Index of Biotic Integrity for Mine Influenced Streams; Pigeon Roost Branch and Railroad Fork, Stearns District, Daniel Boone National Forest, 2014

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Introduction

There is a long history of coal mining in Kentucky, including lands currently managed by the Daniel Boone National Forest (DBNF). Most mining was conducted either prior to the period of Forest Service (USFS) ownership or in more recent times in situations where the mineral estate was split from the surface estate prior to acquisition. Because of the potential for significant impacts from mining on water quality, instream habitat, and aquatic biota, managers need to understand how mining has influenced these attributes on lands managed by the USFS. In spring 2014, the DBNF partnered with the USDA Forest Service, Southern Research Station, Center for Aquatic Technology Transfer (CATT) to complete stream habitat, fish, and macroinvertebrate inventories at two streams affected by the Barren Fork Mines: Pigeon Roost Branch and Railroad Fork.

The Barren Fork Mine Site is located within the Indian Creek watershed (part of the Upper Cumberland River basin) on the Stearns Ranger District, approximately two miles east of the District office. The Mine Site is made up of a series of separate coal mines and refuse piles distributed along Barren Fork and its two tributaries, Pigeon Roost Branch and Railroad Fork. These streams are also designated as Outstanding State Resource Waters due to the sporadic presence of the federally threatened Blackside Dace (*Chrosomus cumberlandensis*).

Pigeon Roost Branch and Railroad Fork have been highly impacted by acid mine drainage (AMD), as has the reach of Barren Fork below their confluences. The Barren Fork Mine Site coal refuse piles encompass approximately 47.8 hectares (118 acres) and extend intermittently along both sides of about 5.6 km (3.5 miles) of the three streams. Mining operations in the Barren Fork coal seam were carried out from the 1880's through 1935. The Forest Service purchased this land in Barren Fork in 1936 from the Barren Fork Mining and Coal Company. On these acquired lands, a number of coal mines were inadequately reclaimed after closure. These sites are characterized by both open and collapsed underground mine portals, large acid/toxic-forming coal refuse piles, landslides, AMD, and burning coal refuse.

Our primary objective was to collect stream habitat and biological data to allow for comparison between streams within the mine influenced watershed to streams outside of the mine influenced watershed on the DBNF. From 2005-2013 we completed sampling at 96 stream sites on the DBNF that were randomly selected by the Environmental Protection Agency (EPA) as part of the DBNF's stream monitoring program (Krause et al., 2013; Olsen, 2005). In this administrative study we compare results from streams within the mine influenced watersheds to those from randomly selected streams outside of the mine influenced watersheds.

Methods

Site Selections and Reach Layout

Site selection was based on watersheds known to contain active or historic mining activity. At each site, we measured the wetted width of 1 – 2 fast water (riffle or run) habitat units and calculated the average wetted width. If the average wetted width was ≤ 3.0 m or ≥7.5 m, the sample reach length was 120 m or 300 m, respectively (Appendix A). In all other cases, sample reach length was 40-times the average wetted width.

In addition to the mine sites, the comparison sites, having little to no mine influences, were previously sampled as part of the DBNF's stream monitoring program (2005-2013). Comparison site locations were determined by the EPA's random site selection program for the state of KY (Olsen, 2005). All EPA sites had to meet two criteria: 1) watershed greater than 13 km^2; 2) depth shallow enough for backpack electrofishing. The 96 EPA sites were sampled by the CATT from 2005-2013 using the same methods as used for the mine sites (Krause et al. 2013).

Habitat Inventory

Two-person crews performed abbreviated stream habitat inventories (Roghair and Nuckols 2005) based on the basinwide visual estimation technique (BVET) (Dolloff et al. 1993). For each habitat unit contained wholly or partially within the sample reach, the crew visually estimated or measured the following attributes:

All Habitat Units	Sub-Sample of Habitat Units
Type of habitat	Bankfull channel width
Length and width	Channel gradient
Maximum and average depth	Water temperature
Riffle crest depth	Photographs
Dominant and subdominant substrate	GPS coordinates
Rosgen channel type (Rosgen, 1996)	
Percent fines	
Large wood counts	

When possible, the crew sub-sampled at least 3 fast water and 3 slow water units within each reach.

In addition, the crew noted stream features, including:

- Waterfalls
- Tributaries
- Side channels
- Braided channels
- Seeps (springs)
- Landslides
- Bridges
- Fords
- Dams
- Culverts

See Appendix A and B for detailed field methods.

Fish Inventory

A 4-person crew using a DC backpack electrofisher collected fish from the same stream reach inventoried for stream habitat (see above). The crew attempted to apply standard effort of approximately 1 sec/m^2 of wetted stream habitat, and recorded the following data:

- Species name
- Counts of adult, age-0, and voucher specimens
- Sample reach length, electrofishing time (sec), and voltage
- GPS coordinates of start and end location

See Appendix A for detailed field methods.

Macroinvertebrate Inventory

A 4-person crew collected macroinvertebrates using riffle sample and multi-habitat sample methods described by the Kentucky Division of Water (KDOW 2011). Macroinvertebrates were collected at least one day before fish sampling. See Appendix A and C for detailed field methods.

Pebble Count Inventory

Fish sampling crews conducted pebble counts (Wolman heel-to-toe steps protocol; Wolman, 1954) in riffle habitat units to characterize the substrate in sample reaches. Crew members measured the intermediate axis of a minimum of 200 pebbles per riffle as described in Bunte and Abt (2001) and Kappesser (2002). In addition to pebble counts, bar counts were conducted by measuring the intermediate axis of 30 dominant large particles residing on a bar or similar depositional feature within the sample reach. See Appendix A and D for detailed field methods.

Kentucky Index of biotic Integrity (KIBI)

Fish collection methods differed between KDOW (2002), Compton et al. (2003), and our methods. Fish data collected by KDOW (2002) occurred between mid-March and the end of October. For headwater streams (<6 mi^2 drainage area), sample reaches included fast and slow habitat types, were 100-125 m in length, had an electrofishing effort of 600-1,000 sec, and a seine was used when larger pool habitat was present (KDOW 2002). For wadeable streams (>10 mi^2 drainage area), sample reaches included fast and slow habitat types, were 100-200 m, had an electrofishing effort of 600-1,800 sec, and a seine effort of 30-60 min (KDOW 2002).

The fish collection methods described by Compton et al. (2003) for use in the development of the KIBI were based on KDOW (2002) and occurred from mid-March to mid-October. Of the 388 collections for KIBI development, some sites were sampled with a seine (n=78), a backpack electrofisher (n=180), or a combination of the two gears (n=130) (Compton et al. 2003). Sample reaches covered all available habitat types, were 100-250 m, and had a sampling effort of 30-180 min (Compton et al. 2003).

Our fish sampling took place in June. Sample reaches included both slow and fast water habitat types, were 93-156 m, and had an electrofishing effort of 270-781 sec, standardized to 1.0 m^2/sec (Appendix A).

Kentucky Macroinvertebrate Bioassessment Index (MBI)

Our macroinvertebrate collection methods (Appendix C) were developed by Pond et al. (2003) and the KDOW (2002). Pond et al. (2003) sampled headwater streams (<5 mi^2 drainage area) from mid-February through late May, and wadeable streams (~5 to 200 mi^2 drainage area) from June through September. We sampled all 7 headwater sites within this time period during May. Like Pond et al. (2003), we collected the riffle sample with a kick seine, 0.25 m^2 sample square, and sieve bucket, and the multi-habitat sample with a D-frame net and sieve bucket (Appendix C).

Results

In 2014 we completed macroinvertebrate, habitat, and fish inventories at 7 sites (Figure 1, Table 1). GPS coordinates for the downstream and upstream end of each inventoried reach are available in Table 2. These data can be used to describe stream condition on the DBNF and serve as a baseline for future comparisons. Additionally, for comparison we evaluated data at 96 EPA randomly selected site locations distributed throughout the DBNF (Figure 2).

Habitat Inventory

The sample site reaches had mean average pool depths ranging from 18 to 38 cm, average bankfull channel widths from 5.8 to 8.1 m, channel gradient from 1 – 3%, and were classified as Rosgen channel types B, C, and F (Table 3). The upstream site on Railroad Fork (DBF02013715) had very high average percent fines (i.e. streambed surface covered with sand, silt, or clay) in pools (83%) and riffles (30%) (Table 3). Two other sites also had high (>35%) average percent fines in pools; the downstream site on Pigeon Roost Branch (DBF02013708) and the second furthest upstream site on Railroad Fork (BDF02013714) (Table 3). The Pigeon Roost Branch sites had lower median average percent fines in pools, as well as riffles, than the Railroad Fork sites, but both were within the range found at the EPA randomly selected sites located throughout the DBNF (Figure 3).

The total area of pools and riffles (Table 4) were relatively similar due to only small differences in inventory length (Table 1) and wetted width (Table 3). All sites on Pigeon Roost Branch and Railroad Fork had a greater percentage of pool than riffle habitat, with the sole exception being Pigeon Roost

Branch site DBF02013716 that was split evenly (Table 4). The median percent pool and riffle area of the Pigeon Roost Branch and Railroad Fork sites were within the range found at the EPA random sites (Figure 4).

The quantity of total large wood per kilometer (LW/km) ranged from 123 to 484 pieces (Table 5). The median amount of LW/km at the Railroad Fork sites is high, exceeding the upper range of LW/km at both Pigeon Roost Branch and the EPA random sites (Figure 5).

The dominant and subdominant substrate in pools and riffles varied by site, but included clay, silt, sand, small gravel, large gravel, cobble, boulder, and bedrock (Table 6). The Pigeon Roost Branch sites had bedrock most frequently occurring in pools and cobble in riffles (Figures 6 and 7). The Railroad Fork sites had small gravel most frequently occurring in pools and large gravel in riffles (Figures 6 and 7). In riffles, the Pigeon Roost Branch and Railroad Fork site's cumulative occurrence of substrate types was similar in pattern to the EPA sites (Figure 7). Whereas in pools, when compared to the EPA sites, the Pigeon Roost Branch sites had fewer, and the Railroad Fork sites more, small gravel to boulder sized substrates (Figure 7).

Fish Inventory

We collected a total of 7 fish species among the 7 sites; we found 7 species in Pigeon Roost Branch and 4 species in Railroad Fork (Table 7). The most prevalent species were Creek Chub (present at all 7 sites) and White Sucker (present at 5 sites) (Table 7). Spotfin Shiner, Fantail Darter, and Lamprey were found in Pigeon Roost Branch, but not Railroad Fork (Table 7). Creek Chub were the most numerous species while all other species were found in relatively low numbers. Some species were only found at a single site within Pigeon Roost Branch and/or Railroad Fork (Southern Redbelly Dace, Spotfin Shiner, and Lamprey) (Table 7). The number of fish species in Pigeon Roost Branch was the lowest at the upstream site and the opposite occurred in Railroad Fork where the upstream site had the most species. Compared to the EPA sites (n=86 had electrofishing conducted out of the 96 sites), which had a median of 12 species/site (range 2 min. and 23 max.), the Pigeon Roost Branch (median of 5 species/site) and Railroad Fork (median of 2 species/site) sites had far fewer species (Figure 8). Railroad Fork's median value is just below the minimum range found among the EPA sites (Figure 8).

Macroinvertebrate Inventory

The macroinvertebrate samples were given to the DBNF (Jon Walker, DBNF Forest Hydrologist) for identification by a contracted entomologist.

Pebble Count Inventory

The riffle stability index (RSI) values ranged from 56.4 to 91.1 among the 7 sites (Table 8). The median RSI value for Pigeon Roost Branch was less than, but within the range found at the EPA random sites, while the RSI value for Railroad Fork was greater than, but within the range found at the EPA random sites (Figure 9).

Index of biotic Integrity Sampling Criteria

The sampling criteria (sampling month, electrofishing duration, etc.) for the KIBI and MBI vary according to whether a stream is categorized as 'headwater' or 'wadeable', which is based on watershed catchment area (Table 9). For the KIBI catchment area, there is also a 'gray' area of 6-10mi^2 and best professional judgment is used to categorize streams located in catchments of this size (Compton et al. 2003). All of the Pigeon Roost Branch and Railroad Fork sites fall in the headwater category (<5 mi^{2}for MBI and <6 mi^2 for KIBI) and had the macroinvertebate samples collected in May during the recommended February to May sample period (Table 9; Pond et al. 2003). Our electrofishing reach lengths (93-156 m) often fell within the recommended range (100-125 m), but our sample durations (270-781 sec) frequently fell below that recommend (600-1,000 sec) due to our applying a standard effort of approximately 1 sec/m^2 of wetted stream habitat (Table 9).

Kentucky Index of biotic Integrity (KIBI)

The KIBI scored the sample sites and rated their biotic integrity as 'excellent' (≥71), 'good' (59-70), 'fair' (39-58), 'poor' (19-38), or 'very poor' (0-18) (Compton et al. 2003). We followed the recommended guideline in Compton et al. (2003), where any KIBI score that falls close (± 2 points) to the classification threshold is to contain both categories (i.e. fair/good). Five of the sites were ranked as 'poor', 1 as 'fair', and 1 as 'good' (Table 10, Figure 10). For the 3 Pigeon Roost Branch sites, there was 1 'poor' site, 1 'fair' site, and 1 'good' site (Table 10). For the 4 Railroad Fork sites, all were ranked as 'poor' (Table 10).

Kentucky Macroinvertebrate Bioassessment Index (MBI)

The MBI scored the headwater sample sites and rated their biotic integrity as either 'excellent' (≥83), 'good' (72-82), 'fair' (48-71), 'poor' (24-47), or 'very poor' (0-23) (Pond et al. 2003). When an MBI score fell close (± 2 points) to the classification threshold, we followed Compton et al.'s (2003) KIBI guideline that the ranking contain both categories (i.e. fair/good) and Pond et al.'s (2003) recommendation that caution and any additional data (i.e. KIBI and BVET) be used to for a more thorough weight-of-evidence approach. Four of the sites were ranked as 'fair', 2 as 'good', and 1 as ‘good/excellent’ (Table 11, Figure 10). For the 3 Pigeon Roost Branch sites, there was 1 ‘fair’ site, 1 ‘good’ site, and 1 ‘good/excellent’ site (Table 11). For the 4 Railroad Fork sites, there were 3 ‘fair’ sites and 1 ‘good’ site (Table 11).

The ratings provided by the KIBI and the MBI were not always similar for a site. Six sites had KIBI and MBI ratings that deviated by one or more ranking categories (Figure 10). There were no sites that had the same ranking category for both KIBI and MBI; the closest was site DBF02013716, which deviated by half a ranking (Figure 10). KIBI and MBI rankings were more consistent for Railroad Fork sites than Pigeon Roost Branch (Figure 10). At all sites, the MBI rankings rated the sites better than the KIBI rankings.

Discussion

The KIBI and MBI rank the biotic integrity of a stream site from ‘very poor’ to ‘excellent’ relative to reference conditions in Kentucky streams. The development of the reference condition is based on stream sites in KY that have had minimal impacts or disturbance within the past 10 years (Compton et al. 2003). Because all regions of KY have been disturbed by humans, the reference sites fall under the classification of ‘least disturbed’ rather than ‘undisturbed.’ Pigeon Roost Branch and Railroad Fork lie in the ‘mountain’ ichthyoregion and bioregion, which has the best discrimination among regions because most of the reference sites are located on heavily forested and relatively undisturbed areas of the DBNF (Compton et al. 2003, Pond et al. 2003). The classification thresholds were established using reference KIBI and MBI scores, where scores >50th percentile were classified as having ‘excellent’ biotic integrity; 5th-50th percentile were ‘good’, and the 5th percentile was trisected to have equal intervals representing ‘fair’, ‘poor’ and ‘very poor’ biotic condition (Compton et al. 2003). Given that most streams on the DBNF are relatively undisturbed and are used as reference sites for the KIBI and MBI development, shows that the DBNF’s management object for its streams should be to maintain or restore them to reference conditions (i.e. having ‘excellent’ biotic integrity).

The KIBI and MBI rankings for Pigeon Roost Branch and Railroad Fork show that the biotic integrity of these streams is significantly less than at comparable reference streams. None of the 7 sites had an ‘excellent’ KIBI or MBI ranking; however, one site (DBF02013716) had an MBI value of 82 placing it within ±2 points of the excellent category, thus receiving a ‘good/excellent’ ranking (Table 11). Most of the KIBI and MBI rankings were ‘poor’ or ‘fair’, a few ‘good’, and one ‘good/excellent’. The fact that habitat attributes (i.e. percent fine sediments, pool vs. riffle area, large wood per km, dominant substrate, and riffle stability indices) at the mine sites are within the range of the non-mine influenced EPA sites, suggests that something other than habitat characteristics has impaired biotic integrity of the mine influenced sites. The only exception is Railroad Fork’s median LW/km exceeding the range at the non-mine influenced sites, however, sufficient LW is beneficial to stream habitat and thus is not an impairing factor.

Fish populations can be impaired by large amounts of fine sediment, a lack of large wood, and a lack of spawning gravels. Fine sediment hinders fish respiration and fills the interstitial space in spawning gravel, thus hampering egg development for gravel spawners. Though there were site specific occurrences of percent fines exceeding an approximate detrimental threshold of 35%, the median percent fines at the mine sites were within the range present at the EPA sites. Large wood is an important feature of streams that slows flow, traps sediment, and dampens flood peaks (Montgomery et al. 2003). Furthermore, large wood forms pool habitat and contributes to aquatic habitat in diverse ways such as providing cover from predators, refuge from high velocity flow, and substrate and organic matter for macroinvertebrates (Benke and Wallace 2003, Dolloff and Warren 2003). The median amount of LW/km at the mine sites was 270 pieces/km for Pigeon Roost Branch and 407 pieces/km for Railroad Fork, both of which are much greater than the 56 pieces/km present at the EPA sites. Clean gravel of the appropriate size is necessary for fish spawning and small gravel was frequently the dominate substrate in Railroad Fork's pools. However, for Pigeon Roost Branch, pool substrate was typically cobble, boulder, and bedrock. Compared to the EPA sites, Pigeon Roost Branch had a lower occurrence of small gravel in both pools and riffles, potentially impacting fish reproduction at these sites. While the opposite is the case for Railroad Fork, which had a high occurrence of small gravel in pools, Railroad Fork had high percentages of fine sediments, typically in pools. In Pigeon Roost Branch and Railroad Fork, the number of fish species present was well below that found at the EPA sites. While the low number of fish species in Pigeon Roost Branch still fall within the range found at the EPA sites, the very low median number of fish species in Railroad Fork fall below the range found at the EPA sites.

All of the sites had a KIBI ranking that was half to two rankings worse than the MBI ranking. The cause of this deviation is unknown, but could be attributed to either a larger variability in fish populations than macroinvertebrates or our collection methods. Though our fish collection methods sometimes differed from the recommendations in reach length, electrofishing duration, and the lack of using a seine in deep pool habitats, we do not believe this to be the cause of the lower KIBI rankings. The data used to develop the KIBI was a compilation of fish data from 180 stream sites collected with a backpack electrofisher, 78 sites collected with a seine, and 130 sites collected with both methodologies (Compton et al. 2003). The deviation between the KIBI and MBI rankings at all seven sites does not mean that one biotic integrity index is better than the other, rather that they are simply different ways to assess a stream's biotic health. The index that is used could be based on management objectives, or in this case we recommend taking a conservative, precautionary approach; use both indices but select the poorer ranking when there is a discrepancy.

In general, the DBNF is more forested and less disturbed than other areas of Kentucky. Despite management for reference conditions, disturbed areas within the Forest such as the mine impacted Pigeon Roost Branch and Railroad Fork streams on Stearns District reflect the challenges facing many national forests with mixed ownership or mineral rights issues as well as lingering legacy influence of past land use. Since the KIBI and MBI rankings typically fell short of 'excellent' or even 'good' biotic integrity, there is potential for habitat and/or water quality improvement at these Stearns District mine sites.

Data Availability

Summer 2014 stream habitat, fish, and pebble count data reside in a MS Access database, which is managed by the CATT, and a copy has been provided to Jon Walker, DBNF Forest Hydrologist. We will work with the DBNF to develop custom queries and reports for the MS Access database, as needed.

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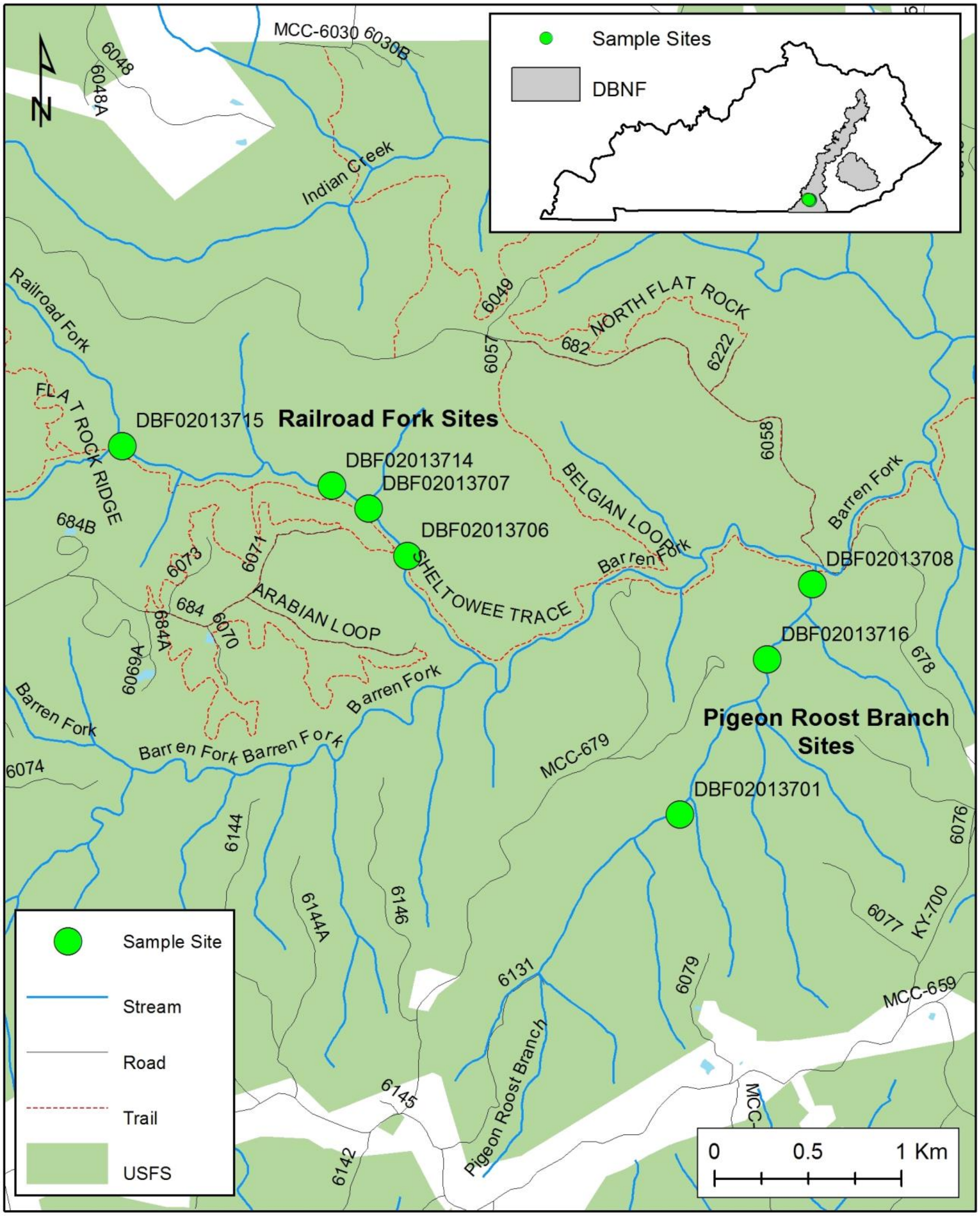

Figure 1. Sample site locations on Pigeon Roost Branch and Railroad Fork, Stearns District, Daniel Boone National Forest, Kentucky.

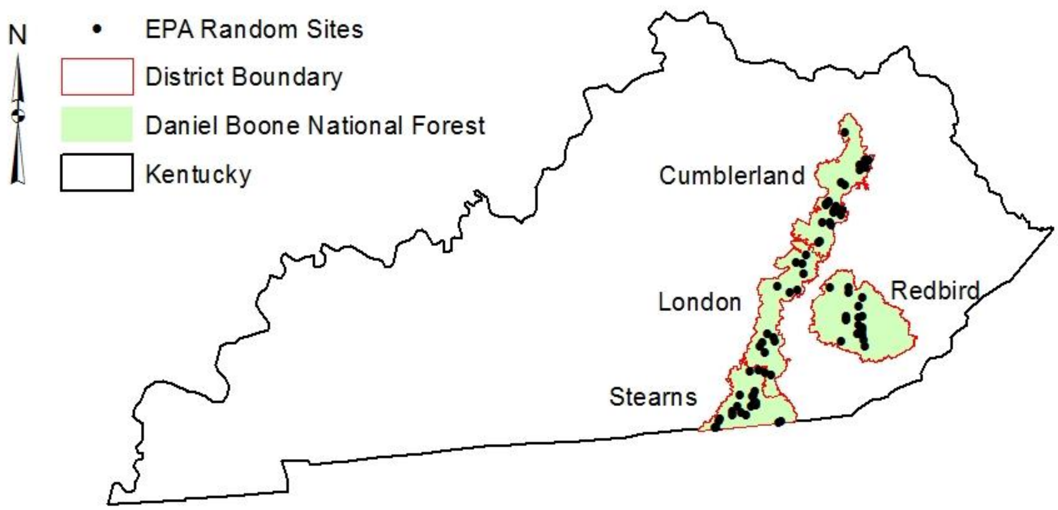

Figure 2. Environmental Protection Agency (EPA) randomly selected site locations sampled by the CATT from 2005 to 2013. Sample site locations are within the Cumberland, London, Redbird, and Stearns Districts, Daniel Boone National Forest, Kentucky.

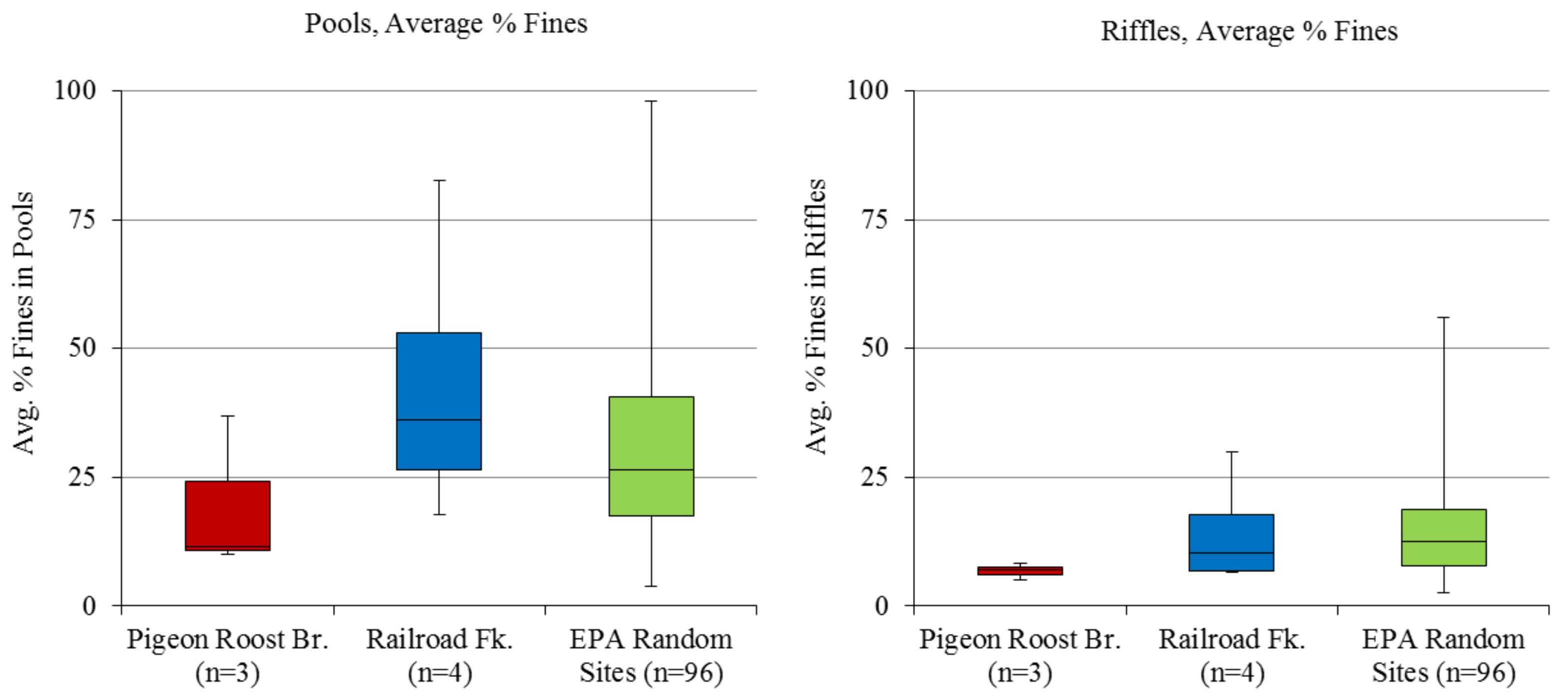

Figure 3. Boxplots of average percent fines (i.e. surface area of the stream bed consisting of sand, silt, or clay) in pools and riffles at sample sites on Pigeon Roost Branch and Railroad Fork, and EPA randomly selected sites located throughout the DBNF.

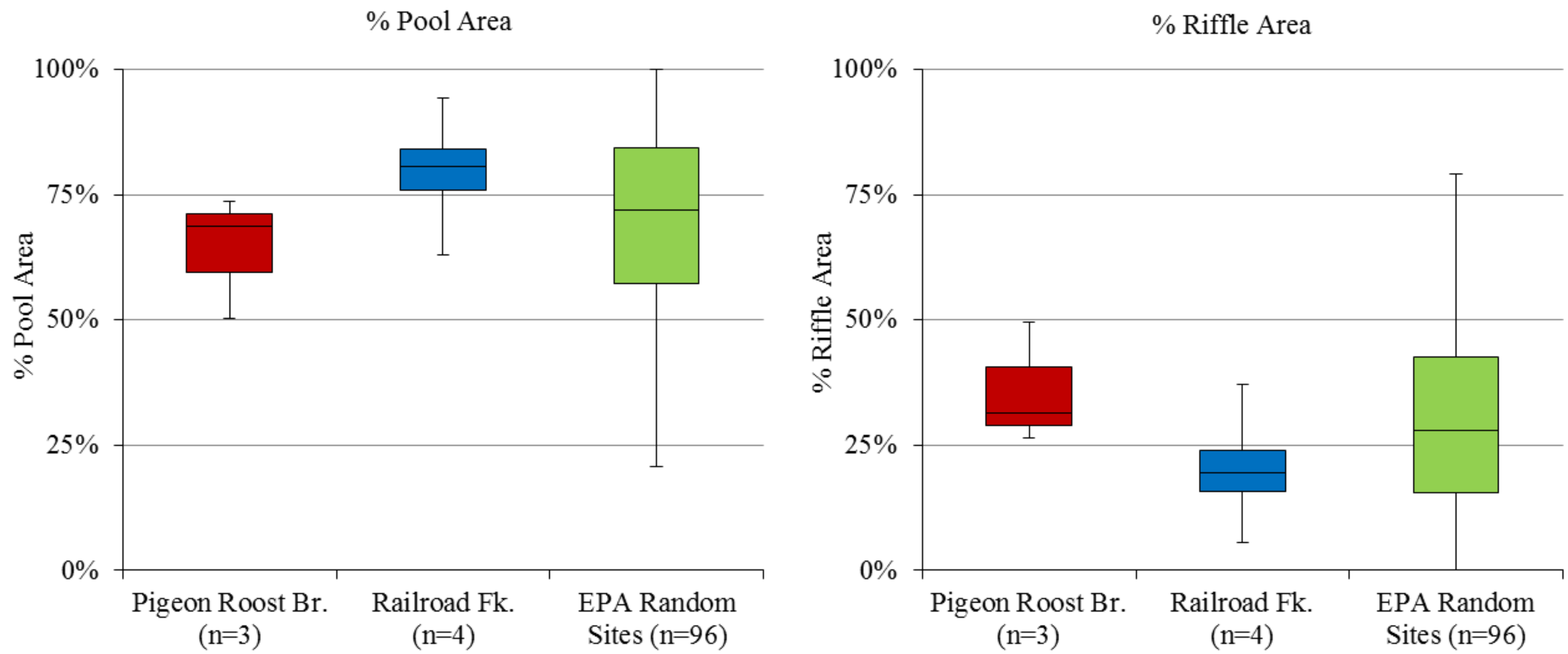

Figure 4. Boxplots of percent pool and riffle area at sample sites on Pigeon Roost Branch and Railroad Fork, and EPA randomly selected sites located throughout the DBNF.

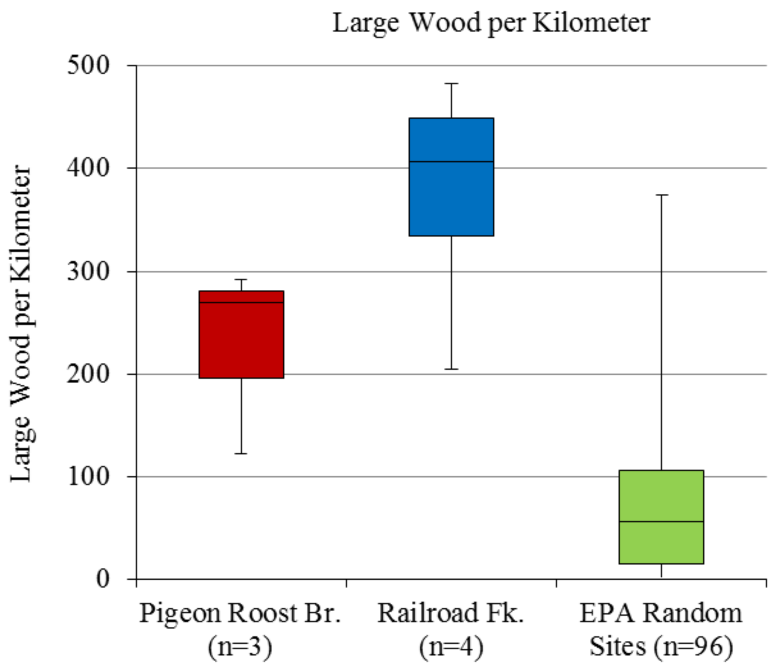

Figure 5. Boxplot of total large wood per kilometer (size classes 1, 2, 3, and 4; see Appendix B for size classes) at sample sites on Pigeon Roost Branch, Railroad Fork, and EPA randomly selected sites located throughout the DBNF.

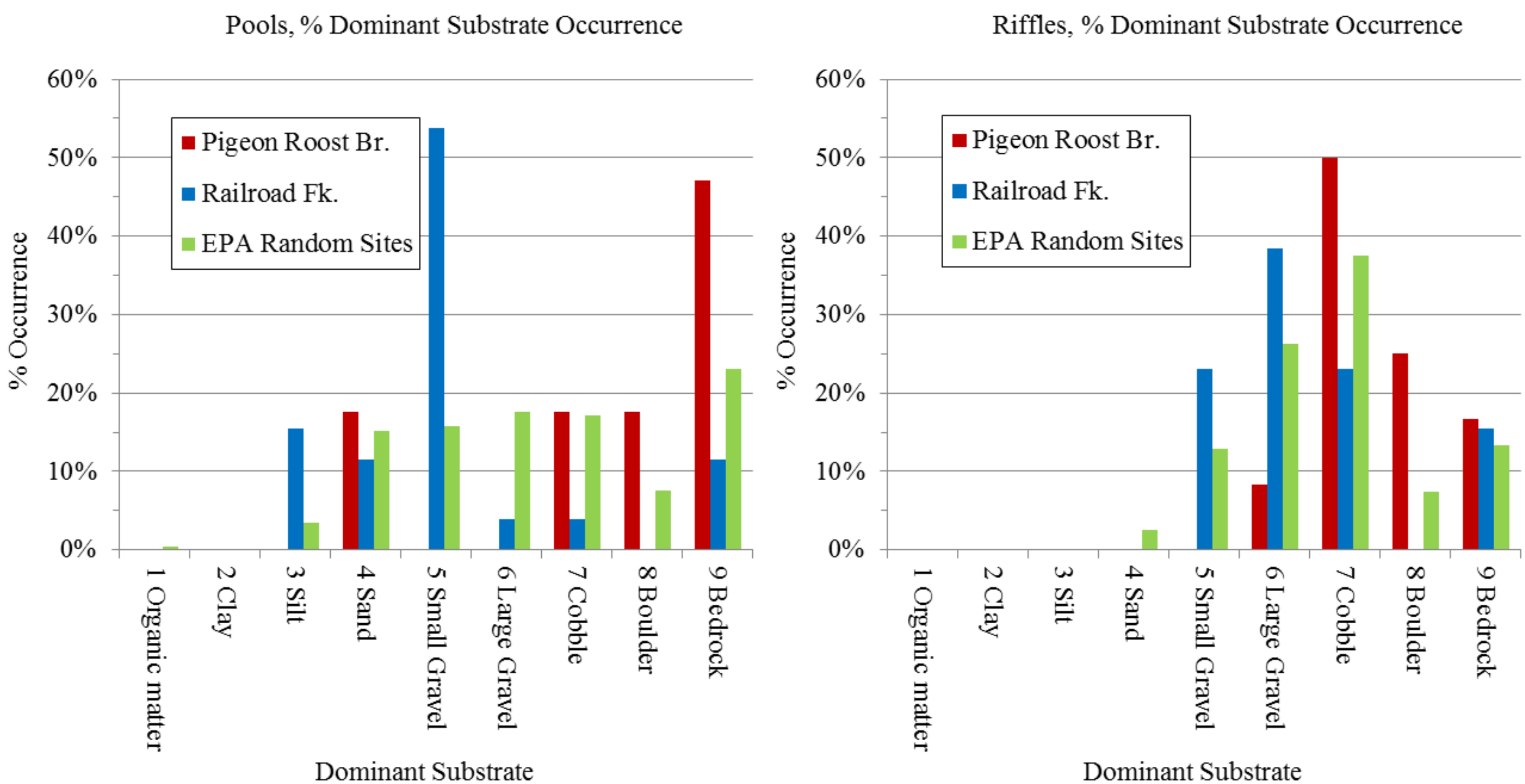

Figure 6. Percent occurrence of dominant substrate size categories in pools and riffles at sample sites on Pigeon Roost Branch (n=3), Railroad Fork (n=4), and EPA randomly selected sites (n=96) located throughout the DBNF.

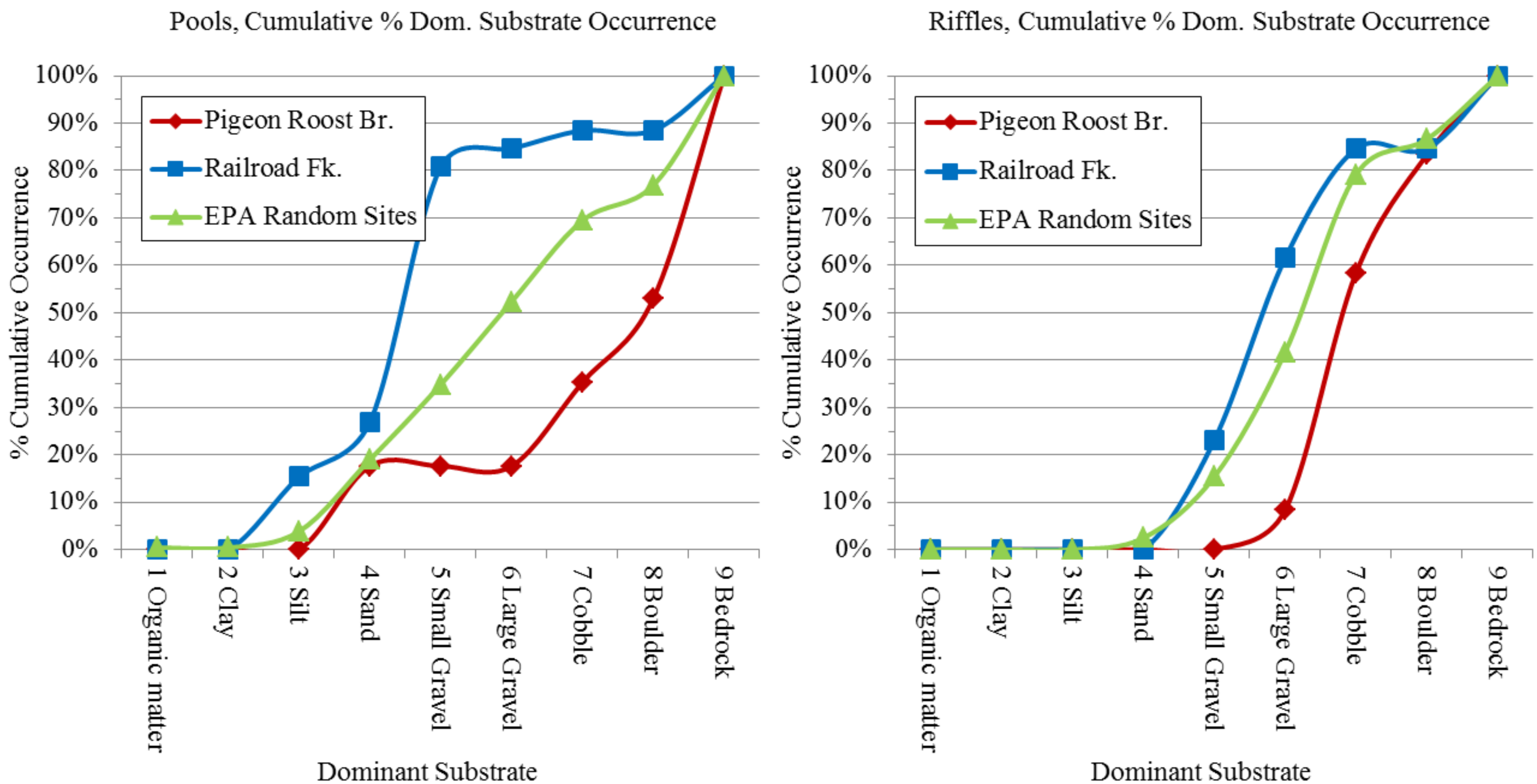

Figure 7. Cumulative percent occurrence of dominant substrate size categories in pools(left graph) and riffles (right graph) at sample sites on Pigeon Roost Branch (n=3), Railroad Fork (n=4), and EPA randomly selected sites (n=96) located throughout the DBNF.

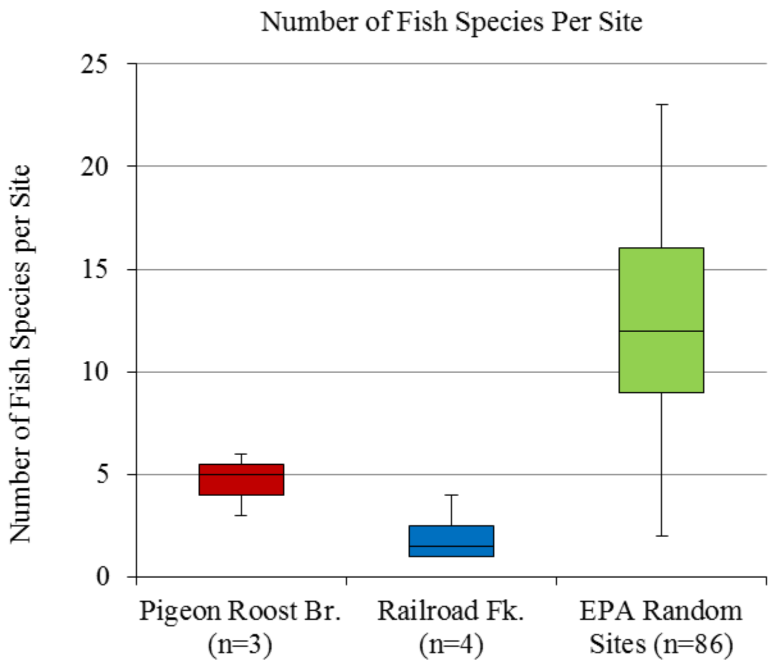

Figure 8. Boxplot of number of fish species at sample sites on Pigeon Roost Branch, Railroad Fork, and EPA randomly selected sites located throughout the DBNF.

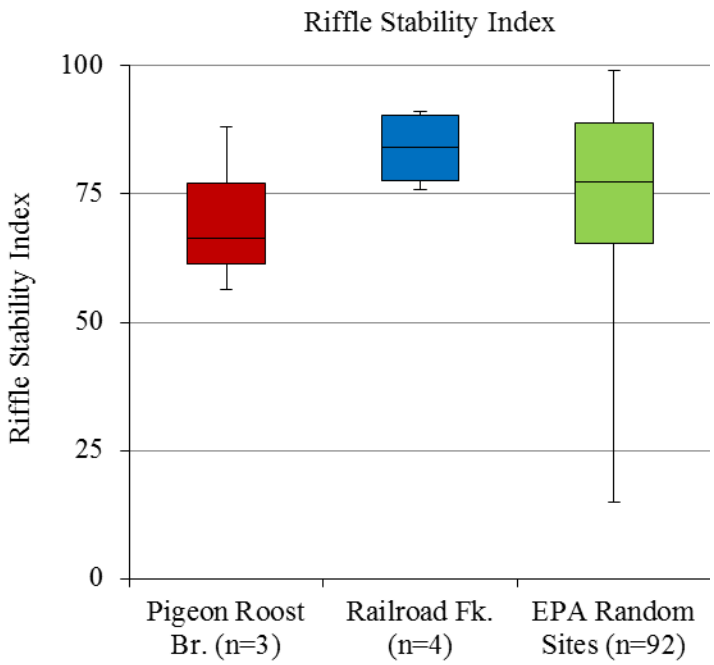

Figure 9. Boxplot of riffle stability index (RSI) values at sample sites on Pigeon Roost Branch, Railroad Fork, and EPA randomly selected sites located throughout the DBNF.

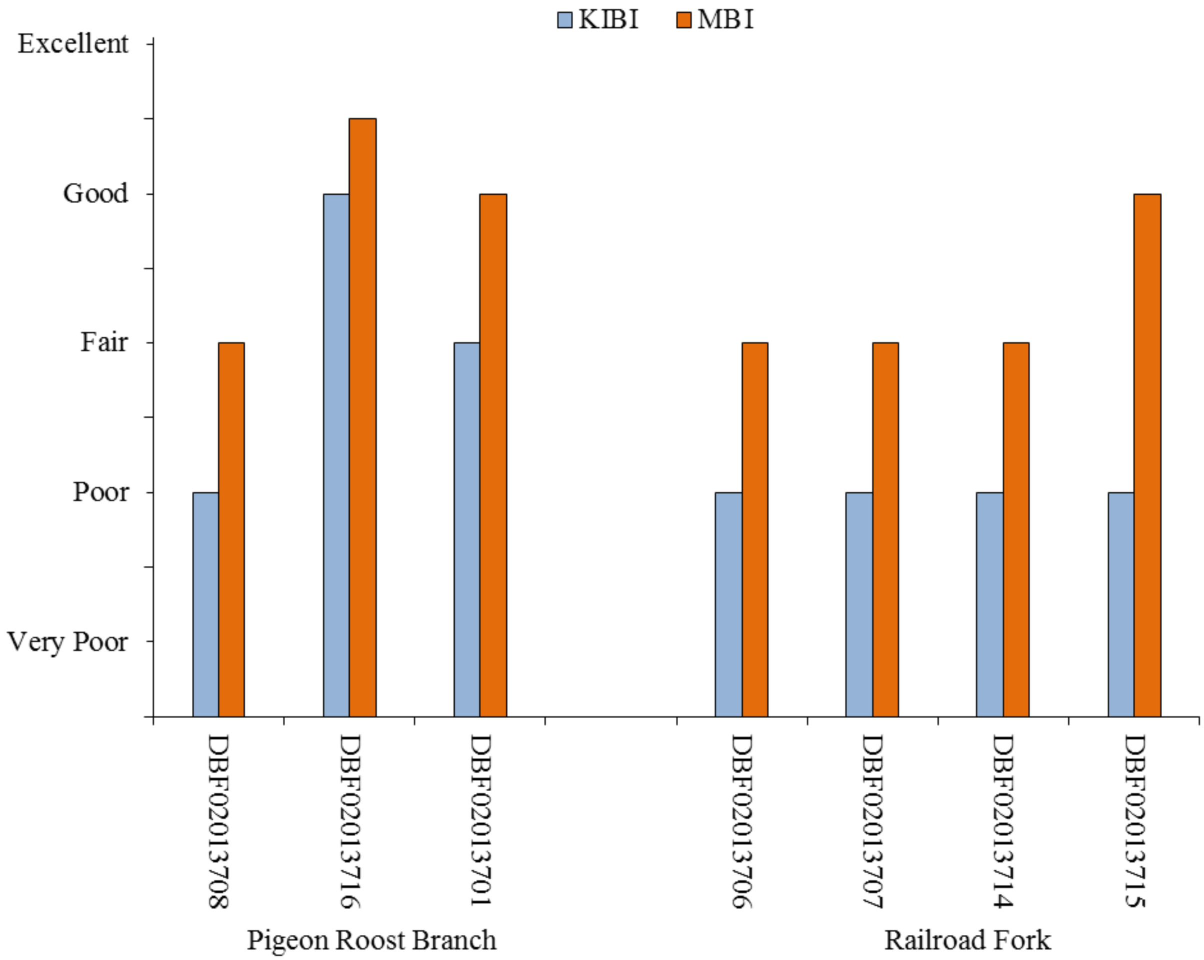

Figure 10. Kentucky index of biotic integrity (KIBI) and macroinvertebrate bioassessment index (MBI) rating results for sites on Pigeon Roost Branch and Railroad Fork, May and June 2014.

Table 1. Data collected at sites on Pigeon Roost Branch and Railroad Fork. Data were collected in May and June 2014.

District	Site #	Stream Name	Topo Quad	Macro-inverts	BVET habitat (m)	Efish (sec)	Comments
Stearns	DBF02013708	Pigeon Roost Branch	Wiborg	Collected	127	567	
Stearns	DBF02013716	Pigeon Roost Branch	Wiborg	Collected	155	781	Mine shaft just above reach end
Stearns	DBF02013701	Pigeon Roost Branch	Wiborg	Collected	141	455	
Stearns	DBF02013706	Railroad Fork	Wiborg	Collected	122	270	Only 1 fish (Creek Chub), lots of crayfish
Stearns	DBF02013707	Railroad Fork	Wiborg	Collected	135	357	Coal and iron in stream; forested; trail
Stearns	DBF02013714	Railroad Fork	Wiborg	Collected	122	270	Heavily forested; channel entrenched
Stearns	DBF02013715	Railroad Fork	Wiborg	Collected	122	277	Forested; Sheltowee trail nearby; stone dam
				Total	924		

Table 2. GPS coordinates recorded at the downstream (start) and upstream (end) extent of stream habitat and fish inventory reaches on Pigeon Roost Branch and Railroad Fork, May and June 2014.

			GPS (UTM NAD83)	
District	Site #	Stream Name	Downstream Inventory Start	Upstream Inventory End
Stearns	DBF02013708	Pigeon Roost Branch	16 S 729823 4073010	16 S 729810 4072920
Stearns	DBF02013716	Pigeon Roost Branch	16 S 729566 4072633	16 S 729603 4072473
Stearns	DBF02013701	Pigeon Roost Branch	16 S 729106 4071757	16 S 728976 4071723
Stearns	DBF02013706	Railroad Fork	16 S 727638 4073127	16 S 727588 4073197
Stearns	DBF02013707	Railroad Fork	16 S 727430 4073373	16 S 727325 4073443
Stearns	DBF02013714	Railroad Fork	16 S 727304 4073469	16 S 727213 4073482
Stearns	DBF02013715	Railroad Fork	16 S 726303 4073590	16 S 726190 4073635

Table 3. Summary of BVET stream habitat attributes collected on Pigeon Roost Branch and Railroad Fork, June 2014.

Site #	Stream Name	Mean Avg. Depth (cm)		Mean Max. Depth (cm)		Mean Pool Residual Depth (cm)*	Avg. Wetted Width (m)		Avg. Bankfull Channel Width (m)	Avg. % Fines		Avg. Gradient (%)	Avg. Water Temp. (C)	Rosgen
		Pools	Riffles	Pools	Riffles		Pools	Riffles		Pools	Riffles			
DBF02013708	Pigeon Roost Br.	21	7	33	12	8	5.0	3.9	6.4	37	8	2	15	F
DBF02013716	Pigeon Roost Br.	24	11	36	18	11	3.9	4.2	6.9	10	5	1	16	F
DBF02013701	Pigeon Roost Br.	18	5	29	9	11	5.1	4.0	5.8	11	7	2	20	B
DBF02013706	Railroad Fork	27	8	36	14	19	3.6	2.2	6.6	18	14	3	16	B
DBF02013707	Railroad Fork	26	8	47	14	21	3.6	1.9	6.7	29	7	1	16	C,F
DBF02013714	Railroad Fork	28	7	46	17	15	4.4	1.9	8.1	43	7	1	16	C,F
DBF02013715	Railroad Fork	38	10	64	25	25	4.3	2.0	8.0	83	30	2	16	F

**Residual pool depth = average pool depth – riffle crest depth*

Table 4. Stream area in pools (includes glides) and riffles (includes runs and cascades) as observed during BVET habitat inventories on Pigeon Roost Branch and Railroad Fork, June 2014.

District	Site #	Stream Name	Pool Area (m^2)	Riffle Area (m^2)	Total Area (m^2)	% Pool Area	% Riffle Area
Stearns	DBF02013708	Pigeon Roost Branch	460	164	625	74%	26%
Stearns	DBF02013716	Pigeon Roost Branch	353	348	701	50%	50%
Stearns	DBF02013701	Pigeon Roost Branch	462	211	673	69%	31%
Stearns	DBF02013706	Railroad Fork	199	118	317	63%	37%
Stearns	DBF02013707	Railroad Fork	337	82	419	80%	20%
Stearns	DBF02013714	Railroad Fork	345	82	428	81%	19%
Stearns	DBF02013715	Railroad Fork	468	28	496	94%	6%

Table 5. Large wood per kilometer observed during BVET habitat inventories on Pigeon Roost Branch and Railroad Fork, June 2014 (see Appendix B for large wood size classes).

District	Site #	Stream Name	Large Wood per Km						Large Wood Count in Sample Reach						Inventory
			LW1/ km	LW2/ km	LW3/ km	LW4/ km	RW/ km	Total LW/km	LW1 n	LW2 n	LW3 n	LW4 n	RW n	Total LW n	Distance (km)
Stearns	DBF02013708	Pigeon Roost Branch	229	0	47	16	0	292	29	0	6	2	0	37	0.13
Stearns	DBF02013716	Pigeon Roost Branch	110	0	13	0	0	123	17	0	2	0	0	19	0.16
Stearns	DBF02013701	Pigeon Roost Branch	248	0	21	0	0	270	35	0	3	0	0	38	0.14
Stearns	DBF02013706	Railroad Fork	320	16	8	8	25	377	39	2	1	1	3	46	0.12
Stearns	DBF02013707	Railroad Fork	230	0	193	7	7	437	31	0	26	1	1	59	0.14
Stearns	DBF02013714	Railroad Fork	270	33	156	0	25	484	33	4	19	0	3	59	0.12
Stearns	DBF02013715	Railroad Fork	131	0	66	0	8	205	16	0	8	0	1	25	0.12

Table 6. Dominant and subdominant substrate types observed in pools (P; includes glides) and riffles (R; includes runs and cascades) during BVET habitat inventories on Pigeon Roost Branch and Railroad Fork, June 2014 (see Appendix B for substrate class descriptions). The first number in each pair is for dominant substrate, the second for subdominant substrate. For example, in pools at the Pigeon Roost Branch sample site (DBF02013708), sand was dominant in 3 pools and subdominant in 0 pools.

	Pigeon Roost Branch						Railroad Fork							
	DBF-02013708		DBF-02013716		DBF-02013701		DBF-02013706		DBF-02013707		DBF-02013714		DBF-02013715	
Substrate Size Class	P	R	P	R	P	R	P	R	P	R	P	R	P	R
Organic matter	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Clay	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**0,1**	0,0	0,0	0,0
Silt	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**1,0**	0,0	**3,0**	0,0
Sand	**3,0**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**1,2**	0,0	**2,2**	0,0	**0,3**	**0,1**
Small gravel	**0,2**	**0,1**	0,0	0,0	0,0	0,0	**4,2**	**3,1**	**4,2**	**0,3**	**5,3**	**0,3**	**1,0**	0,0
Large gravel	0,0	**1,1**	0,0	0,0	0,0	0,0	**0,3**	**0,2**	**1,2**	**2,1**	**0,2**	**3,0**	0,0	0,0
Cobble	**1,0**	**2,1**	**2,2**	**3,1**	**0,3**	**1,3**	**1,2**	**1,1**	**0,1**	**1,1**	0,0	0,0	**0,1**	**1,0**
Boulder	**0,2**	0,0	**2,3**	**1,3**	**1,4**	**2,2**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Bedrock	**1,1**	0,0	**1,0**	0,0	**6,0**	**2,0**	**2,0**	0,0	**1,0**	**2,0**	0,0	0,0	0,0	0,0

Table 7. Total count (adult & age-0) of fish captured at each sample site on Pigeon Roost Branch and Railroad Fork, June 2014.

			Pigeon Roost Branch			Railroad Fork			
Family	Scientific Name	Common Name	DBF-02013708	DBF-02013716	DBF-02013701	DBF-02013706	DBF-02013707	DBF-02013714	DBF-02013715
Catostomidae									
	Catostomus commersoni	White Sucker	**3**	**11**	**5**	0	0	**1**	**1**
Cyprinidae									
	Chrosomus erythrogaster	Southern Redbelly Dace	0	**31**	0	0	0	0	**12**
	Cyprinella spiloptera	Spotfin Shiner	**8**	0	0	0	0	0	0
	Semotilus atromaculatus	Creek Chub	**29**	**63**	**45**	**1**	**23**	**9**	**31**
Percidae									
	Etheostoma flabellare	Fantail Darter	**5**	**10**	**8**	0	0	0	0
	Etheostoma sagitta sagitta	Cumberland Arrow Darter	**2**	**3**	0	0	0	0	**2**
Petromyzontidae									
	Lampetra spp.	Lamprey	0	**3**	0	0	0	0	0

Table 8. Riffle stability index results (Kappesser 2002), based on pebble count data collected on Pigeon Roost Branch and Railroad Fork, June 2014.

District	Site #	Stream Name	Riffle Stability Index	Bar Sample Geometric Mean	Relative Bed Stability	Log of Relative Bed Stability	Median Particle Size			
							D25	D50	D75	D84
Stearns	DBF02013708	Pigeon Roost Branch	88.2	108.2	0.19	-0.73	NA*	20	52	76
Stearns	DBF02013716	Pigeon Roost Branch	66.3	117.3	0.67	-0.18	32	78	140	200
Stearns	DBF02013701	Pigeon Roost Branch	56.4	120.3	0.78	-0.11	NA*	94	380	1,024
Stearns	DBF02013706	Railroad Fork	78.1	103.1	0.21	-0.67	8	22	84	160
Stearns	DBF02013707	Railroad Fork	91.1	94.3	0.17	-0.77	NA*	16	34	60
Stearns	DBF02013714	Railroad Fork	90.2	105.8	0.19	-0.72	4	20	46	66
Stearns	DBF02013715	Railroad Fork	75.8	97.8	0.20	-0.69	NA*	20	92	130

*could not be calculated because the 0-2 mm substrate size-class comprised >25% of the sample

Table 9. Kentucky index of biotic integrity (KIBI) and macroinvertebrate bioassessment index (MBI) sampling criteria. The Pigeon Roost Branch and Railroad Fork sites on the Stearns District are located within the Southwestern Appalachian ecoregion, the Upper Cumberland major river basin, and the Mountain icthyoregion/bioregion. Some sites were not sampled within the KIBI and MBI recommended criteria for sampling month, reach length, and electrofishing duration.

			Catchment	KIBI[1]	MBI[2]	Sampling Month[3]		Electrofishing	
District	Site #	Stream Name	Area (mi^2)	Headwater/Wadeable		KIBI	MBI	Reach Length[4] (m)	Duration[5] (sec)
Stearns	DBF02013708	Pigeon Roost Branch	2.2	Headwater	Headwater	June	May	126	567
Stearns	DBF02013716	Pigeon Roost Branch	2.0	Headwater	Headwater	June	May	156	781
Stearns	DBF02013701	Pigeon Roost Branch	1.9	Headwater	Headwater	June	May	136	455
Stearns	DBF02013706	Railroad Fork	2.0	Headwater	Headwater	June	May	93	270
Stearns	DBF02013707	Railroad Fork	1.9	Headwater	Headwater	June	May	120	357
Stearns	DBF02013714	Railroad Fork	1.9	Headwater	Headwater	June	May	120	270
Stearns	DBF02013715	Railroad Fork	1.1	Headwater	Headwater	June	May	120	277

1. KIBI headwater streams = <6 mi^2 catchment area, wadeable streams = >10 mi^2, and the 'gray' area of 6-10 mi^2 requires best professional judgment (Compton et al. 2003).
2. MBI headwater streams = <5 mi^2 catchment area and wadeable streams = 5-200 mi^2 (Pond et al. 2003).
3. KIBI sampling should occur mid-March through October (Compton et al. 2003). MBI sampling should occur February-May for headwater streams and June-September for wadeable streams (Pond et al. 2003).
4. KIBI sample reach length should be 100-125 m for headwater streams and 100-200 m for wadeable streams (KDOW 2002). MBI sample reach length is generally 100 m (Pond et al. 2003).
5. KIBI electrofishing duration should be 600-1,000 sec for headwater streams and 600-1,800 sec for wadeable streams (KDOW 2002).

Table 10. Kentucky index of biotic integrity (KIBI) results for each sample site on Pigeon Roost Branch and Railroad Fork, June 2014.

		Pigeon Roost Branch			Railroad Fork			
		DBF-02013708	DBF-02013716	DBF-02013701	DBF-02013706	DBF-02013707	DBF-02013714	DBF-02013715
Raw Metric Values	TNI	47	121	58	1	23	10	46
	NAT	5	6	3	1	1	2	4
	DMS	2	2	1	--	--	--	1
	INT	1	2	--	--	--	--	2
	SL	1	2	1	--	--	1	2
	%INSCT	32	11	14	--	--	--	4
	%TOL	68	61	86	100	100	100	70
	%FHW	17	--	--	--	--	--	--
Calc.Metric Scores	NAT	62	68	58	50	50	54	70
	DMS	61	63	52	41	41	42	60
	INT	56	71	45	45	45	45	80
	SL	52	62	54	46	46	54	71
	%INSCT	0	45	49	0	0	0	0
	%TOL	0	65	41	0	0	0	0
	%FHW	0	74	50	0	0	0	0
	KIBI headwater	28	63	49	22	22	23	35
	Rating	Poor	Good	Fair	Poor	Poor	Poor	Poor

TNI = total number individuals; NAT = native species richness; DMS = darter, madtom, and sculpin richness; INT = intolerant species richness; SL = simple lithophilic spawning species richness; %INSCT = relative abundance of insectivorous individuals; %TOL = relative abundance of tolerant individuals; %FHW = relative abundance of facultative headwater individuals

KIBI headwater rankings: Excellent ≥71; Good 59-70; Fair 39-58; Poor 19-38; Very Poor 0-18

Table 11. Kentucky macroinvertebrate bioassessment index (MBI) results for each sample site on Pigeon Roost Branch and Railroad Fork, May 2014.

		Pigeon Roost Branch			Railroad Fork			
		DBF-02013708	DBF-02013716	DBF-02013701	DBF-02013706	DBF-02013707	DBF-02013714	DBF-02013715
Raw Metric Values	TNI	25	126	93	34	49	17	35
	G-TR	21	29	26	17	19	15	31
	G-EPT	12	20	15	9	9	9	21
	mHBI	3	2	2	3	3	2	3
	m%EPT	72	88	92	79	67	94	83
	%Ephem	28	46	24	3	--	0	29
	%Chir+Olig	4	2	0	3	8	0	3
	%Clingers	76	88	91	79	80	76	66
Calc.Metric Scores	G-TR	33	46	41	27	30	24	49
	G-EPT	36	61	45	27	27	27	64
	mHBI	92	99	100	92	92	97	88
	m%EPT	83	100	100	91	77	100	95
	%Ephem	42	69	36	4	0	0	43
	%Chir+Olig	97	99	100	98	92	100	98
	%Clingers	100	100	100	100	100	100	87
	MBI headwater	69	82	75	63	60	64	75
	Rating	Fair	Good/ Excellent	Good	Fair	Fair	Fair	Good

TNI = total number individuals; G-TR = genus taxa richness; G-EPT = genus ephemeroptera, plecoptera, trichoptera richness; mHBI = modified Hilsenhoff biotic index; M%EPT = modified percent EPT abundance; %Ephem = percent ephemeroptera; %Chir+Olig = percent chironomidae+oligochaeta; %Clingers = percent primary clingers

MBI headwater rankings: Excellent ≥83; Good 72-82; Fair 48-71; Poor 24-47; Very Poor 0-23

Appendix A: Field Methods for Stream Inventory

Sampling Strategy

Day 1 – Macroinvertebrate collection & BVET Inventory

- All crew to first site to learn site documentation, reach layout, and macroinvertebrate and habitat sampling methods
- While 2 crew conduct the BVET inventory and reach layout, 2 or more other crew can collect macroinvertebrates
- Split into several crews (depending on crew size) to visit and document other sites, layout reaches, and sample macroinvertebrates and habitat

Day 2 – Efish & Pebble Counts

- Perform efish, pebble, and bar-count sampling at sites visited on day 1
- If crew is large enough, crew can split so that two crew are continuing with site documentation, reach layout, macroinvertebrate, and habitat sampling methods

Day 3

- Continue with approach from day 2, allowing at least 1 day between macroinvertebrate and fish sampling
- If fish sampling crew catches up with layout crew, then take a day to split into several layout crews as during day 1
- When layout crew finishes all sites they can rejoin fish sampling crew

This approach should maximize crew efficiency and prevent biases associated with sampling fish and macroinvertebrates within the same reach in the same day.

Site Documentation

Objective - Record location and description of site for reporting purposes

Methods

- Directions to site
    - Record roads taken to parking area
    - Record trails walked to site
    - Document route to site on quadrangle map

- GPS
    - Record GPS coordinates at start and end of reach

- Photos
    - Take digital photo from downstream end looking up, upstream end looking down
    - Photograph any pertinent features within the reach that may influence habitat and fauna, example, road or trail crossings, erosion, etc.

- Written description
    - Record comments on land use in the reach area, for example private land with mowed lawns, all forested, pasture lands, etc.
    - Record comments on other features that may be influencing stream conditions

Reach Layout

Objective - Use consistent method to lay out reach for fish and macroinvertebrate sampling

Methods

- Locate 1 – 2 riffles or runs and determine the average wetted width by making several measurements and computing the average. Measure width perpendicular to thalweg.

    - If the average wetted width is less than or equal to 3.0 m, then the reach length will be 120 m
    - If the average wetted width is greater than or equal to 7.5 m, then the reach length will be 300 m
    - If the average wetted width is between 3.0 and 7.5 m, then reach length is 40-times the average wetted width, example: average wetted width = 5 m; reach length = 5 x 40 = 200m

- Hang a double orange flag at the downstream end of the reach . Attach topofil from a hipchain and walk to the midpoint of the reach, hang a single orange flag, then continue to the end of the reach and hang another single orange flag (hanging the flags to layout the reach can be done while performing the BVET inventory)

- Record the average wetted width and reach length on the datasheet

- Reaches will not be moved to avoid road or trail crossings – moving reaches violated the assumptions of the stratified random sample design and invalidates statistical analysis. Document these features fully with photos and written descriptions

- Always begin reaches at the downstream end of a defined habitat unit, end points should be at the exact distance as described above

- In large streams make sure the reach includes all of a fast water habitat unit and all of a slow water habitat unit

Habitat Inventory (BVET)

Objective – Characterize stream habitat attribute within the sample reach.

Methods

- Collect attribute as described in Section 2 of Roghair and Nuckols (2005) (Appendix B)

- Increase frequency of paired (sub-) samples to include at least 3 fast and 3 slow water units within each reach
    - Where less than 3 fast or slow occur, sub-sample all units

- Start and end data collection at habitat unit breaks
    - This may extend habitat data collection slightly beyond end of sample reach (however, still hang reach-end flag at calculated distance, not at the upper end of habitat unit)

Macroinvertebrates Inventory

Objective - Collect assemblage sample

Methods

- Using D-frame nets and a seine collect macroinvertebrates using the riffle sample and multi-habitat sample methods described by KDOW (2011)

- Where possible, keep macroinvertebrate samples within designated reaches. If this is not possible be sure to indicate on datasheet.

Kentucky Division of Water (KDOW). 2011. Methods for sampling benthic macroinvertebrate communities in wadeable waters. Kentucky Department for Environmental Protection. Division of Water, Frankfort, KY.

Electrofishing Inventory

Objective - Determine relative abundance and determine catch-per-unit-effort (CPUE). Note: we are not attempting to estimate population size or density for individual species, only assessing the fish assemblage

Methods (based on sampling strategies discussed and approved by R8 and SRS personnel in 3/2005)

- Electrofishing starts in same location as habitat inventory

- Electrofishing ends at location designated in reach layout process
    - Habitat inventory may extend beyond end of designated reach
    - DO NOT extend electrofishing sample beyond end of designated reach

- Single-pass DC backpack electrofishing

- One shocker, 3 netters (a net on the probe can be the 3rd net)

- No blocknets

- Electrofishing effort will be equal to 1.0 seconds for each 1.0 m^2 of wetted area
    - note: this will standardize our effort and remove the potentially confounding effect of changes in wetted width relative to the bankfull channel width in wet or dry years
    - derived Warren et al. data on electrofishing effort in MS streams

- Fish will be counted and released at the site, except for a voucher specimen for each species; endangered species lists will be reviewed before sampling

- Record age-0 fish and all fish older than age-0 separately for each species

- Keep all relic mussel shells encountered

- Record number of crayfish captured (don't actively net crayfish, but bucket any that end up in the net). If also vouchering fish then keep a couple crayfish specimens (ideally Form I & II males)

Pebble Count Inventory

Objective - Determine the riffle stability index (RSI), bar sample geometric mean, and median particle sizes.

Methods

- Pebble count data is collected using methods modified from those in Kappesser (2002) to characterize the substrate composition of sample reaches
- Pebble counts are performed in riffles designated for electrofishing by walking transects perpendicular to the flow within the bankfull channel (Harrelson et al. 1994)
- Walk the transect beginning at the edge of the bankfull channel on one side of the stream and walk heel-to-toe across the stream channel to the opposite bank
- At each step pick up the pebble at the tip of your toe and measure its intermediate axis with a ruler to the nearest millimeter
- For very large particles, the same particle is counted as many times it is encountered
- These procedures are repeated until at least 200 measurements are recorded; Transects are not terminated until the opposite bank is reached even if this results in more than 200 measurements
- Transects are distributed throughout the riffle; If detritus, LW, or other organic materials are encountered the rock substrate found directly below them is sampled
- For the bar sample, measure 30 freshly moved dominant large particles residing on a bar or similar depositional feature to estimate the largest particle size transported at flows of bankfull and above; Freshness is evaluated by lack of growing vegetation and lack of embeddedness of the particles
- The depositional feature must be in close proximity to the riffle being examined, and can include laterally attached bars, side bars, and central bars; The entire bar should be visually inspected to identify the dominant large size of particle present; If a bar deposit cannot be found, trained field personnel may select the large mobile particles from within the riffle; For each particle, measure the intermediate axis to the nearest millimeter

Bunte, K. and S. R. Abt. 2001. Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. General Technical Report RMRS-GTR-74. Fort Collins, CO: U. S. Deparment of Agriculture, Forest Service, Rocky Mountain Research Station.

Harrelson, Cheryl C., Rawlins, C. L., and Potyondy, John P. 1994. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61p.

Kappesser, G. B. 2002. A riffle stability index to evaluate sediment loading to streams. Journal of the American Water Resources Association. 38:1069-1081.

Appendix B: Field Methods for Habitat Inventory

Guide to Stream Habitat Characterization using the BVET Methodology in the Daniel Boone National Forest, KY

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Table of Contents

Introduction

The Basinwide Visual Estimation Technique (BVET) is a versatile tool used to assess streamwide habitat conditions in wadeable size streams and rivers. A crew of two individuals performs the inventory using two-stage visual estimation techniques described in Hankin and Reeves (1988) and Dolloff et al. (1993). In its most basic form the BVET combines visual estimates with actual measurements to provide a calibrated estimate of stream area with confidence intervals, however the crew may inventory any number of other habitat attributes as they walk the length of the stream. Experienced crews can inventory an average of 2-3 km per day, but this will vary depending on stream size and the number of stream attributes inventoried.

Before a crew begins a BVET inventory they must receive adequate training, both in the classroom and in the field. Estimating and measuring a large number of habitat attributes can confuse and overwhelm an inexperienced crew. Individuals must have an understanding of the basic concepts behind the BVET and be familiar with habitat attributes before they can effectively and efficiently perform an inventory.

In summer 2004, resource managers on the Daniel Boone National Forest (DBNF) requested that the USFS Center for Aquatic Technology Transfer (CATT) implement modified BVET inventories to inventory stream reaches previously inventoried in the 1990's. The 1990's inventories followed methods detailed in the 'Daniel Boone National Forest Stream Inventory Work Plan and Sampling Techniques Manual', which were similar in nature to the BVET habitat inventory. After discussion with resource managers from the DBNF, we scaled down the original protocol, eliminating several attributes and modifying others to maximize inventory efficiency during our limited time on the Forest. In summer 2005 the DBNF opted to use identical BVET methods as National Forests in Virginia and North Carolina, which are only slightly different from methods used in Kentucky in 2004.

This document was developed to serve as a guide for classroom and field instructions specific to the ONF BVET habitat inventory and to provide a post-training reference for field crews. It includes an overview of the BVET inventory, defines habitat attributes, instructs how and when to measure attributes, and provides reference sheets for use in the field. Each trainee should receive a copy of this manual and is encouraged to take notes in the spaces provided.

We used an abbreviated version of the BVET to sample habitat within sample reaches only. Paired samples were collected more frequently then described here because reaches were short. Stream attributes were collected as described in Section 2.

References cited in this manual:

Armantrout, N. B., compiler. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, Maryland.

Bunte, K., and S. R. Abt. 2001. Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. General Technical Report RMRS-GTR-74. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Dolloff, C. A., D. G. Hankin, and G. H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. General Technical Report SE-83. Asheville, North Carolina: U.S. Department of Agriculture, Southeastern Forest Experimental Station.

Hankin, D. G., and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences 45:834-844.

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology Books, Pagosa Springs, Colorado.

Rosgen, D.L., and L. Silvey. 1998 Field Guide for Stream Classification, Wildland Hydrology Books, Pagosa Springs, Colorado.

Outline of BVET Habitat Inventory

1. Enter 'Header' information on the data sheet: --- 'Header' information includes date, stream, start location, crew, etc. and is **vitally** important to record for future reference.

2. Enter downstream of the starting point, then move upstream and begin the inventory. Tie off the hipchain, proceed upstream to the starting point, reset the hipchain to zero, and proceed upstream estimating parameters and recording data in every habitat unit.

3. At the paired sample units perform visual estimates, then perform measurements. Pair a minimum of 3 fast and 3 slow-water units; pair more if possible.

4. Progress upstream estimating attributes for every unit until the next paired sample unit is reached, then repeat step 4.

The crew should also take care to record roads, trails, tributaries, dams, waterfalls, road crossing types, riparian features (wildlife openings, trails, campsites, roads, timber harvest, etc.), and other pertinent stream features as they progress upstream. Be sure to record hipchain distances when noting such features. Some features may also require a picture number to be associated with them.

The following sections describe the BVET habitat inventory in detail:

Section 1: Getting Started – equipment, header info, random numbers, starting the inventory
Section 2: Habitat Attributes – definitions, how to estimate or measure, when to record
Section 3: Wrapping Up – what to do when the inventory is completed
Section 4: Summary
Section 5: GPS Instructions
Appendix: field guide, random number tables, equipment checklist

Section 1: Getting Started

Equipment List

Hipchain	Camera
Extra string for hipchain	Backpack
Wading rod	Pencils
50 m tape measure	Flagging
Clinometer	Markers
Datalogger	Waterproof backup datasheets
Thermometer	Clipboard
GPS unit	BVET field guide on waterproof paper
Topographic map w/NHD_ID	Felt bottom wading boots or waders
Cell Phone	Water
First Aid Kit	Water Filter
Rain Gear (optional)	Toilet Paper

The BVET crew consists of two individuals, the ‘observer’ and the ‘recorder’. The observer wears the hipchain and carries the wading rod. The recorder wears the data logger and carries other equipment in the backpack. The duties of each individual are listed below.

Duties

Observer	Recorder
Designate habitat units	Locate changes in NHD_ID
Measure distance	Record data
Estimate width	Determine paired sample location
Estimate depths	Classify and count Large Wood (LW)
Classify substrates	Photo-documentation
Locate features	Document features
Estimate percent fines	GPS-documentation

Both crew members are needed to measure actual widths, channel widths, riparian areas, gradient, and water temperature at designated units. Although the crew has assigned duties, they should not hesitate to consult with each other if they have questions or feel that a mistake may have been made. Working as a team will provide the best possible results.

Header Information

Header information is **vitally important** for future reference. Take the time to record all categories completely and accurately.

Stream Name	Full name of stream
District	National Forest District name
Quad	USGS 1:24,000 quadrangle name
Date	Record date(s) of inventory
Recorder	Full name of recorder
Observer	Full name of observer
GPS	Record at start and end locations, always use NAD83 CONUS, UTM
Location	**Detailed** written description of start point, include landmarks, road #, etc.
Comments	Record signs of activity in area, water conditions, other pertinent information

Starting the Inventory

After the crew has organized their gear, determined their measurement interval, selected a random number, and recorded all the header information they are ready to begin the habitat inventory.

The observer should enter the stream slightly downstream of the starting point, tie off the hipchain, progress upstream to the starting point, reset the hipchain to zero and begin walking upstream through the first habitat unit. As the observer moves upstream they use the wading rod to measure depth at several locations in the habitat unit and make observations of unit type, width, substrates, and percent fines. When they reach the upstream end of the habitat unit they stop, turn to face the unit and report the unit type, maximum and average depth, riffle crest depth (where appropriate), dominant and subdominant substrate classes, percent fines, estimated width, and hipchain distance to the recorder.

As the observer moves upstream through the unit, the recorder follows behind, recording the amount of LW in the habitat unit. The recorder also assigns a number to the habitat unit. The recorder tells the observer if a unit is designated for measurements (i.e. if it is a ‘paired sample’ unit) only after they have recorded visual estimates.

The crew continues upstream making estimates in every habitat unit and making estimates and measurements in every paired sample unit until the inventory endpoint is reached.

Definitions of habitat attributes, how to measure and when to record them, and what to do when the inventory is complete are covered in the following sections.

Unit Type (see abbreviations)

Unit Type	***Abbreviation***	**Definition**
Riffle	R	**Fast water, turbulent, gradient <12%**; shallow reaches characterized by water flowing over or around rough bed materials that break the surface during low flows; also **include rapids** (turbulent with intermittent whitewater, breaking waves, and exposed boulders), **chutes** (rapidly flowing water within narrow, steep slots of bedrock), and **sheets** (shallow water flowing over bedrock) if gradient <12%
Cascade	C	**Fast water, turbulent, gradient ≥12%**; highly turbulent series of short falls and small scour basins, with very rapid water movement; also **include sheets** (shallow water flowing over bedrock) and **chutes** (rapidly flowing water within narrow, steep slots of bedrock) if gradient ≥12%
Run	RN	**Fast water, non-turbulent, gradient <12%**; deeper than riffles with little or no surface agitation or flow obstructions and a flat bottom profile
Pool	P	Slow water, surface turbulence may or may not be present, gradient <1%; generally deeper and wider than habitat immediately upstream and downstream, concave bottom profile; includes dammed pools, scour pools, and plunge pools
Glide	G	**Slow water, no surface turbulence, gradient <1%**; shallow with little to no flow and flat bottom profile
Underground	UNGR	Stream channel is dry or not containing enough water to form distinguishable habitat units

*modified from Armantrout (1998)

How to estimate:
Habitat units are separated by ‘breaks’. Breaks can be obvious physical barriers, such as a debris dam separating two pools or a small waterfall separating a pool and riffle, or may be less obvious transitional areas. Questions often arise as to whether a break is substantial enough to split two habitat units and where the exact location of the break occurs. When in doubt, the observer should consult with the recorder and the team should ‘think like a fish’. To determine if a break should be made, consider whether a fish would have to make an effort to move across the break and into the next habitat unit. If not, then it is probably a single habitat unit.

The channel may have both pool and riffle type habitat in the same cross-sectional area. Determine the predominate habitat type and record it as the unit type. For example if an area contains both pool and riffle, but the majority of the flow is into and out of the pool habitat, then call the unit a pool.

Questions also often arise as to the minimum size of individual habitat units. Generally, if a habitat unit is not at least as long as the wetted channel is wide, then do not count it as a separate habitat unit. This rule may need to be adjusted for streams wider than 5 m. Use best professional judgment in such cases.

See the section 2.1 for a list of features that should also be recorded while performing the inventory.

When to record: every habitat unit

Unit Number (#)

Definition:
Count of habitat units of similar types, used to determine location of paired sample units

How to estimate:
When counting habitat units, group pools and glides (slow water) together, and group riffles, runs, and cascades (fast water) together. For example, consider the following sequence of habitat units:

Pool – Riffle – Pool – Pool – Riffle - Cascade – Riffle - Glide – Riffle – Pool – Run – Pool – Riffle

Habitat units in this sequence would be counted in the following manner (similar types are shaded same color):

Unit Type	Unit Number
P	1
R	1
P	2
P	3
R	2
C	3
R	4
G	4
R	5
P	5
RN	6
P	6
R	7

In the above example, the crew has counted six slow water (pool/glide) units and seven fast water (riffle/run/cascade) units.

When to record: every habitat unit; not recorded for features

Distance (m)

Definition:
Number of meters (rounded to the whole meter) from the start of the inventory to the upstream end of the habitat unit or distance from the start of the inventory to upstream end of a feature, used as spatial reference for data analysis and to locate features in the future.

How to estimate:
The observer walks upstream in the middle of the stream channel with a hipchain measuring device. When they reach the upstream break between habitat units or the upstream end of a feature they stop and report the distance to the recorder.

Care should be taken to keep the hipchain string in the middle of the stream, especially around bends and meanders. If the hipchain should break, retreat to the location where the break occurred, tie off the hipchain, and continue. If the hipchain is reset for any reason be sure to note it in the comments.

When to record: every habitat unit and feature

Estimated Width (m)

Definition:
Average wetted width of the habitat unit as estimated visually (typically to half-meter accuracy), used to calculate stream area. Wetted width is the distance from the edge of the water on one side of the main channel to the edge of the water on the opposite side of the main channel.

How to estimate:
The observer notes the general shape and width of the unit while walking to the upstream end. When they reach the upstream end of the unit the observer stops, turns to face the unit, and estimates the average wetted width. Measure the wetted width of the stream before starting each day to calibrate yourself.

When to record: every habitat unit

Maximum and Average Depth (cm)

Definitions:
Maximum Depth – vertical distance from substrate to water surface at deepest point in habitat unit
Average Depth – average vertical distance from substrate to water surface in habitat unit

How to estimate:
The observer uses a wading rod marked in 5 cm increments to measure water depth as they walk upstream through the habitat unit. Water depth in deepest spot is recorded as the maximum depth. Average depth is the average of several depth measurements taken throughout the habitat unit.

When to record: every habitat unit

Riffle Crest Depth (cm)

Definition:
Vertical distance from the substrate to the water surface at the deepest point in the riffle crest. The riffle crest is the shallowest continuous line (usually not straight) across the channel where the water surface becomes continuously riffled in the transition area between a riffle (or a run or cascade) and a pool (or glide) (Armantrout 1998); think of it as the last place water would flow out of the pool if the riffle ran dry.

How to estimate:
When the observer reaches the upstream end of a riffle (or a run or cascade) leading into a pool (or glide), they use the wading rod to measure the deepest point in the riffle crest. Record the depth in the RCD column for the riffle habitat row.

When to record: at the upstream end of any riffle, run, or cascade leading into a pool or glide

Dominant and Subdominant Substrate (1-9)

Definitions:
Dominant Substrate – size class of stream bed material that covers the greatest amount of surface area within the wetted channel of the habitat unit.

Subdominant Substrate – size class of stream bed material that covers the 2nd greatest amount of surface area within the wetted channel of the habitat unit.

How to estimate:
The following size classes are used to categorize substrates*. The substrate 'Number' is entered into the dominant and subdominant substrate columns on the datasheet.

Type	***Number***	***Size (mm)***	**Description**
Organic Matter	1		dead leaves, detritus, etc. – **not live plants**
Clay	2		sticky, holds form when rolled into a ball
Silt	3		slippery, does not hold form when rolled into a ball
Sand	4	silt – 2	grainy, does not hold form when rolled into ball
Small Gravel	5	3-16	sand to thumbnail
Large Gravel	6	17-64	thumbnail to fist
Cobble	7	65-256	fist to head
Boulder	8	>256	larger than head
Bedrock	9		solid rock, parent material, may extend into bank

* these size classes are based on the modified Wentworth scale

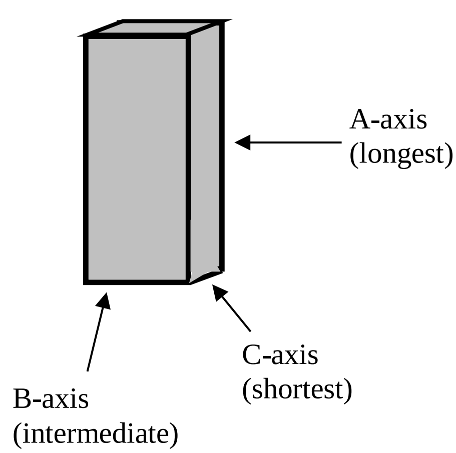
As the observer walks through the unit they scan the substrate. When they reach the upstream end of the unit they stop, turn to face the unit, and determine the dominant and subdominant substrate classes.

Estimate substrate size along the intermediate axis (b-axis). The b-axis is not the longest or shortest axis, but the intermediate length axis (see below). It is the axis that determines what size sieve the particle could pass through. Remember that your eyes are naturally drawn to larger size substrates. Be careful not to bias your estimate by focusing on the large size substrate.

Some units will contain a mixture of particle sizes. Consult with the recorder and use your best professional judgment to choose the dominant and subdominant sizes.

In units where the substrate is covered in moss, algae, or macrophytes classify the underlying substrate and make note of the plant growth in the comments. Only call organic substrate where there is dead and down leaves or other detritus covering the bottom of the unit.

When to record: every habitat unit



Rosgen Channel Type (A-G)

Definitions:
Stream channel classification system described in Rosgen (1996) based on entrenchment, width/depth ratio, sinuosity, and percent slope

How to Measure:
Before the crew begins the inventory they should make the measurements described below to determine the channel type. Channel types are based on the following channel characteristics:

	A	B	C	D	E	F	G
Entrenchment	< 1.4	1.4 – 2.2	> 2.2	n/a	> 2.2	< 1.4	< 1.4
W/D Ratio	< 12	> 12	> 12	> 40	< 12	> 12	< 12
Sinuosity	1 – 1.2	> 1.2	>1.2	n/a	> 1.5	> 1.2	> 1.2
Slope (%)	4 – 9.9	2 – 3.9	< 2	< 4	< 2	< 2	2 – 3.9

Although we record channel type for every unit, it was designed to describe a reach of stream. Our main objective here is to locate changes between channel types, which could either be abrupt (such as change from a B to a G near a road crossing) or less obvious transitional areas (such as a natural transition from a B to an A channel as you move upstream). If you think channel type may have changed take the time to make the calculations listed below to determine the channel type for the reach you are entering.

Full channel type descriptions and how to measure each of the channel characteristics in the table above can be found in Rosgen (1998). Never perform measurements in a pool, always attempt to find a run or deep riffle with well-defined bankfull indicators to perform measurements. A summary of each is listed below:

Entrenchment (page 31 & 32 in Rosgen field guide):

- locate suitable riffle or run area for bankfull measurement (page 24-25 in Rosgen field guide)
- measure the bankfull width the maximum bankfull depth
- stretch a tape across the channel at 2x the maximum bankfull depth (this is the flood prone area)
- divide the flood prone area width by the bankfull width to determine entrenchment ratio

Width to Depth Ratio (page 32 in Rosgen field guide):

- locate suitable riffle or run area for bankfull measurement (page 24-25 in Rosgen field guide)
- measure the bankfull width and the maximum bankfull depth
- divide bankfull width by depth to determine width to depth ratio

Sinuosity (need aerial photo to determine)

Slope (page 37 in Rosgen field guide):

- Measure riffle to riffle gradient using clinometer

When to measure: every paired fastwater habitat unit*

* record for every fastwater paired unit, but remember this is describing a reach characteristic – see above

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology Books, Pagosa Springs, Colorado.

Rosgen, D.L., and L. Silvey. 1998 Field Guide for Stream Classification, Wildland Hydrology Books, Pagosa Springs, Colorado.

Percent Fines (%)

Definition:
Percent of the total surface area of the stream bed in the wetted area of the habitat unit that consists of sand, silt, or clay substrate particles (i.e. particles < 2 mm diameter).

How to estimate:
As the observer walks through the habitat unit they note the amount of sand, silt, and clay in the habitat unit. When they reach the upstream end of the unit, they stop, turn to face the unit and estimate the amount of the total surface area within the wetted channel that consists of sand, silt, or clay.

Where to estimate: every habitat unit

Large Wood (1-4 and rootwad)

Definition:
Count of dead and down wood within the bankfull channel of a habitat unit

How to estimate:
The recorder classifies and counts LW as they walk through the habitat unit. LW counts are grouped by the size classes listed below:

Category	Length (m)	Diameter (cm)	Description
1	1-5	10-55	short, skinny
2	1-5	>55	short, fat
3	>5	10-55	long, skinny
4	>5	>55	long, fat
RW	rootwad	rootwad	roots on dead and down tree

Only count wood that is:

- 1 m in length and > 10.0 cm in diameter
- Within the bankfull channel
- Fallen, not standing dead

Additionally:

- Count rootwads separately from attached pieces of LW
- Estimate the diameter of LW at the widest end of the piece
- A piece that is forked, but is still joined counts as only one piece of LW
- Only count each piece one time, do not count a piece that is in two habitat units twice
- Enter the total count for each size category into the appropriate column on the datasheet

Where to estimate: every habitat unit

Actual Width (m)

Definition:
Average wetted width of the habitat unit as measured with 50 m tape, used to calculate stream area. Wetted width is the distance from the edge of the water on one side of the main channel to the edge of the water on the opposite side of the main channel.

How to measure:
Use a meter tape to measure the wetted width of the stream in at least three locations. Average the measurements to obtain the average wetted width.

Where to measure: paired sample habitat units

Bankfull Channel Width (m)

Definition:
Actual width of channel at bankfull elevation as measured with meter tape. Depending on channel type, bankfull may or may not be represented by the top of the banks. Use bankfull indicators to locate the top of the bankfull channel (Rosgen 1996).

How to measure:
Determine the location of bankfull water depth on both banks of the habitat unit and measure across the channel perpendicular to flow from bankfull to bankfull.

Where to measure: paired sample riffles, runs, or cascades

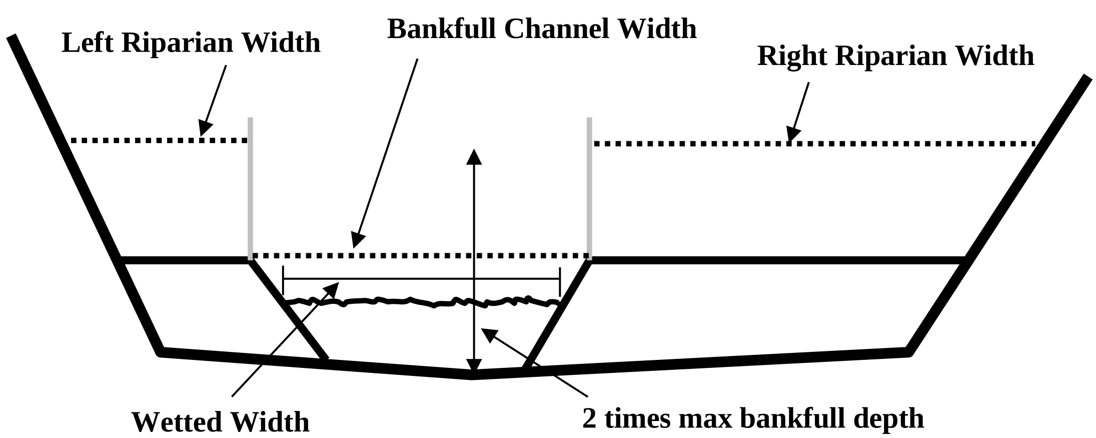
Riparian Width (m)

Definition:
Width of the riparian area at an elevation of two times the maximum bankfull depth, measured for both left and right banks (left and right as oriented facing upstream). Maximum bankfull depth is the greatest vertical distance from the substrate to the top of the bankfull channel across a bankfull transect.

How to measure:
- Stretch a measuring tape across the top of the bankfull channel – this is your bankfull transect
- Use a wading rod to find the maximum bankfull depth
- Place the clinometer against the wading rod at two-times the maximum bankfull depth
- Using the clinometer to maintain a slope of zero degrees, site perpendicular to the channel to the intersection with the nearest landform. It may be necessary to site to an intermediate point, move the wading and clinometer, and site again if the tape measure is too short or the view is obstructed
- Measure the distance from the edge of the bankfull channel to the landform – do this separately for the left and right (as facing upstream) riparian areas

Note: if riparian width is more than 50 m, record 51 as the riparian width and note in ‘Comments’ that riparian width was longer than meter tape

Where to measure: paired sample riffles, runs, or cascades



Gradient (%)

Definition:
Change in vertical elevation per unit of horizontal distance of the water surface (Armantrout 1998)

How to measure:
Gradient is measured in riffles with a clinometer using the following steps:

- Observer stands at upstream end of riffle, recorder stands at downstream end of riffle
- Recorder sites upstream to the height of their eye on the observer using clinometer
- Record the **percent** slope, **not the degrees** (tip the clinometer all the way back to determine which side of the scale is percent)

The recorder should determine the height of their eye on the observer at the beginning of the inventory. Be certain that the observer and recorder are standing with their feet in the same position (preferably with feet at top of water surface) within the stream channel. If the observer is standing on top of a boulder and the recorder is standing in a depression, the measured gradient will be incorrect.

Where to measure: paired sample riffles, runs, or cascades

Water Temperature (C)

Definition:
Temperature of the water in degrees Celsius.

How to measure:
Place the thermometer in moving water in an area not exposed to direct sunlight. Leave the thermometer sit for at least three minutes, then record the water temperature in degrees Celsius.

Where to measure: paired sample riffles, runs, or cascades

Photo (ID#)

Definition:
Photograph of habitat unit or crossing feature.

How to measure:
Take photo facing upstream with observer holding wading rod in picture. Be sure to get entire width (and length if possible) of habitat unit or crossing feature in the photo.

Where to measure: paired sample riffles, runs, or cascades and any crossing features encountered

Features

Definition: Points on a stream that could potentially serve as landmarks, may be natural or manmade.

How to measure: Record the distance to the upstream end of all features and take a photograph of all crossing features.

Where to record: wherever found

Channel Feature	Abbreviation	What to Record
Waterfall[1]	FALL	Distance, estimated height
Tributary	TRIB	Distance, average wetted width, into main channel on left or right (as facing upstream)
Side channel[2]	SCH	Distance, average wetted width, whether it is flowing into or out of main channel on left or right (as facing upstream)
Braid[3]	BRD	Distance at start and distance at end; continue with normal inventory up channel with greatest discharge
Seep (Spring)	SEEP	Distance, left or right bank (as facing upstream), size, coloration
Landslide	SLID	Distance, left or right bank (as facing upstream), estimated size
Other	OTR	Distance, description of feature, *example:* found water intake pipe going to house here; old burned out shack on side of stream; Big Gap campground on left; alligator slide here, etc.

[1] must be vertical with water falling through air to be a waterfall and not a cascade, do not record unless >1m high

[2] two channels, continue with normal inventory up channel with most volume

[3] three or more channels intertwined, continue with normal inventory up channel with most volume

Crossing Feature	Abbreviation	What to Record*
Bridge	BRG	Distance, width, height, road or trail name and type (gravel, paved, dirt, horse, ATV, etc.), photo
Ford	FORD	Distance, road or trail name and type (gravel, paved, dirt, etc.), photo
Dam	DAM	Distance, type, condition, estimated height, dam use, name of road or trail, if applicable; include beaver dams, photo
Culvert	V	Distance, road or trail name, type, # of outlets, diameter/width, height, material, perch (distance from top of water to bottom lip of culvert, natural substrate (present or absent through length), photo

* photograph all crossing features with person and wading rod for scale, record 'Y' in 'Photo' column

We cannot stress enough the importance of fully and accurately describing features. This means getting out a quadrangle map and finding road, trail, and tributary names and recording them in 'Comments' and taking the time to describe the location of features in relation to landmarks found on quadrangle maps.

Take photos of all crossing features!

Section 3: Wrapping Up

End the inventory where:

- Forest Service property ends
- Stream is dry for more than 500 m
- Stream channel is < 1.0 m wide for more than 500 m

Record the following in the Comments:

- Time and date
- Reason for ending the inventory
- Detailed written description of location using landmarks for reference
- **Be sure the header information is completed – GPS, etc**

When you return to home base:

- Immediately download the data and check file to be sure all data downloaded
- Check header information to be sure it is complete
- Save to the computer and create a backup copy
- Document any photographs
- If using paper, make a photocopy of the data and store in secure location

Section 4: Summary

Before starting:

- fill in header information

Record for every habitat unit:

- Unit Type
- Unit Number
- Distance
- Estimated Width
- Maximum Depth
- Average Depth
- Dominant Substrate
- Subdominant Substrate
- Percent Fines
- Large Wood

Record for every riffle, run, or cascade leading into a pool or glide:

- Riffle Crest Depth

Record for every paired sample pool:

- Measured Width

Record for every paired sample riffle:

- Measured Width
- Bankfull Channel Width
- Riparian Width (left and right)
- Gradient
- Rosgen Channel Type
- Water temperature
- Photograph

Record features and full feature descriptions wherever they are encountered.

Photograph all crossings!

Section 5: GPS Instructions

Garmin BVET Waypoint Labels:

Garmin BVET Waypoint Label Examples:

S123	**Start** location of BVET survey
E123	**End** location of BVET survey

123 = Site identification number

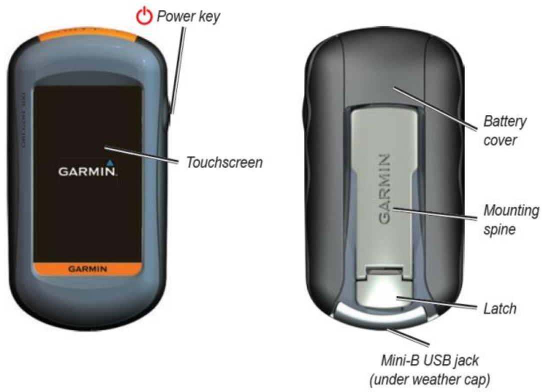
How to Find a Waypoint on GPS:

- Turn Power On.
- On the main menu screen touch the **Where To?** icon with the magnifying glass.
- Touch the **Waypoints** icon with the red golf flag.
- At the bottom of the next screen touch the **ABC** pyramid button.
- Start typing in the name of the desired waypoint. Once the waypoint name is identified by the GPS it will list the waypoints associated with that waypoint name.
    - Note: Touch the left and right arrows at the bottom of the screen to move from letters to numbers to symbols. Touch the down arrow on the letters to get lowercase and up arrow to get back to uppercase.
- Touch the waypoint name you were looking for when the list pops up.
- To navigate to this location touch the big green **Go** button.

Changing Waypoints:

- To switch waypoints close the map screen by touching the **X** close button in the lower left corner of the screen.
- On the main menu screen touch the **Where To?** icon with the magnifying glass.
- Touch the Stop Navigation button and repeat the top process to get to a new waypoint.

Garmin GPS Oregon 400T Cheatsheet



Turn On

- Press Power key, wait for GPS to boot

Turn Off

- Press and hold Power key

Backlight Strength

- Press and quickly release Power key, adjust with touchscreen options

Create New Waypoint

1. To create a waypoint of your current position touch "*Mark Waypoint*"
2. Touch "*Save and Edit*", touch "*Change Name*", type desired label, touch "*Green Check Icon*" to save

Calibrate compass

1. Whenever batteries are removed you must calibrate the compass so the map orients correctly
2. Touch "*Setup*", touch "*Heading*", touch "*Press to Begin Compass Calibration*"
3. Touch "*Start*", hold GPS level and rotate it twice on your palm

Data Fields

1. To change the data fields on the map page touch "*Map*"
2. Touch a data field at the top of the map, then select your desired data field

Calibrating the Touchscreen

1. If the touchscreen buttons are not responding properly, recalibrate the touchscreen
2. While the GPS is turned off, press and hold the power key for ~30 seconds
3. Follow instructions on the screen until calibration is complete

Appendix: Field Guide, Equipment Checklist, Rosgen Worksheet

Record for every habitat unit:

- **Unit Type** – pool, riffle, run, cascade, glide, feature (see below)
- **Unit Number** – group pools & glides; group riffles, runs, cascades
- **Distance (m)** – at upstream end of unit
- **Estimated Width (m)** – visual estimate of average wetted width
- **Maximum Depth (cm)** – deepest spot in unit
- **Average Depth (cm)** – average depth of unit
- **Dominant Substrate (1-9)** – covers greatest amount of surface area in unit
- **Subdominant Substrate (1-9) –** covers 2nd most surface area in unit
- **Percent Fines (%)** – percent of bottom consisting of sand, silt, or clay
- **Large Wood (1-4, RW)** – count of dead and down wood in the bankfull channel

Record for every riffle, run, or cascade leading into a pool or glide:

- **Riffle Crest Depth (cm) –** deepest spot in hydraulic control between riffle type habitat and pool type habitat

Record for paired sample pools:

- **Measured Width (m)** – measurement of average wetted width

Record for paired sample riffles:

- **Measured Width (m)** – measurement of average wetted width
- **Channel Width (m)** – measurement of bankfull channel width
- **Riparian Width (m) –** L&R, measurement of floodplain
- **Gradient (%)** – clinometer measurement of riffle slope
- **Water Temperature (C)** – temperature of water in Celsius
- **Rosgen –** channel type classification
- **Photo (y or n) –** picture of habitat unit or crossing feature

Unit Types

- **Riffle (R) –** fast water, turbulent, gradient <12%; includes rapids, chutes, and sheets if gradient <12%
- **Cascade (C)** – fast water, turbulent, gradient ≥12%, includes sheets and chutes if gradient ≥12%
- **Run (RN) –** fast water, little to no turbulence, gradient <12%, flat bottom profile, deeper than riffles
- **Pool (P) –** slow water, may or may not be turbulent, gradient <1%, includes dammed, scour, and plunge pools
- **Glide (G)** – slow water, no surface turbulence, gradient <1%, shallow with little flow and flat bottom profile
- **Underground (UNGR) –** distance at upstream end, why dry

Features

- **Waterfall (FALL)** – distance, height
- **Tributary (TRIB)** – distance, width, in on L or R
- **Side Channel (SCH)** – distance, width, in or out on L or R
- **Braid (BRD)** – distance at downstream and upstream ends
- **Seep or Spring (SEEP)** – distance, on left or right, amount of flow
- **Landslide (SLID)** – distance, L or R, est. size and cause
- **Other (OTR)** – record distance, describe feature in comments
- **Crossing Features** – photograph and record the following:
- **Bridge (BRG)** – distance, height, width, road or trail name & type
- **Dam (DAM)** – distance, type, est. height, road or trail name &type
- **Ford (FORD)** – distance, road or trail name & type
- **Culvert (V)** – distance, type (pipe, box, open box, arch, open arch), size, material, natural substrate, perch, road or trail name

Substrates

- **Organic Matter** – dead leaves detritus, etc., not living plants
- **Clay** – sticky, holds form when balled
- **Silt** – slick, does not hold form when balled
- **Sand** – >silt-2mm, gritty, doesn't hold form
- **Small Gravel** – 3-16mm, sand to thumbnail
- **Large Gravel** – 17-64mm, thumbnail to fist
- **Cobble** – 65-256mm, fist to head
- **Boulder** – >256, > head
- **Bedrock** – solid parent material

Large Wood

- **#1** <5m long, 10-55cm diameter
- **#2** <5m long, >55cm diameter
- **#3** >5m long, 10-55cm diameter
- **#4** >5m long, >55cm diameter
- **RW** – rootwad, count separately from attached LW, record in comments, do not record wood <10cm diameter, <1m length

Rosgen Channel Types

Rosgen Channel Types	A	B	C	D	E	F	G
Entrenchment	< 1.4	1.4 – 2.2	> 2.2	n/a	> 2.2	< 1.4	< 1.4
W/D Ratio	< 12	> 12	> 12	> 40	< 12	> 12	< 12
Slope (%)	4 – 9.9	2 – 3.9	< 2	< 4	< 2	< 2	2 – 3.9

Measuring Riparian Width (paired fast-water units only)

- Place clinometer against the wading rod at two times max bankfull depth
- Use the clinometer as a level – keep the slope at 0.0 – and site to the nearest landform perpendicular to the channel
- Measure the distance from the edge of the bankfull channel to the intersection with the landform
- Do this for both the left and right banks
- If riparian width in more than 50 m, record 51 as the riparian width and in 'Comments' note that riparian was > 50 m wide

End inventory

- End the inventory when the calculated sample distance has been inventoried.

Equipment Checklist

- ☐ hipchain
- ☐ extra string for hipchain
- ☐ wading rod
- ☐ 50 m tape measure
- ☐ clinometer
- ☐ thermometer
- ☐ datalogger
- ☐ GPS unit
- ☐ camera
- ☐ backpack
- ☐ pencils
- ☐ flagging
- ☐ markers
- ☐ waterproof backup datasheets
- ☐ clipboard
- ☐ BVET field guide on waterproof paper
- ☐ topographic maps
- ☐ water
- ☐ water filter
- ☐ lunch
- ☐ first aid kit
- ☐ radio/cell phone
- ☐ toilet paper
- ☐ felt bottom wading boots
- ☐ raingear

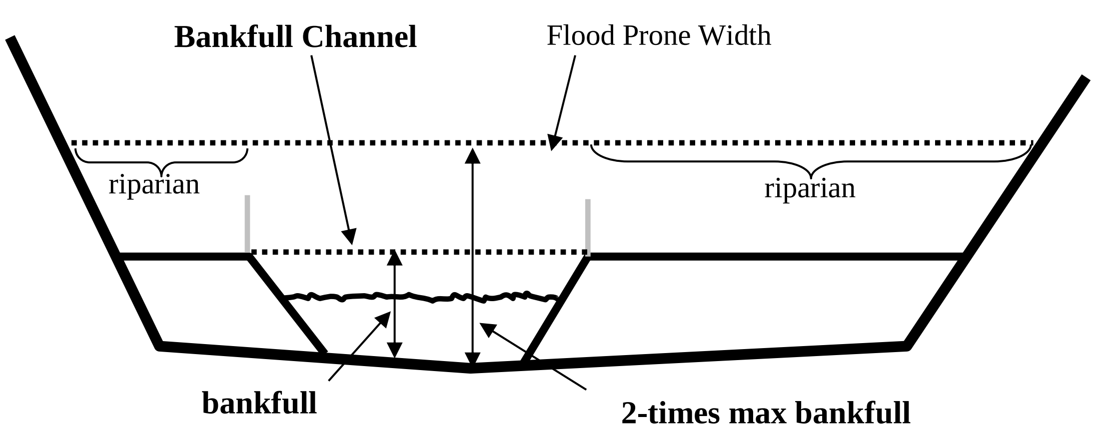
Rosgen Measurements

All measurements should be made across a transect in an area of uniform flow, specifically riffle or run sections with few irregularities in cross-sectional shape. **Avoid** areas influenced by culverts, bridges, tributaries, side-channels, etc.

- What is the **entrenchment ratio**?
    - Entrenchment ratio = flood prone width / bankfull width
    - Floodprone width = width at two-times maximum bankfull depth

- What is the **width/depth ratio**?
    - Width/depth ratio = bankfull width / average bankfull depth
    - Be sure to use same units of measure (centimeters) for width and depth
    - Measure *bankfull* depth (**not** *water* depth) at several locations across transect to obtain average bankfull depth

- What is the **gradient**?
    - Measure riffle to riffle slope (%) with clinometer



Rosgen Worksheet

A. Bankfull Channel Width (m) _____

B. Maximum Bankfull Depth (cm) _____ *2 = _____

C. Average Bankfull Depth (cm) _____

D. Right Riparian Width (m) _____

E. Left Riparian Width (m) _____

F. Gradient (%) _____

Entrenchment Ratio = (A+D+E)/A

(_____ + _____ + _____) / _____ = _____

Width Depth Ratio = (100*A)/C

(100* _____) / _____ = _____

	A	B	C	D	E	F	G
Entrench. ratio	< 1.4	1.4 – 2.2	> 2.2	n/a	> 2.2	< 1.4	< 1.4
W/D ratio	< 12	> 12	> 12	> 40	< 12	> 12	< 12
Gradient (%)	4 – 9.9	2 – 3.9	< 2	< 4	< 2	< 2	2 – 3.9

*these are the dominant ranges, values may be slightly outside these ranges

Appendix C: Field Methods for Macroinvertebrate Sampling

Macroinvertebrate Equipment List

- Mesh wash bucket
- Rinse bucket
- Squirt bottle
- Seine
- D-Frame nets
- PVC ¼ sq meter quadrates
- Tweezers
- Collection jars
- Sample labels
- Pencils
- Markers
- Ethyl alcohol

Macroinvertebrate Sampling Methods

1. **Riffle Sample**
   - Take four 0.25 m^2 samples from midriffle or the thalweg (path of deepest thread of water).
   - For each of the 4 samples, place a seine (600 μm mesh, one meter wide) in moderate to fast current in areas with gravel to cobble substrate. Place some rocks on the bottom edge of the seine to hold it on the channel bottom.
   - Dislodge benthos by vigorously disturbing 0.25 m^2 (20 x 20 in.) in front of the net (use 0.25 m^2 PCV quadrate to sample correct area). Large rocks should be hand washed into the net.
   - After each of the 4 samples is collected wash the contents of the net into a mesh wash bucket to prevent loss of inverts when collecting the next sample. All four samples are composited in the bucket.
   - Find a suitable location on the side of the stream, spread the seine out on the ground, and wash the contents of the bucket onto the seine. With tweezers methodically sort through the sample picking out the invertebrates and placing them in a sample jar containing ethyl alcohol.
   - The picking process can easily take an hour to complete; be patient and thorough. When complete be sure there is a sample label inside the jar as well as one on the outside.
   - *This sample must be kept separate from all other subhabitat collections.*

2. **Multi-Habitat Sample**

   A. **Sweep Sample** - Involves sampling a variety of non-riffle habitats with the aid of an 800 x 900 μm mesh D-frame dipnet. Each habitat is sampled in at least three (3) replicates, where possible.

      1) *Undercut banks/root mats* - sampled by placing a large rootwad into the D-frame dipnet and shaken vigorously. The contents are removed from the dipnet and placed into a mesh wash bucket. Note: if undercut banks are present in both run and pool areas, each is sampled separately with three replicates.

2) *Marginal emergent vegetation* (exclusive of *Justicia americana* beds) – sampled by thrusting (i.e., “jabbing”) the dipnet into the vegetation for ca. 1 m, and then sweeping through the area to collect dislodged organisms. Material is then rinsed in the wash bucket and any sticks, leaves and vegetation are thoroughly washed and inspected before discarding.

3) *Bedrock or slab-rock habitats* - sampled by placing the edge of the dipnet flush on the substrate, disturbing approximately 0.1 m^2 of area to dislodge attached organisms. Material is emptied into a wash bucket.

4) *Justicia americana (water willow) beds* - sampled by working the net through a 1 m section in a jabbing motion. The material is then emptied into a wash-bucket and any *J. americana* stems are thoroughly washed, inspected and discarded.

5) *Leaf Packs* - preferably “conditioned” (i.e., not new-fall material) where possible; samples are taken from a variety of locations (i.e., riffles, runs and pools) and placed into the wash-bucket. The material is thoroughly rinsed to dislodge organisms and then inspected and discarded.

B. Silt, sand, and fine gravel

1) *Netting* - a D-frame dipnet is used to collect sand and silt depositional areas by placing the net on the substrate and vigorously stirring the sediments in front of the net. An area of 0.1 m^2 is sampled for each replicate making sure, where possible, that replicates are taken from different depositional areas.

C. Aufwuchs sample - small invertebrates associated with this habitat are obtained by washing a small amount of rocks, sticks, leaves, filamentous algae and moss into a medium-sized bucket half filled with water. The material is then elutriated and sieved with the nitex sampler.

D. Rock Picking - invertebrates are picked from 15 rocks (large cobble-small boulder size; 5 each from riffle, run and pool). Selected rocks are washed in a bucket half filled with water, then carefully inspected to remove invertebrates with fine-tipped forceps.

E. *Wood Sample* - pieces of submerged wood, ranging from roughly 3 to 6 meters (10 to 20 linear feet) and ranging from 5–15 cm (2–6 inches) in diameter, are individually rinsed into the wash-bucket. Pieces of wood are inspected for burrowers and crevice dwellers. Large diameter, well-aged logs should be inspected and handpicked with fine-tipped forceps.

Macroinvertebrate Sampling Summary

	Sample	Sampling Device	Habitat	Replicates (composited)
1	Riffle*	Kick Seine/Mesh bucket/PVC Sq.	Riffle	4 - 0.25 m^2
2	Sweep - Undercut banks	Dipnet/Mesh Bucket	Undercut Banks/Roots	3
3	Sweep - Emergent vegetation	Dipnet/Mesh Bucket	Emergent Vegetation	3
4	Sweep - Bedrock	Dipnet/Mesh Bucket	Bedrock/Slabrock	3
5	Sweep - Justicia beds	Dipnet/Mesh Bucket	Justicia beds	3
6	Sweep - Leaf packs	Dipnet/Mesh Bucket	Riffle-Run-Pool	3
7	Silt,Sand, Fine Gravel	Dipnet/Mesh Bucket	Margins	3
8	Aufwuchs	Dipnet/Mesh Bucket	Riffle-Run-Pool	3
9	Rock Picking	Forceps	Riffle-Run-Pool	15 rocks (5-5-5)
10	Wood	Mesh Bucket	Riffle-Run-Pool	3-6 linear m

*Sample contents kept separate from other habitat samples.

Appendix D: Field Methods for Riffle Stability Index

Riffle Stability Index Field Methods

The Riffle Stability Index procedure is best applied to stream channels with gradients from 1.5 to 5 percent. The channel is best described as a Rosgen B-2, B-3, B-4or F-2, F-3, F-4 type. Three riffles are measured within each uniform Rosgen reach. Each riffle selected for measurement should be representative or typical within the reach. An ideal riffle is located in a straight section of reach, has uniform depth in the cross-section, and is at a point of thalweg crossover. Flow is evenly distributed across the channel and is not concentrated toward either bank. For each riffle, field data are gathered to determine the distribution of particle sizes present. An estimate of the common large size of particle capable of movement at bankfull flow is obtained by sampling a nearby bar deposit.

1. Pebble Count - Particle Size Distribution on the Riffle

A particle size distribution is obtained on the riffle by a bed material sampling procedure called a "Wolman Pebble Count". A sample size of at least 200 is necessary for RSI. The sample points are identified by establishing a sampling grid over the riffle, with transects across the channel from bankfull to bankfull over the entire length of riffle. Samples are taken every foot along the transect. Thus, bankfull width in feet will equal the number of samples per transect. Dividing 200 by the number of samples per transect and rounding up will determine the number of transects needed. Spacing between transects is determined by dividing the length of riffle by the number of transects needed. For each sample, the intermediate axis of the particle is measured using a metric caliper, and is tallied by size class. For very large particles, count the same particle as many times as you encounter it. The cumulative percent finer is then calculated for each size class, and plotted on the graph.

2. Bar (Cobble) Count - Dominant Large Particles on a Bar

Measure 30 of the freshly moved dominant large particles residing on a bar or similar depositional feature to estimate the largest particle size transported at flows of bankfull and above. Freshness is evaluated by lack of growing vegetation and lack of embeddedness of the particles. The depositional feature must be in close proximity to the riffle being examined, and can include laterally attached bars, side bars, and central bars. The entire bar should be visually inspected to identify the dominant large size of particle present. If a bar deposit cannot be found, trained field personnel may select the large mobile particles from within the riffle. When this is done, a sample size of at least 20 is needed. For each of the particles, the intermediate axis is measured and recorded to the nearest millimeter. Calculate the arithmetic mean of the sample, and compare this with the plotted cumulative particle size distribution for the riffle. On the X axis, find the mean bar sample grain size. Go up to the cumulative particle size distribution, and read from the Y axis the percentile this represents. This percentile is the Riffle Stability Index.