miles upstream of its entry into the Jacobsburg Environmental Education Center, and the east and west branches of Sober's Run, a tributary of Bushkill Creek. The purpose of the survey was to confirm the presence of brook trout in the survey area and document the fish species assemblages at the survey sites. The last officially confirmed report of brook trout in the Bushkill Creek Watershed was in 1976 by the Pennsylvania Fish and Boat Commission on a section of Bushkill Creek about .5 miles downstream of Copella (Stream Examination Report PFBC Bushkill Creek section 02, September 15, 1976).

Brook trout were the targeted fish species of the survey because of their ecological value. Brook trout require cold, clear, stream water for sustainable populations, and so, are ecological indicators of such conditions, which in Pennsylvania are usually provided by extensively forested habitat of high ecological integrity. Strong wild brook trout populations demonstrate that a coldwater stream or river ecosystem is healthy and that water quality is excellent. A decline in brook trout populations can serve as an early warning that the health of an entire system is at risk (EBTJV 2006).

Once found in nearly all of Pennsylvania's streams (MacCrimmon and Campbell 1969), brook trout have had their range reduced over the last 200 years to where only 1% of the state's subwatersheds now have intact brook trout populations (>90% of historical habitat occupied by self-reproducing brook trout) (EBTJV 2006). A subwatershed typically contains 25-75 miles of streams. In subwatersheds where self-sustaining populations were present, 39% have lost over half the habitat supporting brook trout, and 34% of Pennsylvania's subwatersheds have been documented as having brook trout being extirpated or no longer present (EBTJV 2006). A map created by Trout Unlimited in 2006 of Pennsylvania's brook trout status by subwatershed (map 1) shows Northampton County's Monocacy Creek and Martin's Creek as greatly reduced (1-50% historical habitat occupied by self-reproducing brook trout) and Bushkill Creek as being extirpated for brook trout.

As Pennsylvania's only native stream salmonid the brook trout is a coldwater species dependent on waters colder than 24^0C or 75.2^0F, making summer stream temperatures an important factor influencing their distribution and abundance (MacCrimmon and Campbell 1969). The apparent upper limit for the natural occurrence of self-sustaining populations is about 19^0C or 66.2^0F, with the optimum temperature range for growth reported at 10-19^0C or 50-66.2^0F (Hokanson *et al.* 1973).

Although brook trout are generally more acid tolerant than other salmonid species, with brook trout in Pennsylvania reported to have inhabited a bog stream with a pH less than 4.75 (Dunson and Martin 1973), their optimal pH range is reported to be 6.5-8.0 (Creaser 1930; Raleigh 1982). Stream alkalinity levels (the amount of dissolved calcium carbonate) has been associated with brook trout growth, with higher alkalinity increasing the probability of a stream supporting harvestable-length ($\geq$7 in.) brook trout (Kocovsky and Carline 2006) and having greater annual net brook trout production (Cooper and Scherer 1967).

Stream fertility has also been related to size at first maturity. Brook trout inhabiting softwater, infertile, freestone streams in Pennsylvania have been found to grow slowly and mature at a small size; while those in hardwater, fertile, limestone streams grow fast and mature at the same age, but at a larger size (Cooper and Scherer 1967).

In both infertile and fertile streams wild brook trout are relatively short-lived, with few living more than four or five years and none more than six years in one study (Cooper 1967). Sexual maturity has been reported to be attained by the majority of brook trout in infertile Pennsylvania streams at age 2 (3rd year of life), although many males and females mature at age 1 (2nd year of life) (Wydoski and Cooper 1966). Most of these individuals mature, spawn, and

die before reaching six inches in total length, with spawning occurring each year from September to early November (Wydoski and Cooper 1966).

In general, brook trout populations have been found to respond most negatively to factors that lower survival of brook trout near the age of first reproduction (large juveniles and small adults with high reproductive value), and to factors that decrease the growth of small juveniles (Marschall and Crowder 1996).

Human activity that warms stream water, increases siltation, and negatively alters stream chemistry, such as deforestation and development, can impact environmentally sensitive brook trout populations at all life stages. Within the Mid-Atlantic region (MD, PA, WV, VA, NJ) it has been found that when human land use exceeded 18% in a subwatershed, brook trout were likely extirpated, while in subwatersheds where human land use was less than 10%, intact populations were most likely to be found (Hudy et.al 2005). In watersheds where impervious surface area (roads, rooftops, parking lots) exceeded 4%, brook trout were eliminated, with substantial reductions in populations occurring with as little as .5% impervious surfaces (Southerland 2005).

Introduction of the European brown trout, having a higher tolerance of warmer water conditions and generally larger maximum size, has led to this exotic species outcompeting, displacing or replacing native brook trout in some stream habitats.

Differences in the distribution of brook and brown trout in Pennsylvania's Ridge and Valley Physiographic Province have been related to a stream's base-flow pH, gradient, and elevation (Kocovsky and Carline 2005). Exclusively allopatric (brook trout only), and brook trout predominated populations (more than 50% brook trout), tend to occur in more acidic, steeper, higher elevation streams; while brown trout predominated and allopatric brown trout populations increase with a lower gradient and elevation, and pH levels above 7.0 (Kocovsky and Carline 2005). As pH decreases from 7.1 to 6.1, it has been found that the proportion of brown trout to brook trout in mixed communities decreases sharply from equal proportions of each species, on average, to brook trout only communities (Kocovsky and Carline 2005).

This "headwaters-brook trout" and " lower reaches-brown trout " distributional pattern may be related to the brown trout's observed physical limitation (caused by a loss of body sodium affecting circulation) at acidic pH, resulting in a reduced ability to compete against brook trout for habitat and food at increasingly acidic stream pH levels (Kocovsky and Carline 2005). Another possible contributing factor is that the brown trout first stocked in Pennsylvania in the 1880's originated from European strains that were adapted to more alkaline conditions (Kocovsky and Carline 2005).

Whatever the reasons, the existing distributional pattern of brook trout in Pennsylvania makes forested headwater streams important refuges for brook trout populations. Recognizing the need to protect these populations, the Pennsylvania Fish and Boat Commission in June 2007 submitted an amendment to the Pennsylvania Wildlife Action Plan, adding the eastern brook trout as a species of greatest conservation need.

As part of the amendment, various conservation, management, and enhancement goals and objectives, derived from Pennsylvania's Brook Trout Conservation Strategy, are outlined. The goals and objectives focus on improving conditions for wild brook trout populations on a statewide basis. Goal 1: "Improve the scientific basis for making conservation decisions for wildlife, with special emphasis on species of greatest conservation concern", has a strategic objective to "inventory unassessed waters to confirm presence of brook trout" (Pennsylvania Wildlife Action Plan Amendment #1). This fish survey addresses that objective by documenting the status of brook trout populations in the Bushkill Creek Watershed.

Sampling Sites

The survey sampling sites can be described as being on low (1-2) order, low gradient, wadeable stream reaches generally having a series of riffle, run, and pool habitats. With primarily shale substrate, the stream reaches could be considered freestone and relatively infertile, particularly at upstream sites. The substrate size ranged from mostly boulder and cobble, to pebble, gravel, and sand, with silt at some locations. The type and amount of surrounding riparian vegetation varied with site location.

A total of seven sampling sites were surveyed on Bushkill Creek: site #1 on the east (Katellen) branch, site #2 on the west (Bender's Junction) branch, and sites #3-7 progressing downstream on the mainstem from Copella to Hahn Road. A total of six sampling sites were surveyed on Sober's Run: sites #1 and #2 on the east fork of the west branch, site #3 on the west fork of the west branch, site #4 on the west branch at the Jacobsburg Environmental Education Center boundary, and sites #5 and #6 on the east branch. Map 2 shows the locations of the sampling sites. A summary of the sampling site characteristics can be found in Appendix A-1, with selected site photographs in Appendix A-2.

All sampling sites except one were located on private land, requiring land owner permission prior to sampling.

Methods

Fish surveys were conducted from July through October during low-flow conditions. Fish assemblages at the sampling sites were surveyed using a Smith-Root, Inc. Model 12-B battery operated backpack electrofishing unit. A two-member team captured the stunned fish in dip nets while working upstream over varying stream lengths, mainly determined by the extent of the landowner's property. Since low-flow conditions during the sampling period often concentrated fish in pool zones isolated by sections of shallow riffles, the pool habitats were targeted to maximize effort. When water depth allowed, riffle zones were sampled to obtain representative fish species.

During collection in a pool or riffle, fish were removed and placed into buckets to assure for thorough sampling. All fish collected during the survey were identified to the species level and released. Brook trout individuals were counted and measured for total length, with photographs of selected brook trout taken for documentation. Stream temperature was also recorded with a hand-held thermometer during each sampling period and a general habitat description of each site was noted. Water pH was measured using a LaMotte colorimeter and stream alkalinity using a LaMotte alkalinity test kit.

Results and Discussion

The fish surveys resulted in a total of 18 fish species identified at the seven sampling sites on Bushkill Creek, and a total of 17 fish species identified at the six sampling sites on Sober's Run. There was a total of 19 fish species for all sampling sites on Bushkill Creek and Sober's Run. A table summarizing the fish species collected for each sampling site can be found in Appendix B, and a table listing fish species guild classifications can be found in Appendix C.

White sucker (*Catostomus commersoni)*, and creek chub (*Semotilus atromaculatus*) were found at all sites on Bushkill Creek and Sober's Run. Blacknose dace (*Rhinichthys attratulus*), cutlips minnow (*Exoglossum maxillingua*), and tessellated darter (*Etheostoma olmstedi*) were found at all sites on Bushkill Creek, and, with the exception of cutlips minnow, at a majority of sites on Sober's Run. Brown trout (*Salmo trutta*) became more prominent at downstream sampling sites.

These indicator species may be used to generally classify the fish assemblages at the sampling sites as coldwater/transitional (mean temperature = 17^0 C or 62.6^0F) fish

communities. Within this category, The Pennsylvania Aquatic Community Classification Project Phase I Final Report 2004 has described Community 1 (Dace and white sucker dominant cold/transitional community) as a: "community found throughout the state in primarily first- and second-order streams that maintained a cool summer temperature of approximately 16°C. The dominant species that defined this community were longnose and blacknose dace, along with white sucker and cutlips minnow, though other generalist headwater species such as creek chub were also commonly present."

The increased presence of brown trout at downstream sites, particularly on Sober's Run, may categorize some sampling sites as Community 2 (Non-native trout dominant cold/transitional community) described in The Pennsylvania Aquatic Community Classification Project Phase I Final Report 2004 as: "very similar to Community 1 in terms of physical stream characteristics. These two communities were the most similar in terms of general species assemblage, but the dominance of non-native brown and rainbow trout may indicate that past or present trout stocking programs have influenced the separation of these two groups."

Water temperatures measured in mid-August at Bushkill Creek sampling sites ranged from 17-22^{0}C. For Sober's Run, sampling site water temperatures measured for all but one site in September and October, ranged from 10-20^{0}C.

Brook trout populations totaling 35 individuals at four sampling sites on Bushkill Creek, and 7 individuals at one sampling site on Sober's Run (another site had just a single brook trout) indicate stream conditions at these stream sections, particularly summer water temperatures, are currently sufficient for their occurrence. Brook trout have been associated with Community 1 and to a lesser degree Community 2 in The Pennsylvania Aquatic Community Classification Project Phase I Final Report 2004. Photographs of several brook trout individuals collected can be found in Appendix D.

The presence of YOY or young-of-the-year (age 0) brook trout ($\leq$80mm total length or 2-3 in.) and the number of individuals collected with total lengths < 180mm or < 7 in. (7 in. is minimum stocking size) provides evidence that successful spawning must be taking place in sections of the Bushkill Creek and Sober's Run.

A table in Appendix E lists the number of brook trout collected at each site and their total lengths. Appendix F contains length-frequency histograms for all brook trout individuals collected and summed for Bushkill Creek Sites #1-4 (figure 1 a and b), and for each of these sites separately (figure 2 a-d). Length-frequency histograms for brook trout individuals collected at Sober's Run Site #1 are also found in Appendix F (figure 3a and b).

Since brook trout spawn only once a year in the fall, with all the eggs hatching around the same time the following spring, that set of young tend to grow at about the same rate for the first few years of life. The yearly separation between the hatching and growth of fish of different ages can be related to their lengths, and the grouping of different age classes.

The length histograms for Bushkill Creek Sites #1-4, separate the lengths of individuals by 5mm increments (figure 1a), and length groups associated with age classes (figure 1b). In naturally reproducing trout populations, a length histogram will be skewed to the left side, indicating YOY (age 0) and trout in their second (Age 1) and third (Age 2) year of life, with decreasing numbers of individuals as size increases (Schoss, Sharpe, Carline 2003). Characterizing a small, but self-sustaining brook trout population, Figure 1b displays this pattern: with YOY present, relatively strong age 1 and age 2 classes (classes with the highest reproductive value), and a decreasing abundance of individuals over 180mm (>7 in.). Figure 3b shows a similar pattern, indicating natural reproduction is also occurring in Sober's Run.

Of the total number of brook trout individuals collected, 20% at sites on the Bushkill Creek, and 7% at Sober's Run Site 1 were >180mm (>7 in.) in total length. One brook trout, or 2.9% of those collected at sites on Bushkill Creek, was 245mm (9.7 in.) in total length. In analyzing 25 years of Pennsylvania wild trout stream data, biologists from Pennsylvania Fish and Boat Commission found very few legal brook trout ($\geq$7 in.) and no brook trout nine inches or longer in half of the state's infertile, freestone, wild brook trout streams (Kaufman 2003).

Using past studies as a reference, brook trout $\geq$ 180mm (>7 in.) in infertile streams are likely in their fourth (age 3) year of life, and trout > 230mm (>9 in.) are possibly in the fifth (age 4) year of life (Cooper 1967); (Cooper and Scherer 1967); (Wydoski and Cooper 1966). The estimated longevity of some of the brook trout collected may be representative of populations in equilibrium with their natural environment with light levels of exploitation (Cooper 1967).

One large brook trout with a total length of 325 mm (13 in.) was collected in late August at site #4 on Sober's Run, in a deep pool beneath the damaged bridge on Keller Rd. It is possible that this fish was naturally occurring, having moved into the stream section from an upstream location. Large adult brook trout have been found to be significantly more mobile than small adults, using this mobility to access more productive, larger-sized stream reaches throughout a watershed in the summer months, then returning upstream in the fall to spawn (Petty and Lamothe 2005). But the size of this individual greatly exceeds expectations, and the fact that no other brook trout were found at this site, or other sites in direct sequence upstream, makes the origin of this trout questionable.

Of the sites sampled, Bushkill Creek Site #1 and Sober's Run Site #1 were found to have exclusively allopatric, brook trout only, populations. Bushkill Creek site #2 on the west (Bender's Junction) branch was found to have a brook trout-predominated population with 79% of the nineteen trout collected being brook trout with the remaining being brown trout. Brown trout were collected only from the downstream-most pool in the sampling length.

The stream at Bushkill Creek Site #1, part of the east (Katellen) branch, receives water from a large, red maple-highbush blueberry swamp upstream. The stream was at base-flow during the time of sampling in August and was tannin-colored, likely a result of organics received from the wetland. At a later date, during higher flow, the water was clear, with a measured pH of 6.5 and an alkalinity of 22 mg/l. It is conceivable that the water's pH would be lower when at base-flow and tannin-colored.

Sober's Run Site #1, at the headwaters of the east fork of the west branch of Sober's Run, flows through mature deciduous forest with some of the larger trees estimated at 150 years of age (William Sweeney, personal communication). The stream had a measured pH of 6.3 and an alkalinity of 20 mg/l. Bushkill Creek site #2 also flows through mature deciduous forest, with sections lined by eastern hemlock and giant rhododendron. The stream had a measured pH of 6.6 and an alkalinity of 20 mg/l.

One possible reason for these three sites having allopatric and brook trout-predominated populations may be the competitive restrictions placed on brown trout by more acidic water, resulting in the pattern observed in Pennsylvania streams of an increasing proportion of brook trout in mixed brook-brown trout populations as base-flow pH declines below 7.1 (Kocovsky and Carline 2005).

This factor may be protecting the existing brook trout from encroachment by brown trout, while the still adequate habitat conditions provided by the surrounding landscape act as a buffer against the human impacts affecting lower stream reaches.

If so, these headwater streams, requiring intact forests and wetland complexes to maintain them, serve as reproductive havens, critical to the persistence of brook trout populations in the Bushkill Creek Watershed.

Acknowledgements

I'd like to thank Mr. William Sweeney, Jacobsburg Environmental Education Center, for his assistance with the fish surveys, and his time in acquiring landowner permission.

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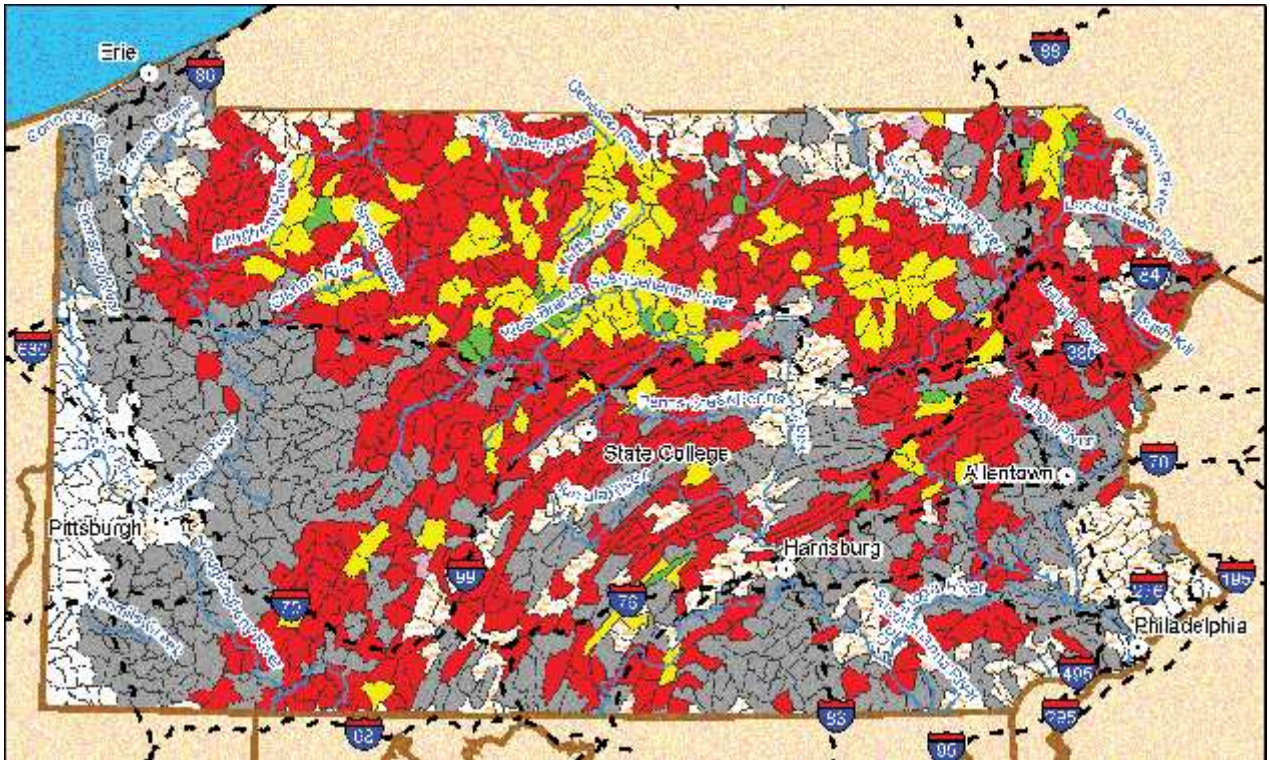
MAP 1: Pennsylvania Brook Trout Population Status by Subwatershed



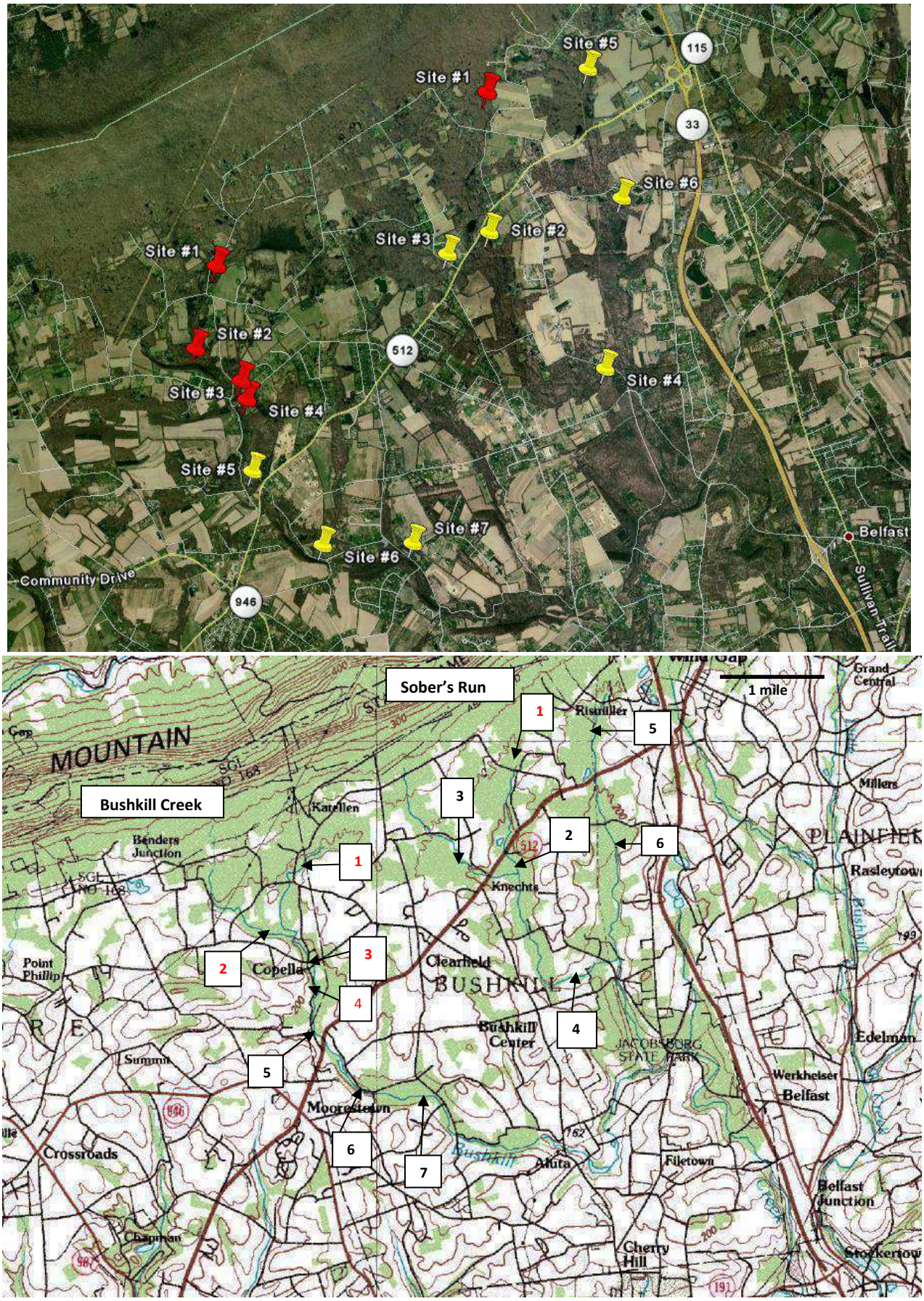
Legend

- Intact (16)
- Reduced (118)
- Greatly Reduced (507)
- Qualitative Presence (5)
- Extirpated (449)
- Unknown, No Data (218)
- Never Occurred (72)
- Rivers
- Lake
- Interstate
- Cities

0 25 50
Miles

Subwatershed Classifications within Lehigh Valley

Map data derived from state and federal data and compiled in EBTJV assessment results titled, *Distribution, status, and perturbations to brook trout within the eastern United States, 2006.* **Authored by Mark Hudy, US Forest Service; Teresa Thieling, James Madison University; Nathaniel Gillespie, Trout Unlimited; Eric Smith, Virginia Tech. Map created on 2/24/06 by Nathaniel Gillespie, Trout Unlimited.**



MAP 2: Bushkill Creek and Sober's Run Fish Survey Sampling Site Locations.

Red Pins (top satellite image) and Box Numbers (bottom topographical map) designate sites with Brook Trout Populations.

(Sober's Run Site #4 only 1 brook trout individual) (Image sources: ***Google satellite image (USGS and PA DCNR)***; ***USGS topographical map Wind Gap Quadrant***)

Sampling Site	latitude/longitude for Map 2 pin (approx. site center)	Elevation (feet above sea level)	Nearest Road/Bridge crossings	Sampling site length (meters (m) miles (mi.)	Riparian tree buffer	Substrate emdeddedness	Water Temperature Date/Time
Site #1 Bushkill Creek	40 48 48.45 N 75 22 13.37 W	703 ft.	Bushkill Drive bridge upstream	150m (.09 mi.)	decid. forested except near road/fields	low	8/13/07 20.5°C @ 1215 hrs.
Site #2 Bushkill Creek	40 48 15.71 N 75 22 27.43 W	680 ft.	500m downstream of West End Drive bridge	450m (.28 mi.)	mature decid. forest w/some hemlock	low	8/15/07 17°C @ 1130 hrs.
Site #3 Bushkill Creek	40 48 01.61 N 75 22 03.97 W	651 ft.	Bushkill Drive Bridge downstream to Bushkill Center Road bridge	150m (.09 mi.)	narrow to none	low	8/16/07 21°C @ 1530 hrs.
Site #4 Bushkill Creek	40 47 54.04 N 75 22 01.65 W	647 ft.	100m downstream of Bushkill Center Road Bridge	170m (.11 mi.)	narrow /some decid.forested	low	8/17/07 21°C @ 1430 hrs.
Site #5 Bushkill Creek	40 47 24.92 N 75 22 01.12 W	613 ft.	small bridge 50m upstream of Rt. 512	200 m (.12 mi.)	narrow / some decid.forested	some siltation	8/18/07 19°C @ 1315 hrs.
Site #6 Bushkill Creek	40 46 53.36 N 75 21 26.01 W	606 ft.	Creamery Road Bridge upstream	280 m (.17 mi.)	narrow/some conif. forested	some siltation by bridge	8/17/07 22°C @ 1330 hrs.
Site #7 Bushkill Creek	40 46 51.94 N 75 20 38.11 W	566 ft.	25m upstream of Hahn Road Bridge	250m (.16 mi.)	narrow to decid. forested	some siltation by bridge	8/16/07 21°C @ 1345 hrs.
Site #1 Sober's Run	40 49 51.76 N 75 19 44.00 W	707 ft.	150 upstream from East Mtn. Road off Allentown Road	375 m (.23 mi.)	mature decid. forest	low	10/20/07 16°C @1200 hrs.
Site #2 Sober's Run	40 48 55.66 N 75 19 47.06 W	642 ft.	Downstream of Rt. 512 bridge to powerline	310 m (.2 mi.)	decid. forested/ narrow near road	some siltation over cobble	9/24/07 19°C @ 1830 hrs.
Site #3 Sober's Run	40 48 47.82 N 75 20 10.22 W	667 ft.	45m upstream of Rt. 512 off Broad Road	320 m (.2 mi.)	some decid. forested narrow near road	some siltation over cobble	9/24/07 18°C @ 1630 hrs.
Site #4 Sober's Run	40 47 55.77 N 75 18 49.59 W	562 ft.	upstream of Keller Road bridge	425 m (.26 mi.)	decid. forested	low	8/29/07 20°C @ 1600 hrs.
Site #5 Sober's Run	40 49 58.96 N 75 18 49.69 W	701 ft.	370 m upstream of Rt. 512	370 m (.23 mi.)	decid.forested/ open by powerline	some siltation over cobble	7/6/07 NA
Site #6 Sober's Run	40 49 06.25 N 75 18 35.64 W	612 ft.	160 m downstream of Kromer Road	235 m (.15 mi.)	decid. forested	low	10/31/07 10°C @ 1600 hrs.

Appendix A-1: Summary of Sampling Site Characteristics

Appendix A-2

Site #1 Bushkill Creek

Site #2 Bushkill Creek

Fish Species Collected at Bushkill Creek and Sober's Run Sampling Sites (July-October 2007)

		Bushkill Creek Sampling Sites								Sober's Run Sampling Sites					
Common Name	**Scientific Name**	**Site #1**	**Site #2**	**Site #3**	**Site #4**	**Site #5**	**Site #6**	**Site #7**		**Site #1**	**Site #2**	**Site #3**	**Site #4**	**Site #5**	**Site #6**
Brook Trout	*Salvelinus fontinalis*	X	X	X	X					X			X		
Brown Trout	*Salmo trutta*		X	X	X	X	X	X				X	X	X	X
Rainbow Trout	*Oncorhynchus mykiss*							X			X				
White Sucker	*Catostomus commersoni*	X	X	X	X	X	X	X		X	X	X	X	X	X
American Eel	*Anguilla rostratus*			X		X	X	X			X		X	X	
Blacknose Dace	*Rhinichthys attratulus*	X	X	X	X	X	X	X		X			X	X	X
Longnose Dace	*Rhinichthys cataractae*			X		X							X		
Creek Chub	*Semotilus atromaculatus*	X	X	X	X	X	X	X		X	X	X	X	X	X
Fallfish	*Semotilus corporalis*										X				
Cutlips Minnow	*Exoglossum maxillingua*	X	X	X	X	X	X	X					X		X
Common Shiner	*Luxilus cornatus*	X		X	X	X		X			X	X	X		X
Tessellated Darter	*Etheostoma olmstedi*	X	X	X	X	X	X	X		X	X	X	X		X
Bluegill Sunfish	*Lepomis macochirus*				X	X	X				X	X		X	X
Pumpkinseed Sunfish	*Lepomis gibbosus*	X		X	X		X	X		X	X	X	X	X	
Rock Bass	*Ambloplites rupestris*	X		X	X	X	X	X							
Largemouth Bass	*Micropterus salmoides*	X		X	X		X			X	X				X
Margined Madtom	*Notorus insignis*			X											
Brown bullhead	*Ameiurus nebulosus*			X							X				
Redfin Pickeral	*Esox americanus americanus*	X		X	X	X	X	X			X	X	X	X	X
Total Species =19	***Number of Species per Site***	**11**	**7**	**16**	**13**	**12**	**12**	**12**		**7**	**12**	**8**	**12**	**8**	**10**

Appendix B

Fish Species Guild Classifications

Common Name	Scientific Name	EP Tolerance Guild	Feeding Guild	Temperature Guild
Brook Trout	*Salvelinus fontinalis*	I	TC	C
Brown Trout	*Salmo trutta*	I	TC	Ct
Rainbow Trout	*Oncorhynchus mykiss*	I	TC	C
White Sucker	*Catostomus commersoni*	T	GF	E
American Eel	*Anguilla rostratus*	T	TC	E
Blacknose Dace	*Rhinichthys attratulus*	T	GF	E
Longnose Dace	*Rhinichthys cataractae*	M	BI	Ct
Creek Chub	*Semotilus atromaculatus*	T	GF	E
Fallfish	*Semotilus corporalis*	M	GF	E
Cutlips Minnow	*Exoglossum maxillingua*	I	BI	E
Common Shiner	*Luxilus cornatus*	M	GF	E
Tessellated Darter	*Etheostoma olmstedi*	M	BI	E
Bluegill Sunfish	*Lepomis macochirus*	T	GF	W
Pumpkinseed Sunfish	*Lepomis gibbosus*	M	GF	W
Rock Bass	*Ambloplites rupestris*	M	TC	E
Largemouth Bass	*Micropterus salmoides*	M	TC	W
Margined Madtom	*Notorus insignis*	M	BI	W
Brown Bullhead	*Ameiurus nebulosus*	T	GF	W
Redfin Pickeral	*Esox americanus americanus*	M	TC	E

Guild Attributes: Leonhardt (Adapted in-part from: Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities, ed Simon Table 12.1)

Environmental Perturbation Tolerance Guilds

T = Tolerant
M = Intermediate
I = Intolerant (sensitive to a wide range of environmental stresses)

Temperature Guilds

C= Coldwater
Ct = Coldwater transitional
E = Eurythermal (inhabits Cold &W arm waters)
W = Warmwater

Feeding Guilds

GF = Generalist Feeder
BI = Benthic Insectivore
TC = Top Carnivore

Appendix C

Appendix D

Brook Trout *Salvelinus fontinalis*

Number of Brook Trout Individuals per Total Length

Total Length (Inches)	Total Length (Millimeters)	Bushkill Creek Site #1	Bushkill Creek Site #2	Bushkill Creek Site #3	Bushkill Creek Site #4	Sober's Run Site #1	Sober's Run Site #4
2.4	60	1	1		1		
2.6	65					2	
3.1	80			2			
4.75	120					1	
5.1	130			3			
5.3	135		1				
5.5	140	3	1	1		1	
5.7	145		1			1	
6.0	150	2	2		1		
6.1	155		2				
6.3	160		2	1		1	
6.7	170			2			
6.9	175		1				
7.5	190		1				
7.7	195		1				
7.9	200		1				
8.1	205				1		
8.3	210			1			
8.7	220					1	
8.9	225			1			
9.7	245		1				
13.0	330						1
Total Number of Individuals Collected @ Site		6	15	11	3	7	1

Appendix E

Appendix F

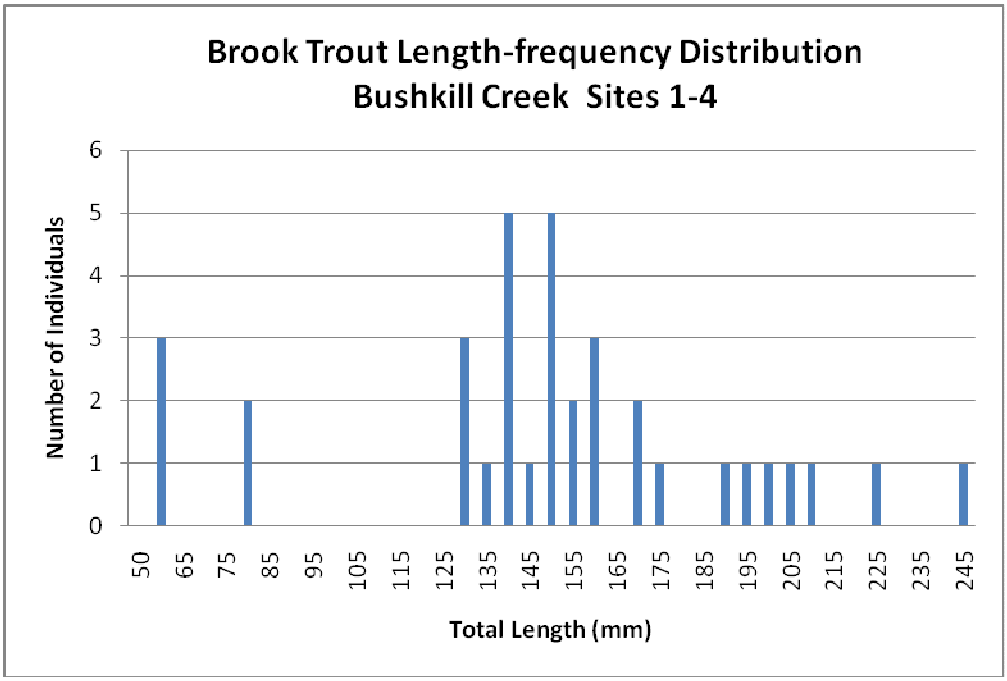


Figure 1a

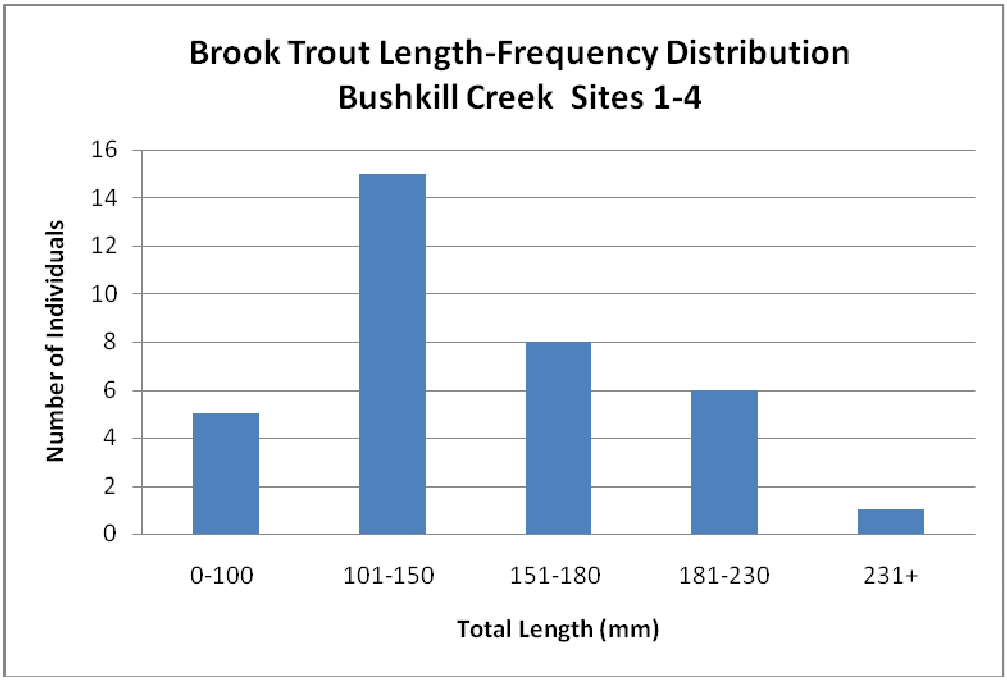


Figure 1b

Appendix F

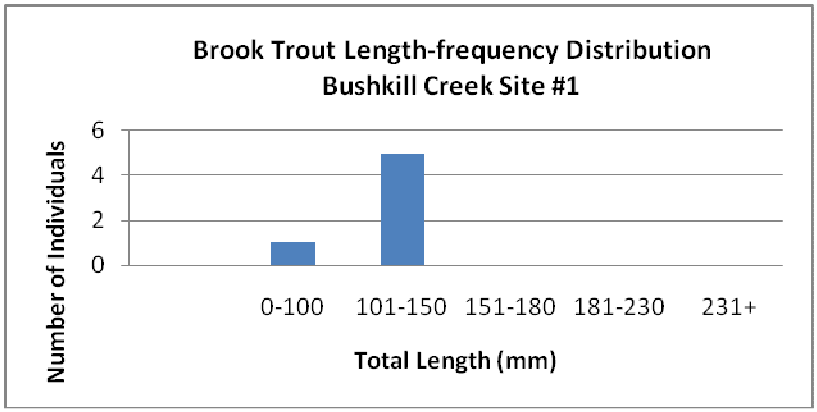


Figure 2a

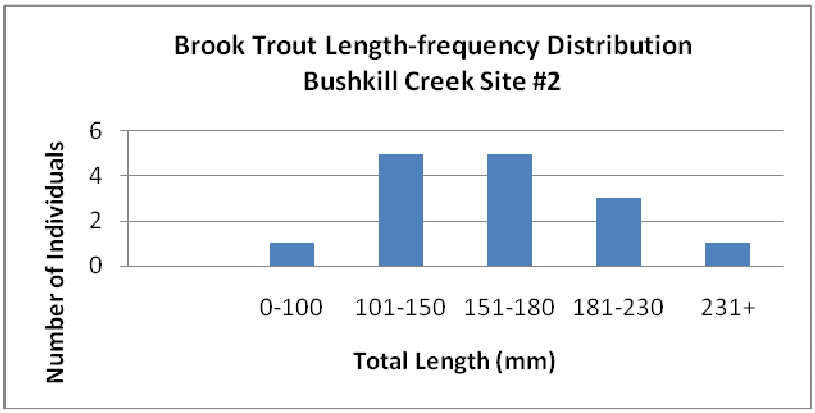


Figure 2b

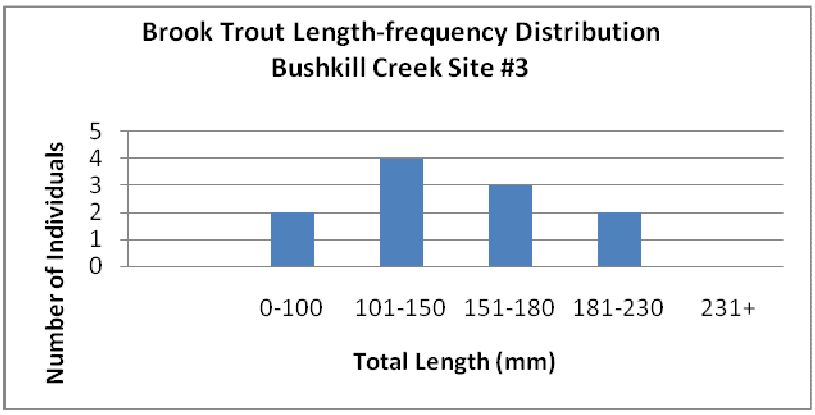


Figure 2c

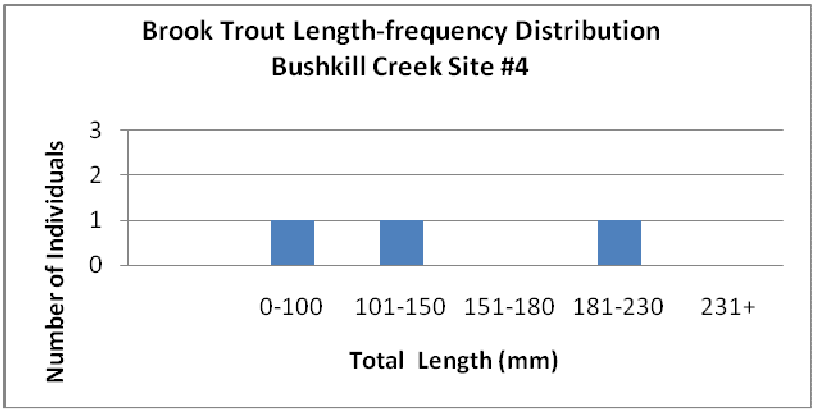


Figure 2d

Appendix F

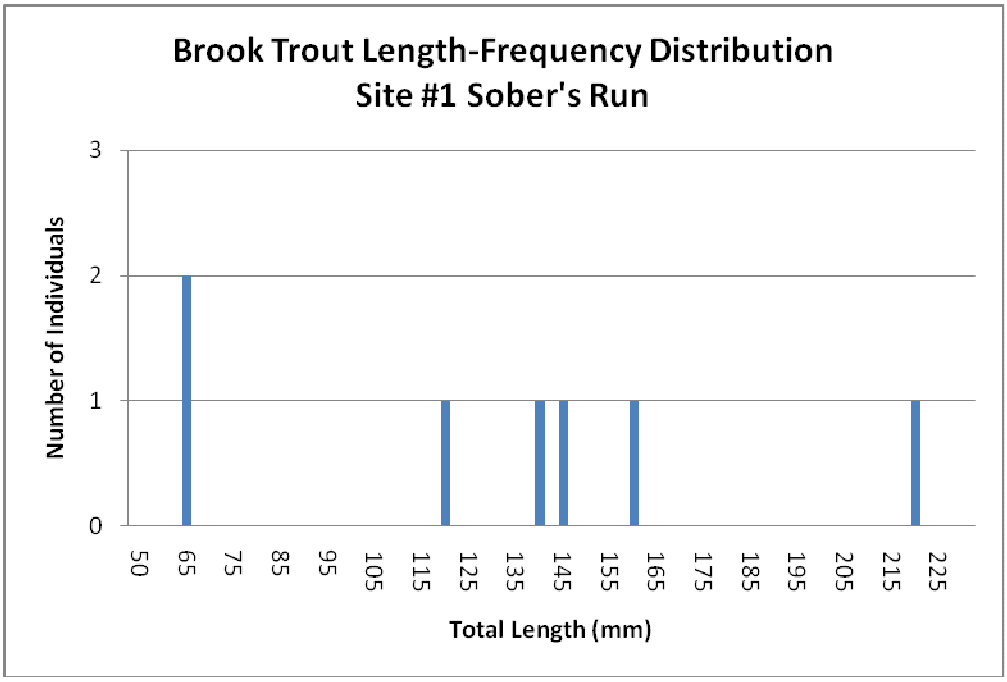


Figure 3a

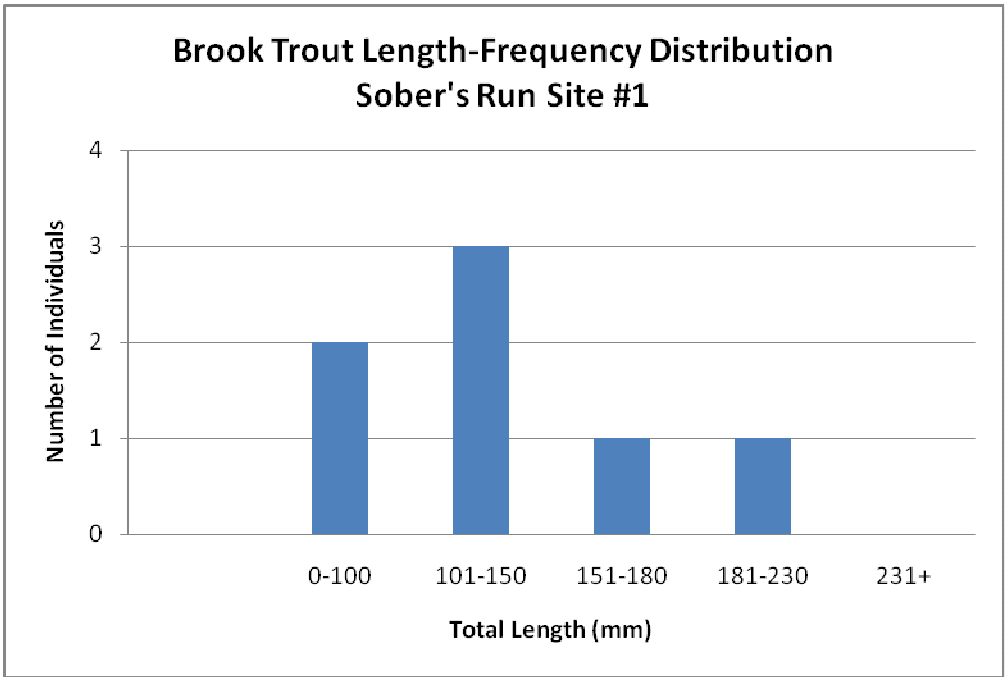


Figure 3b