## INTRODUCTION

During 2017 a second collection effort was performed to obtain data regarding aquatic macroinvertebrates and substrate characteristics at Hudson River tributary sites collected during initial study in 2016. During 2017, all five tributary sites were again sampled: Wynantskill, Annandale Dam – Sawkill; Shapp Pond – East Branch Wappingers Creek; Browns Pond – Otterkill; and Oscawana Dam – Furnace Brook (Figure 1). Since the 2016 sampling effort, the Shapp Pond dam was completely removed. Thus, 2017 sampling represents the first post-removal data at that site. The barrier on the Wynantskill was removed in May 2016, therefore the 2017 effort represents the second post-removal data collection at that site. Barriers at Brown's Pond, Oscawana Dam, and Annandale Dam remained intact during the 2017 sampling effort. As such, 2017 collection efforts represent the second year of baseline pre-removal data at existing barrier sites.

## METHODS

*Sample Locations*

Aquatic macroinvertebrates were collected from five streams within the Hudson River watershed: (1) 'Troy Gate' on the Wynantskill in Rensselaer County, (2) 'Annandale Dam' at Bard College on the Sawkill in Dutchess County, (3) 'Shapp Pond' on the East Branch Wappingers Creek in Dutchess County, (4) 'Brown's Pond' on the Otterkill in Orange County, and (5) 'Maiden Lane Dam' on Furnace Brook in Westchester County. Collectively, these sites are distributed over 170km of longitudinal Hudson River length. This spatial distribution allows for a wide representation of invertebrate taxa to be included in the sampling effort. A tabular summary of the collection dates and GIS locations by site can be found in Table 1.

Each of the sampling locations contained a historic impoundment. At Troy Gate the barrier was a metallic tidal gate, which was removed in May 2016, resulting in the conversion of upstream locations from lentic to lotic habitat conditions. The Shapp Pond dam was damaged and partially breached during Hurricane Irene (2012), causing water levels to decline from historic levels of greater than 2m. It was completely removed in October 2016. Brown's Pond Dam, Annandale Dam, and Oscawana Dam possessed fully intact barriers and impoundments with depths ranging from 1.1-2.5m.

At each location, paired upstream/downstream locations were sampled for aquatic macroinvertebrates. Troy Gate was kick-sampled at four riffle locations at increasing distances upstream of the former barrier. Four samples were chosen to increase sample size due to the lack of a downstream location. At Shapp Pond, due to the conversion to lotic habitat, three upstream kick-samples were collected at the locations of former Ponar-samples collected during summer 2016. Three kick samples were also taken at the downstream reach within wadeable riffles. At currently impounded sites, three replicate kick-samples were taken at wadeable riffle habitats at increasing distance (~15-50m) downstream of the barrier, beginning at the first accessible riffle. Upstream locations within impoundments were accessed by canoe. Three replicate benthic Ponar-grab samples were taken at increasing distances upstream of the barrier (~20-80m) at points estimated to be in or near the thalweg of the former stream channel. Additionally, three Hester-Dendy multiplate substrate samplers were deployed for 5-weeks within upstream impoundments at the locations of Ponar-grab samples. The dual sampling strategy at upstream locations allows for a more accurate comparison of species representation which can be compared to downstream locations. Site accessibility, both upstream and downstream, was limited by private property boundaries.

At each sample point habitat parameters were measured. Physical measurements included air and water temperature, water depth, substrate composition, overhead canopy cover, and additional habitat structure such as woody debris. Additionally, biological observations of periphyton cover, aquatic macrophyte abundance, algal bloom presence, as well as any human impacts (trash, point sources, angling remnants) were also recorded.

To accurately track changes in habitat composition post-removal, at each downstream sample point and at Shapp Pond upstream sampling points, a comprehensive cross-stream transect was established in 2017. Beginning and end points of the transect were set using 18# staking nails at permanent points spanning bankfull width. At interval points of 1-foot along the transect, water depth, stream-bottom elevation, and substrate composition was measured. Substrate composition was conducted by recording the first substrate class encountered when touching a point on the stream bottom, as described in the Wolman Pebble Count method (Bevenger and King, 1995). Stream-bottom elevation was surveyed using a rod and level. A local benchmark was established for each transect, allowing future surveying measurements to be indexed to the same relative elevation.

Due to the lentic nature of upstream habitats, detailed transect measurements were infeasible. At each upstream sample point, water depth and sediment composition was recorded. Sediment composition was estimated by sieving sediment volume captured in the Ponar grab through a 500-micron sieve.

*Invertebrate Collection*

Specific methodological techniques can be in the 2014 Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State (Smith, 2014). At each downstream riffle, a 5-min travelling kick sample was performed across the width of the stream angled in an upstream direction. Downstream replicates were collected from downstream to upstream, avoiding drift/dislodge bias within subsequent samples. Following sample collection, large debris (rocks, woody debris, and leaves) were rinsed, picked of invertebrates, and removed from the netted sample. Remaining sample volume was preserved on-site with 70% Ethanol.

To capture the functional diversity of aquatic invertebrate communities at upstream locations within the impoundments, a dual sampling strategy was employed. Ponar grabs at three replicate points ascending upstream from the barrier, across a similar 50-80m spacing, were collected to capture benthic invertebrates. Additionally, to capture taxa found within the water column and in drift, Hester-Dendy type substrate samplers were deployed at each of the Ponar grab locations for a 5-week colonization period. This approach allows the collection and representation of taxa from dual habitat types within the impoundment and provides for a more appropriate comparison with the downstream benthic samples which do not have the same level of habitat separation.

Ponar grab sediments were rinsed through 500um sieves to remove silt and fine detritus, and the remaining sample was preserved on site in 70% ethanol. Substrate samplers were captured by slowly retrieving the sampler to the canoe and placing it in a two gallon ziplock bag to avoid loss of organisms escaping the plates once it was removed from the water. Once all substrate samplers were retrieved and bagged, technicians returned to land for sample processing. Processing included washing and scraping the plates clean and free of organisms over a 500um sieve. All sample material collected in the sieve was then preserved on site in 70% ethanol.

Collected invertebrate samples were returned to the lab and identified to the lowest practicable taxonomic level using a 40x dissecting microscope. Chironomidae taxa were archived for future slide mounting identification. All taxa were stored in 70% ethanol and archived. For identification of kick and Ponar samples, a 100-count individual subsample was randomly removed from respective sample collections. For multiplate samples, a 250-count individual subsample was randomly removed.

*Biological Assessment of Water Quality*

Following enumeration and identification of aquatic macroinvertebrates, calculations of water quality impairment were made. Metrics used for the calculation of water quality impairment designations associated with kick, Ponar, and multiplate samples include (1) Species Richness (SPP), (2) Ephemeroptera-Plecoptera-Trichoptera Richness (EPT), (3) Hilsenhoff's Biotic Index (HBI), (4) Percent Model Affinity (PMA), (5) Species Diversity (DIV), and (6) Dominance-3 (DOM). Once individual metric scores are determined, they are converted to a common 0-10 scale, with 0 being poor water quality and 10 being excellent water quality. The assignment of a Biological Assessment Profile (B.A.P) per sampling location is made by averaging the water quality scores across each metric. Water quality impairment designations are assigned by the B.A.P and include four categories: non-impact, slight impact, moderate impact, and severe impact. Detailed methodologies and calculation formulae for macroinvertebrate metrics and water quality conversion scores can be found in The Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State (Smith, 2014).

Statistical Analyses

To compare 2017 Biometric responses across sampling sites, we used multiple linear regression. We conducted a two-way analysis of variance with year and site as covariates to test differences in Biometric responses between 2016 and 2017 within the same site location. All analyses were performed with R software version 3.1.2 (R Development Core Team 2008).

## 2017 RESULTS

### *WYNANTSKILL*

Upstream

During 2017, the formerly impounded Wynantskill segment upstream of the former tidal gate measured a mean bankfull width of 10.0m and a mean depth of 0.21m. The mean substrate profile within the wetted width of each of four transects this reach, assessed visually in June 2017, composed of 0% bedrock, 15% boulder, 42% cobble, 35% gravel, 6% sand, and 2% fines (Table 2). Comprehensive transect survey data documented bankfull-to-bankfull mean substrate analyses to be 0% bedrock, 8% boulder, 25% cobble, 48% gravel, 12% sand, and 7% fines (Table 4, Figures 22-25). The mean water temperature observed during the aquatic macroinvertebrate collections was 15.8°C. This reach was dominated by mayflies, midges, and oligochaetes, representing 52.9%, 15.5%, and 15.2% relative abundances respectively (Figure 6). Minority taxa included caddisflies (7.5%)and beetles (6.5%). Rare taxa, including stonefly nymphs and crane fly larvae, comprised the remaining 2.1% of abundances.

### *SAWKILL – ANANDALE DAM*

Downstream

The Sawkill segment at Annandale Dam measured a mean wetted width of 13.2m and a mean depth of 0.18m. The mean substrate profile within the wetted width of each of three transects this reach, assessed visually in June 2017, composed of 0% bedrock, 6% boulder, 55% cobble, 32% gravel, 3% sand, and 4% fines (Table 2). Comprehensive transect survey data documented bankfull-to-bankfull mean substrate analyses to be 0% bedrock, 7% boulder, 33% cobble, 32% gravel, 2% sand, and 26% fines (Table 4, Figures 26-28). The mean water temperature observed during the aquatic macroinvertebrate collections was 20.5°C. This reach was dominated by mayflies, caddisflies, and midges, representing 30.0%, 24.5%, and 19.5% relative abundances respectively (Figure 7). Minority taxa included beetles (8.2%) and stoneflies (4%).

Upstream

The Annandale Dam impoundment measured a mean depth of 1.24m and exhibited a substrate composition of 100% fines. The mean water temperature observed during ponar collections was 22°C. The upstream impoundment ponar samples were dominated by midges with 52.7% abundance. Minority taxa included oligochaetes (8%), leeches (8%), mayflies (5.8%), snails (5.8%), and copepods (5.8%) (Figure 8). At multiplate samplers deployed above Annandale Dam, colonizing macroinvertebrates were dominated by midges and caddisflies, representing 68.1% and 20.1% relative abundances respectively (Figure 15). Minority taxa included mayflies (5.2%), oligochaetes (2.7%), and beetles (1.6%).

## *EAST BRANCH WAPPINGERS CREEK – SHAPP POND*

Downstream

The downstream segment at Shapp Pond measured a mean wetted width of 13.7m and a mean depth of 0.13m. The mean substrate profile within the wetted width of each of three transects this reach, assessed visually in June 2017, composed of 7% bedrock, 1% boulder, 28% cobble, 38% gravel, 25% sand, and 1% fines (Table2). Comprehensive transect survey data documented bankfull-to-bankfull mean substrate analyses to be 9% bedrock, 6% boulder, 21% cobble, 33% gravel, 21% sand, and 10% fines (Table 4, Figures 29-31). The mean water temperature observed during the aquatic macroinvertebrate collections was 17.3°C. This reach was dominated beetles (34.4%), mayflies (23.7%), midges (17.9%), and caddisflies (12.6%) (Figure 9). Minority taxa included stoneflies (4.0%) and amphipods (3.1%).

Upstream

The barrier removal at Shapp Pond (Oct 2016) caused the upstream segment to change from lentic to lotic habitat. The upstream reach measured a mean wetted width of 7.01 m and a mean depth of 0.18m. The mean substrate profile within the wetted width of each of three transects this reach, assessed visually in June 2017, composed of 0% bedrock, 1% boulder, 13% cobble, 35% gravel, 37% sand, and 15% fines (Table 2). Comprehensive transect survey data documented bankfull-to-bankfull mean substrate analyses to be 1% bedrock, 0% boulder, 15% cobble, 42% gravel, 17% sand, and 25% fines (Table 4, Figures 32-34). The mean water temperature observed during the aquatic macroinvertebrate collections was 17.1°C. This reach was dominated midges (37.3%), mayflies (24.5%), oligochaetes (13.1%), and beetles (9.3%) (Figure 10). Minority taxa included caddisflies (5.8%), amphipods (5.0%), and stoneflies (2.6%).

**OTTERKILL – BROWN'S POND**

Downstream

The downstream segment at Brown's Pond measured a mean wetted width of 18.1m and a mean depth of 0.14m. The mean substrate profile within the wetted width of each of three transects this reach, assessed visually in June 2017, composed of 15% bedrock, 20% boulder, 47% cobble, 12% gravel, 5% sand, and 1% fines (Table 2). Comprehensive transect survey data documented bankfull-to-bankfull mean substrate analyses to be 18% bedrock, 11% boulder, 33% cobble, 19% gravel, 10% sand, and 10% fines (Table 4, Figures 35-37). The mean water temperature observed during the aquatic macroinvertebrate collections was 25°C. This reach was dominated by midges (28.7%), amphipods (23.7%), caddisflies (11.8%), and isopods (10.3%) (Figure 11). Minority taxa included oligochaetes (7.5%), snails (7.2%), and flatworms (6.2%).

Upstream

The Brown's Pond impoundment measured a mean depth of 2.52m and exhibited a substrate composition of 100% fines. The mean water temperature observed during ponar collections was 26°C. The upstream impoundment ponar samples were dominated by oligochaetes (36.7%), midges (30%), Daphnia (10%), and copepods (10%) (Figure 12). Minority taxa included caddisflies (6.7%), snails (3.3%), and amphipods (3.3%). At multiplate samplers deployed above Browns Pond, colonizing macroinvertebrates were dominated by oligochaetes and midges representing 99% of macroinvertebrate abundance (52.4% and 47% relative abundance, respectively) (Figure 15). Minority taxa comprising less than one-percent included leeches, copepods, and damselflies.

**FURNACE BROOK – OSCAWANA DAM**

Downstream

The downstream segment at Oscawana Dam measured a mean wetted width of 10.8m and a mean depth of 0.17m. The mean substrate profile within the wetted width of each of three transects this reach, assessed visually in June 2017, composed of 0% bedrock, 32% boulder, 28% cobble, 34% gravel, 4% sand, and 1% fines (Table 2). Comprehensive transect survey data documented bankfull-to-bankfull mean substrate analyses to be 0% bedrock, 18% boulder, 24% cobble, 38% gravel, 5% sand, and 16% fines (Table 4, Figures 38-40). The mean water temperature observed during the aquatic macroinvertebrate collections was 24°C. This reach was dominated by midges (70.0%) and caddisflies (11 %) (Figure 13). Minority taxa included isopods (4.4%), true flies (3.8%), and mayflies (2.1%).

Upstream

The Oscawana Dam impoundment measured a mean depth of 1.28m and exhibited a substrate composition of 100% fines. The mean water temperature observed during ponar collections was 23.5°C. The upstream impoundment ponar samples were dominated by oligochaetes (58.5%), midges (15.4%), amphipods (10%) (Figure 14). Minority taxa included copepods (9.4%) and snails (2%). At multiplate samplers deployed above Oscawana Dam, colonizing macroinvertebrates were dominated by oligochaetes (42.5%) and midges (42.3%). Minority taxa included true flies (5.1%), snails (2.7%), dragonflies (2.0%), and mayflies (1.9%) (Figure 15).

## BIOLOGICAL ASSESSMENT OF WATER QUALITY - 2017

A total of 5,475 aquatic macroinvertebrates were enumerated and identified from collected samples across all five sites. Taxa representation spanned 12 Classes, 19 Orders, 48 Families, and 68 genera of aquatic macroinvertebrates. A complete taxa list can be found in the supplemental information. A tabular summary of mean Biometric values by Site/location can be found in Table 5.

*Kick Sample Impairment Designations*

The downstream segment below Annandale Dam possessed the highest water quality among our five sites with a mean B.A.P score of 7.15, designating slight impairment. The downstream segment below the former Shapp Pond dam possessed the second highest water quality among our sites with a mean B.A.P score of 7.15, designating slight impairment. The upstream segment at Shapp Pond possessed the third highest mean B.A.P. score with 6.54, designating slight impairment. The upstream segment above the Wynantskill gate is also designated as slight impairment with a mean B.A.P score of 5.62. The downstream segments below Browns Pond and Oscawana Dam possessed moderate impact designations. The mean B.A.P score on Furnace Brook below Oscawana Dam calculated to 4.15, while the Otterkill below Browns Pond represented the lowest mean B.A.P score of 3.36.

*Upstream Ponar and multiplate Impairment Designations*

The Annandale Dam impoundment possessed the highest mean B.A.P score of 4.35, designating moderate impact, when combining the multiplate and Ponar scores. The mean Ponar B.A.P score calculated to 5.33 and the mean multiplate score calculated to 3.38. Both individual upstream sampling scores represent the highest values comparatively across upstream impounded sites. Browns Pond had a mean Ponar B.A.P score of 4.00, designating moderate impact and a mean multiplate B.A.P score of 1.10-the lowest impoundment score-and designating severe impact. Averaging the upstream B.A.P scores at Browns Pond yields a score of 2.55, designating moderate impact. The Oscawana Dam impoundment possessed a mean Ponar B.A.P score of 3.33, the lowest upstream Ponar score, designating moderate impact; and a mean multiplate B.A.P score of 2.28, designating severe impact. Averaging the Oscawana Dam upstream scores provides an impoundment B.A.P score of 3.08, designating moderate impact.

Overall Site Ranking

When all Site sampling points are averaged together, both upstream and downstream, we find the Shapp Pond site to possess the highest B.A.P score with 6.81, designating slight impairment. The Annandale Dam site possesses an overall B.A.P score of 5.29, designating slight impact. The Oscawana Dam site possessed an overall B.A.P score of 3.44, designating moderate impact. Finally, the Browns Pond site possessed the lowest overall B.A.P score with 2.82, designating moderate impact.

We found Shapp Pond to have significantly higher BAP score than Annandale Dam ($P=0.0405$), Browns Pond ($P<0.001$), and Oscawana Dam ($P<0.0001$). We found no significant difference among Wynantskill BAP score and Annandale Dam or Shapp Pond, but did find Browns Pond and Oscawana Dam exhibited significantly lower BAP scores ($P=0.0011$, $P=0.0084$, respectively) than Wynantskill. Both Browns Pond and Oscawana Dam exhibited significantly lower BAP scores than all other sites, but did not differ significantly from each other. Annandale Dam exhibited significantly higher BAP scores than Browns Pond ($P=0.002$) and Oscawana Dam ($P=0.0036$).

## ANNUAL CHANGES WITHIN SITES BETWEEN 2016 - 2017

WYNANTSKILL

At our Wynantskill upstream site, we did not find any significant differences in biometric values between 2016 and 2017 (Figures 17,21). However, we did observe changes in the benthic macroinvertebrate community that favored impact-sensitive taxa: 26% increase in mayflies, 5.4% increase in caddisflies, 11% decrease in midges, 9% decrease in oligochaetes (Figure 6). This shift can also be attributed to habitat changes in substrate composition (Table 3) that favor stream invertebrates, such as the loss of finer substrate particles (sand, silts) which favor midges and oligochaetes.

ANNANDALE DAM

We did not observe any significant changes to downstream biometric values or upstream Ponar biometric values on this section of the Sawkill (Figures 17,21). However, we did observe significantly lower Taxa Richness colonizing our multiplate Hester-Dendy samplers ($P=0.0310$) (Figure 20). We did not observe significant differences in overall BAP scores for Annandale Dam between 2016-2017 (Figure 20).

Since the barrier on the Sawkill remains intact, we would expect some annual community variation – as with any natural system – but no major changes due to a substantial habitat alteration, such as barrier removal. Overall, we observed a 5% increase in mayflies, a 13% increase in caddisflies, a 5% increase in beetles, and a 4% increase in stoneflies (Figure 7). To offset these changes, we observed a 15% decrease in midges. We document nearly all the representatives of the community in 2017 as we did in 2016. Such shifting amongst taxa year-to-year falls within normal annual community variability that can be caused by environmental conditions and individual taxa year-class successes.

Upstream Ponar samples showed a 15% decrease in midge abundance and increases in mayflies (+6%), beetles (+5%), and oligochaetes (+3%) (Figure 8). Multiplate samplers demonstrated strong increases in midge and caddisfly abundance (+20%, +16%, respectively) and strong decreases in oligochaetes (-19%) and amphipods (-10%) (Figures 15,16). Within the impoundment, many of the changes between the two sampling strategies can be partially explained by increased precipitation and higher spring and early summer flows. With higher flows, more organisms can be taken up in drift and colonize from upstream, non-impounded segments of the Sawkill. This effect can be seen in the comparative differences in midge larvae between benthic (Ponar) and littoral (Multiplate) samples. With higher water velocities due to increased flows, more individuals would be contained in the upper water layer in drift, and allow colonization of multiplate samplers, than allowed to drop to the bottom substrate.

SHAPP POND

We did not observe any significant changes to biometric values at our downstream location (Figures 17,21), but document changes in benthic invertebrate community. We observed a 34% increase in beetles, as well as a 2% increase in caddisflies (Figure 9). We observed a 10% decrease in mayflies. We observed a 12% decrease in midges and a complete removal of oligochaetes. With the barrier removal, a large increase in sand was washed into the downstream reach (Tables 2,3). This change in habitat likely accounts for the differences in beetle, mayfly, and caddisfly abundances. Our decreases in midges and oligochaetes can be attributed to both alterations in substrate habitat (to their detriment), but also to the removal of a population source upstream as the barrier was removed, and fines present upstream were washed out over the course of ~8 months (Oct '16 – June '17). The 2017 upstream community composition compared to 2016 downstream composition) suggests invertebrates were colonizing newly regained upstream habitat from nearby downstream reaches.

We documented wide improvement at our Shapp Pond upstream location post dam removal. All biometric values except community dominance exhibited significant improvement. Improved biometrics included Taxa Richness (P=0.0011), Hilsenhoff Biotic Index (P=-0.0146), E-P-T (0.0121), Percent Model Affinity (P=0.0173), Species Diversity (P=0.0294), and overall BAP score (P=0.0297) (Figures 18,19). These gains are further demonstrated by the improvement in benthic macroinvertebrate community structure, shifting remarkably from a lentic, silt-favoring community to a lotic stream community (Figure 10). Such notable changes include broad decreases in relative abundance of midges (-17%), oligochaetes (-18%), and amphipods (-19%), as well as now absent nematoda, freshwater clams (Sphaeriidae), and Ostracods. These losses were replaced by mayflies (+17%), beetles (+9.3%), and caddisflies (+5.8%).

BROWNS POND

We did not observe any significant differences in downstream biometric values or upstream multiplate biometric values (Figures 17,20). We did not observe significant differences in upstream Ponar biometric except a significant increase in PMA value (P=0.0075) (Figure 18). Downstream benthic macroinvertebrate communities demonstrated mild changes from 2016, including a 20% decrease in amphipods and a 4% decrease in flatworms (Figure 11). These losses were offset by an 8% increase in caddisflies, a 5% increase in oligochaetes, and a 7% increase in snails. Again, increased rainfall/hydrological regime during the spring and early summer of 2017 can likely attribute to such annual variation-as mentioned above-as no major habitat changes have occurred at this site.

The Browns Pond upstream macroinvertebrate community showed mild variability in Ponar samples, with increases in caddisflies (+7%), copepods (+7%), and oligochaetes (+4%); and decreases in midges (-6%) and Daphnia (-8%) (Figure 12). Multiplate samplers in 2017 demonstrated total domination of oligochaetes (52%) and midges (47%) (Figure 15). This is a reversal of dominance from 2016 when midges comprised 86% of the total abundance (Figure 16). While we observed a wide swing in midge/oligochaete numbers between 2016 and 2017, midges and oligochaetes combined still represent 95%+ of the upstream community at Browns Pond.

OSCAWANA DAM

We observed a significant decline in downstream Taxa Richness (P=0.0198) and overall BAP score (P=0.0450) (Figures 17,21). We did not observe any significant differences in upstream Ponar or multiplate biometric scores (Figures 18-20). The decline in downstream biometrics can be largely attributable to the 30% increase in midges in 2017. This couples with the loss of caddisflies (-10%), as well as near total loss of freshwater clams, flatworms, snails, amphipods, and beetles (Figure 13). Oscawana Dam remains intact, and Furnace brook showed only nominal differences in substrate habitat between 2016-2017 (Table 3).

The upstream community showed a strong decrease in copepod abundance (-33%) and an increase in midges (+15%), oligochaetes (+15%) and amphipods (+10%) (Figure 14). Despite the decrease in copepod abundance from 2016, taxa making gains in place of copepods represent those which are indicative of moderately to highly impacted, silty lentic environments. We observed strong decreases in midge larvae in our multiplate samples with a 30% decrease from 2016-2017 (Figures 15,16). Oligochaetes offset that loss with a 30% annual increase. We observed increases in other lentic representatives, including true flies (+5%), snails (+3%), and dragonflies/damselflies (+2%). Mayflies declined 2%.

## BASELINE BANKFULL SUBSTRATE AND CHANNEL MORPHOLOGY DATA

We collected new stream channel morphology data in 2017 at a scale of greater resolution than the wetted-width / visual estimation methods in 2016. Detailed surveyed stream channel elevational cross-sections at each of our lotic transects can be viewed in Figures 22-40. These figures also illustrate the substrate classification type along our transect at each 1-foot interval. A tabular summary of the surveyed substrate data can be seen in Table 4. It is anticipated that future years of data collection can be comparted to these data to comprehensively assess how stream channel morphology (incision/deposition) and substrate classification (emigration/immigration) change over the course of time as barriers either remain intact or are removed.

### OVERALL CONCLUSIONS

In the two instances of barrier removal in this study, both sites demonstrate improvement in benthic macroinvertebrate community assemblages and/or Biological Assessment Profile scores. The rate of improvement at the site level may be affected by multiple factors, including local hydrology, taxa distribution, and landscape context. Future data collection allows the opportunity to measure the rate of ecological improvement and assess how biological, physical, and landscape influences govern recovery rates at these sites over time. Identification of causative factors to ecological improvement across sites in the Hudson River watershed could then provide a framework used to prioritize future removal efforts aimed at maximizing habitat connectivity, accessibility, and ecological vitality.

## REFERENCES

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Smith, Alexander. 2014. Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State. New York State Department of Environmental Conservation, Division of Water.

*Table 1: Collection dates and method type at our five Hudson River tributary study sites in 2017.*

| Site | Location | Date (2016) | Northing (m) | Easting (m) | Sample Type |
|---|---|---|---|---|---|
| Wynantskill Gate | Upstream | 25 May | 4728925 | 606493 | Kick |
| Annandale Dam | Upstream | 12 June, 25 July | 4651573 | 590357 | Ponar, Multiplate |
| | Downstream | 12 June | 4651778 | 590371 | Kick |
| Shapp Pond | Upstream | 8 June | 4629687 | 603074 | Ponar |
| | Downstream | 8 June | 4629810 | 603090 | Kick |
| Browns Pond | Upstream | 13 June, 19 July | 4589807 | 565958 | Ponar, Multiplate |
| | Downstream | 13 June | 4589721 | 566082 | Kick |
| Oscawana Dam | Upstream | 13 June, 26 July | 4564967 | 590901 | Ponar, Multiplate |
| | Downstream | 13 June | 4564940 | 590808 | Kick |

*Table 2: Depth, width, and visual substrate assessment summaries at our five Hudson River tributary study sites in 2017.*

| Site | Location | Mean Wetted-Width (m) | Mean Depth (m) | Mean % Bedrock | Mean % Boulder | Mean % Cobble | Mean % Gravel | Mean % Sand | Mean % Fine |
|---|---|---|---|---|---|---|---|---|---|
| Wynantskill Gate | Upstream | 6.78 | 0.82 | 0 | 15 | 42 | 35 | 6 | 2 |
| Annandale Dam | Upstream | - | 1.24 | 0 | 0 | 0 | 0 | 0 | 100 |
| | Downstream | 13.2 | 0.18 | 0 | 6 | 55 | 32 | 3 | 4 |
| Shapp Pond | Upstream | 7.01 | 0.18 | 0 | 1 | 13 | 35 | 37 | 15 |
| | Downstream | 13.7 | 0.13 | 7 | 1 | 28 | 38 | 25 | 1 |
| Browns Pond | Upstream | - | 2.52 | 0 | 0 | 0 | 0 | 0 | 100 |
| | Downstream | 18.1 | 0.14 | 15 | 20 | 47 | 12 | 5 | 1 |
| Oscawana Dam | Upstream | - | 1.28 | 0 | 0 | 0 | 0 | 0 | 100 |
| | Downstream | 10.8 | 0.17 | 0 | 32 | 28 | 34 | 4 | 1 |

*Table 3: Annual differences in visual substrate summaries at our five Hudson River tributary study sites between 2016 - 2017.*

| Site | Location | Mean % Bedrock | Mean % Boulder | Mean % Cobble | Mean % Gravel | Mean % Sand | Mean % Fine |
|---|---|---|---|---|---|---|---|
| Wynantskill Gate | Upstream | 0 | +12 | +13 | -14 | -7 | -4 |
| Annandale Dam | Upstream | 0 | 0 | 0 | 0 | 0 | 0 |
| | Downstream | 0 | -1 | -3 | +1 | 0 | +3 |
| Shapp Pond | Upstream | 0 | +1 | +13 | +25 | -36 | -2 |
| | Downstream | 0 | -17 | -4 | +2 | +20 | -1 |
| Browns Pond | Upstream | 0 | 0 | 0 | 0 | -4 | +4 |
| | Downstream | +12 | -7 | -10 | +3 | +2 | +1 |
| Oscawana Dam | Upstream | 0 | 0 | 0 | 0 | 0 | 0 |
| | Downstream | 0 | +6 | -4 | +3 | -7 | +1 |

*Table 4: Surveyed substrate summaries at our five Hudson River tributary study sites 2017.*

| Site | Location | Mean % Bedrock | Mean % Boulder | Mean % Cobble | Mean % Gravel | Mean % Sand | Mean % Fine |
|---|---|---|---|---|---|---|---|
| Wynantskill Gate | Upstream | 0 | 8 | 25 | 48 | 12 | 7 |
| Annandale Dam | Upstream | - | - | - | - | - | - |
| | Downstream | 0 | 7 | 33 | 32 | 2 | 26 |
| Shapp Pond | Upstream | 1 | 0 | 15 | 42 | 17 | 25 |
| | Downstream | 9 | 6 | 21 | 33 | 21 | 10 |
| Browns Pond | Upstream | - | - | - | - | - | - |
| | Downstream | 18 | 11 | 33 | 19 | 10 | 10 |
| Oscawana Dam | Upstream | - | - | - | - | - | - |
| | Downstream | 0 | 18 | 24 | 38 | 5 | 16 |

***Table 5: Biological assessment metric data and impact designation summaries at our five Hudson River tributary study sites in 2017.***

| Site | Location | Sample Type | Mean SPP Score | Mean HBI Score | Mean EPT Score | Mean PMA Score | Mean DIV Score | Mean DOM3 Score | Mean B.A.P Score | Mean Impact Designation |
|---|---|---|---|---|---|---|---|---|---|---|
| Wynantskill Gate | Upstream | Kick | 12.75 | 5.98 | 5.50 | 74.05 | - | - | 5.62 | Slight |
| Annandale Dam | Downstream | Kick | 21.00 | 4.80 | 11.00 | 67.3 | - | - | 7.15 | Slight |
| | Upstream | Ponar | 10.00 | 6.25 | 1.33* | 60.26 | 2.26 | 75.46 | 5.33 | Slight |
| | | Multiplate | 10.00 | 6.07 | 4.00 | - | 1.61 | - | 3.38 | Moderate |
| Shapp Pond | Downstream | Kick | 18.33 | 4.55 | 10.00 | 74.23 | - | - | 7.06 | Slight |
| | Upstream | Kick | 17.33 | 5.60 | 10.00 | 69.9 | 2.99* | 66.2* | 6.54 | Slight |
| Browns Pond | Downstream | Kick | 12.33 | 6.37 | 1.33 | 38.76 | - | - | 3.36 | Moderate |
| | Upstream | Ponar | 4.66 | 6.56 | 0.67* | 61.36 | 1.90 | 86.6 | 4.00 | Moderate |
| | | Multiplate | 3.00 | 7.04 | 0.00 | - | 1.01 | - | 1.10 | Severe |
| Oscawana Dam | Downstream | Kick | 11.33 | 5.92 | 3.66 | 44.00 | - | - | 4.15 | Moderate |
| | Upstream | Ponar | 7.00 | 7.16 | 0.00* | 55.30 | 1.68 | 92.43 | 3.33 | Moderate |
| | | Multiplate | 10.33 | 6.96 | 1.66 | - | 1.80 | - | 2.82 | Moderate |

** For annual comparative purposes only, value does not contribute to BAP calculation.*

*Table 6: Annual change in biological assessment metrics between 2016 and 2017.*

| Site | Location | Sample Type | SPP Change | HBI Change | EPT Change | PMA Change | DIV Change | DOM3 Change | B.A.P Change | Impact Designation Change |
|---|---|---|---|---|---|---|---|---|---|---|
| Wynantskill Gate | Upstream | Kick | -0.95 | +0.25 | -1.00 | +5.05 | - | - | -0.18 | None |
| Annandale Dam | Downstream | Kick | +1.40 | -0.65 | +1.00 | -1.70 | - | - | +0.35 | None |
| | Upstream | Ponar | -1.20 | -0.08 | +1.33 | +24.66 | +0.88 | -14.14 | +1.73 | Improve |
| | | Multiplate | -6.60 | -0.62 | +0.60 | - | -0.70 | - | -0.92 | None |
| Shapp Pond | Downstream | Kick | +1.03 | +0.11 | +1.60 | -6.37 | - | - | -0.45 | Decline |
| | Upstream | Kick | +9.73 | +0.06 | +9.00 | +30.90 | - | - | +2.34 | Improve |
| Browns Pond | Downstream | Kick | -1.33 | +0.22 | -0.27 | +7.46 | - | - | +0.06 | None |
| | Upstream | Ponar | -0.34 | -0.25 | +0.67 | +33.36 | +0.14 | -4.00 | +0.40 | None |
| | | Multiplate | -1.50 | -0.70 | 0.00 | - | +0.36 | - | -0.20 | None |
| Oscawana Dam | Downstream | Kick | -2.03 | +0.28 | -1.06 | +22.00 | - | - | -0.55 | None |
| | Upstream | Ponar | -3.00 | +0.23 | 0.00 | +24.7 | -0.05 | +1.83 | +1.03 | Improve |
| | | Multiplate | -0.27 | +0.56 | +1.06 | - | +0.27 | - | +0.72 | Improve |


***Figure 1: Hudson River tributary dam-removal sites studied during 2017. Wynantskill and Shapp Pond barriers were removed prior to 2017 sampling efforts.***

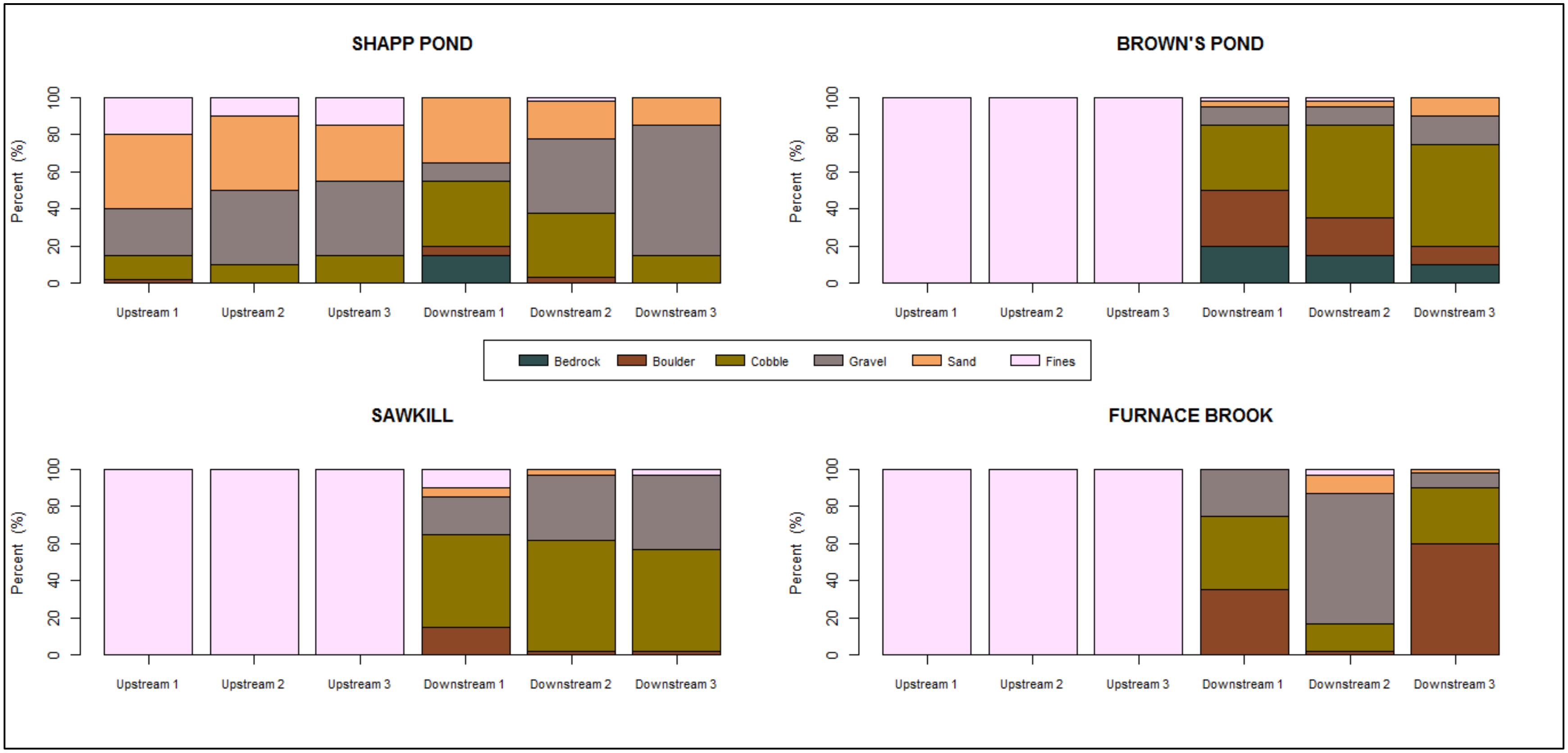


***Figure 2:  Visually estimated substrate profiles at upstream and downstream sampling locations across our four traditional barrier sites during 2017.  Downstream locations substrate visual estimates were made within the wetted-width of our transects during invertebrate kick-sample collection.***

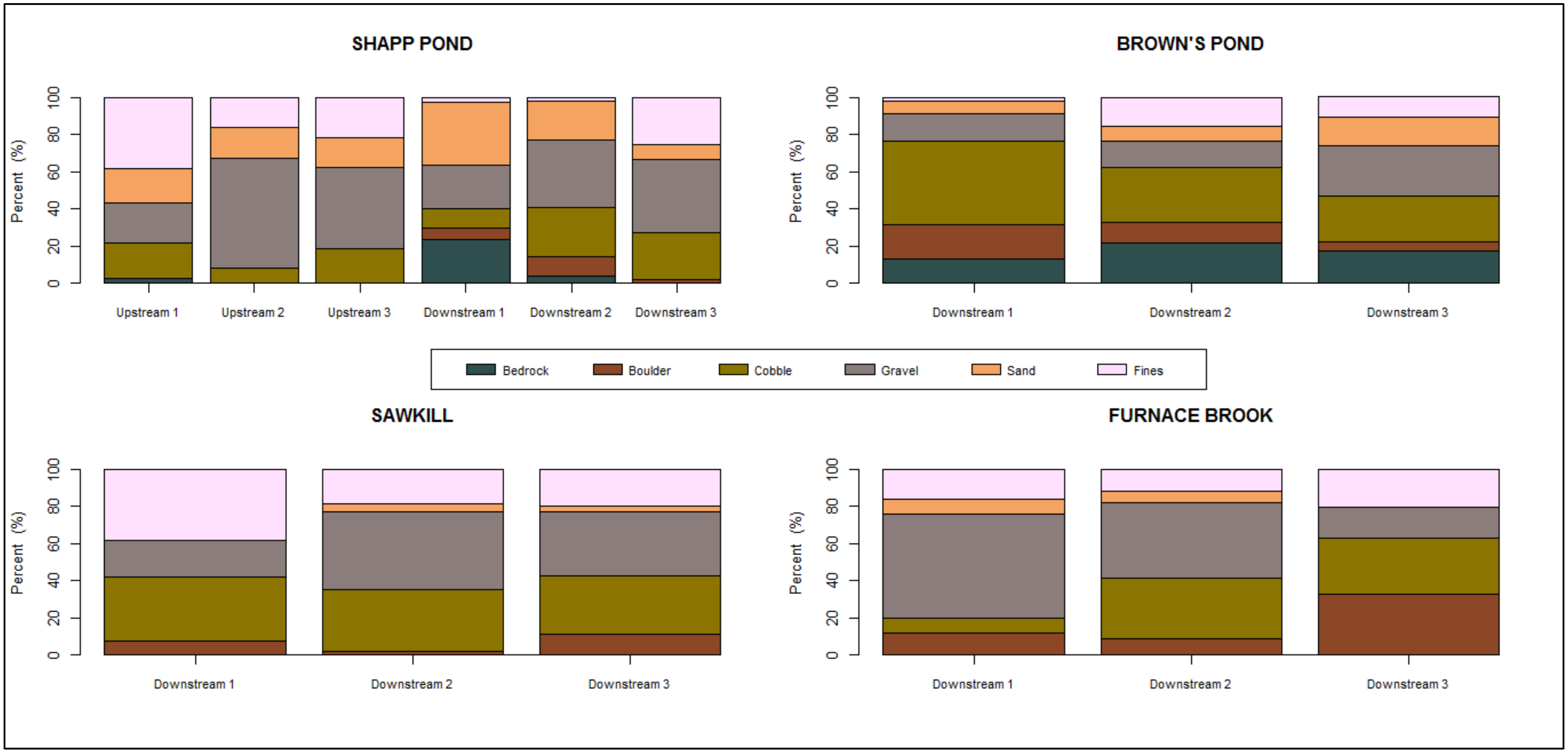


***Figure 3: Surveyed transect substrate profiles at lotic habitats across our four traditional barrier sites using the blind-touch method at each 1-foot interval.***

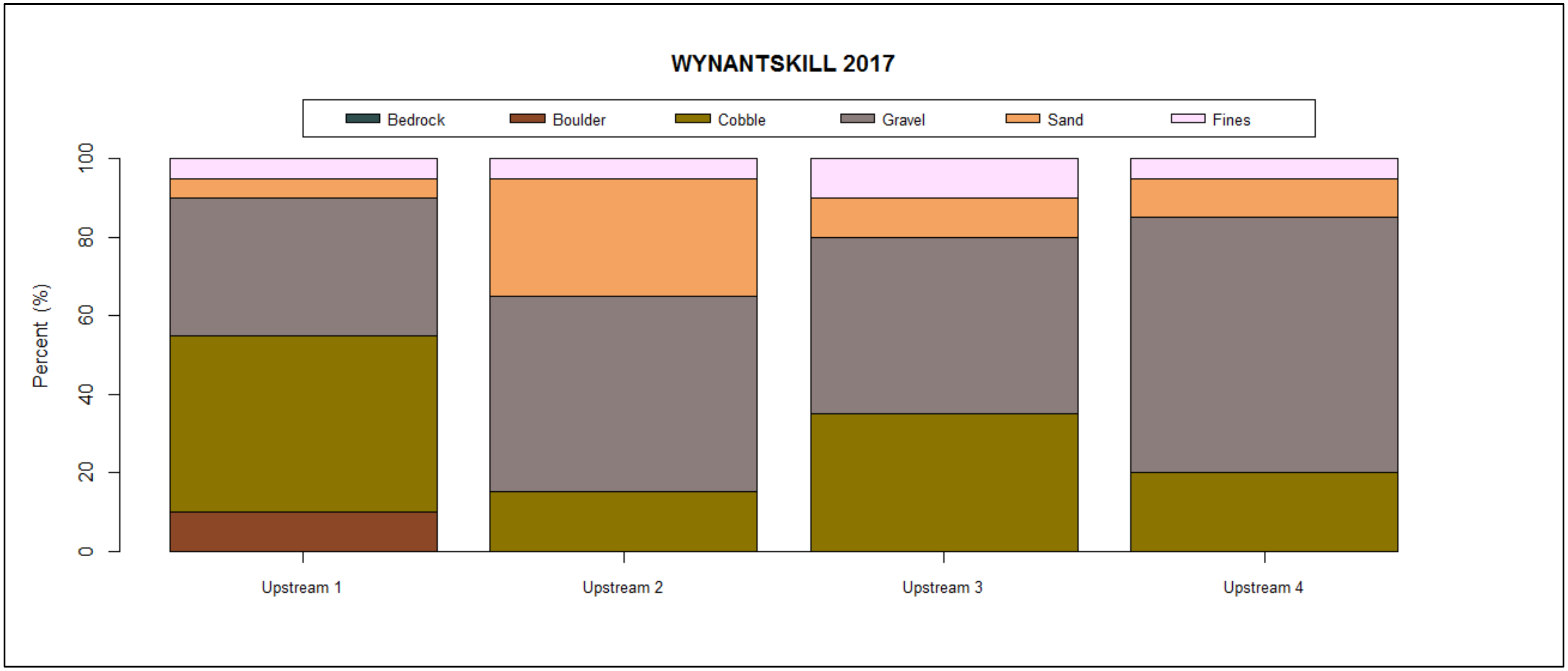


***Figure 4: Visually estimated substrate profiles at the upstream Wynantskill site during 2017. Visual estimates were made within the wetted-width of our transects during invertebrate kick-sample collection.***

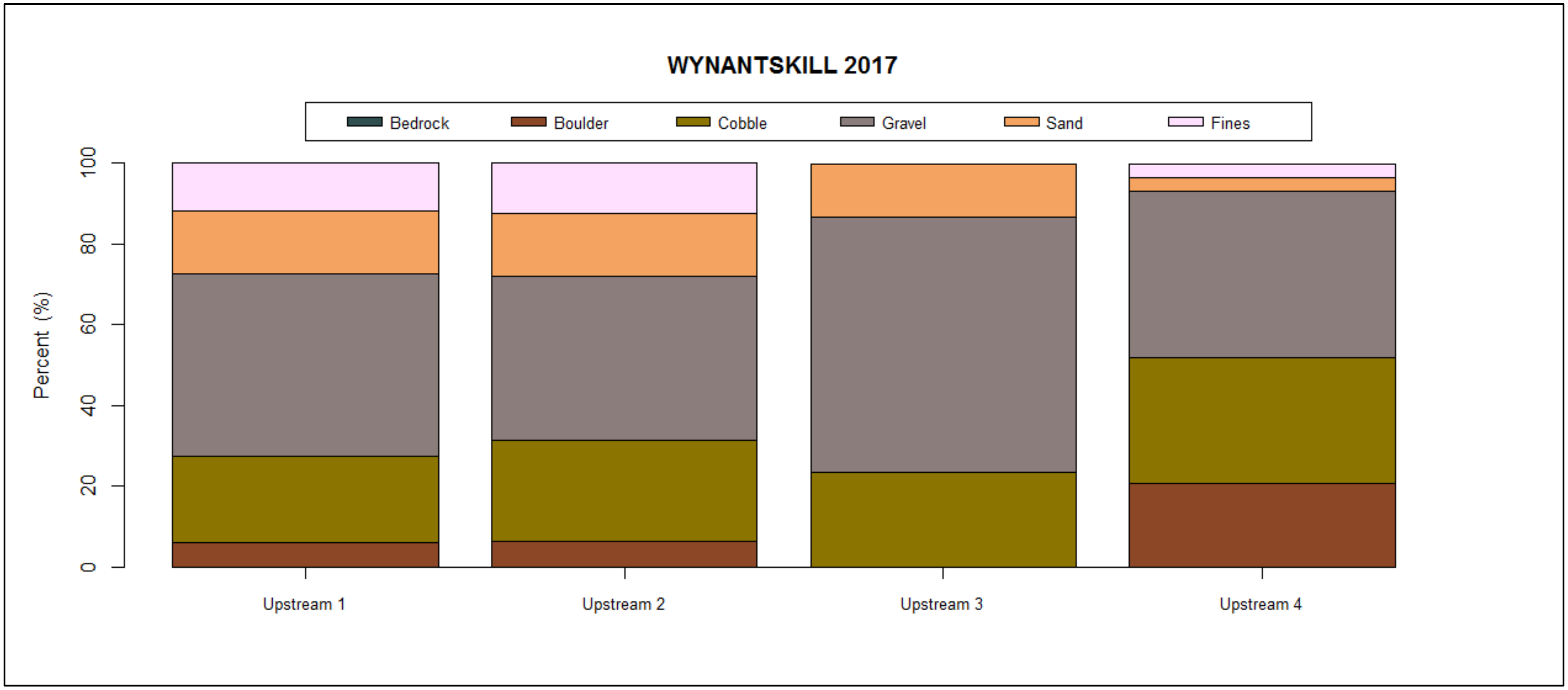


***Figure 5: Surveyed transect substrate profiles at the upstream Wynantskill Site using the blind-touch method at each 1-foot interval.***

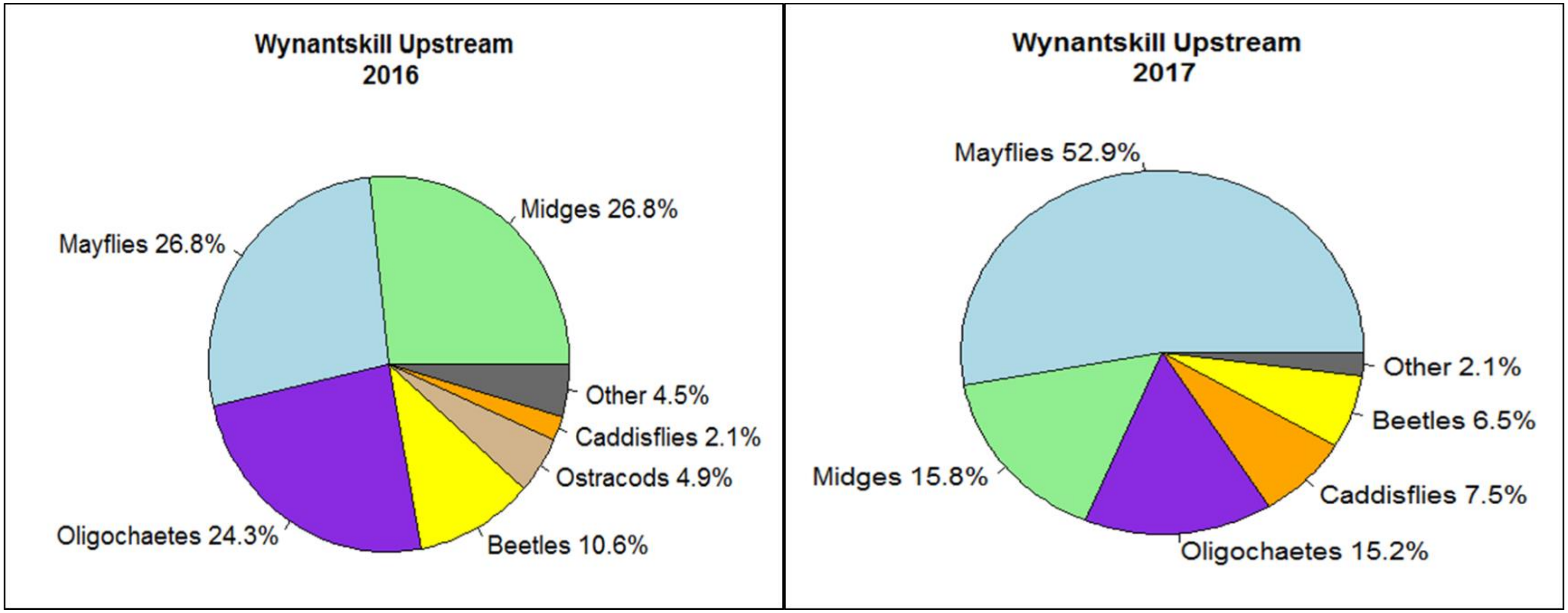


***Figure 6: Annual comparison of benthic macroinvertebrate community structure upstream on the Wynantskill between 2016-2017.***

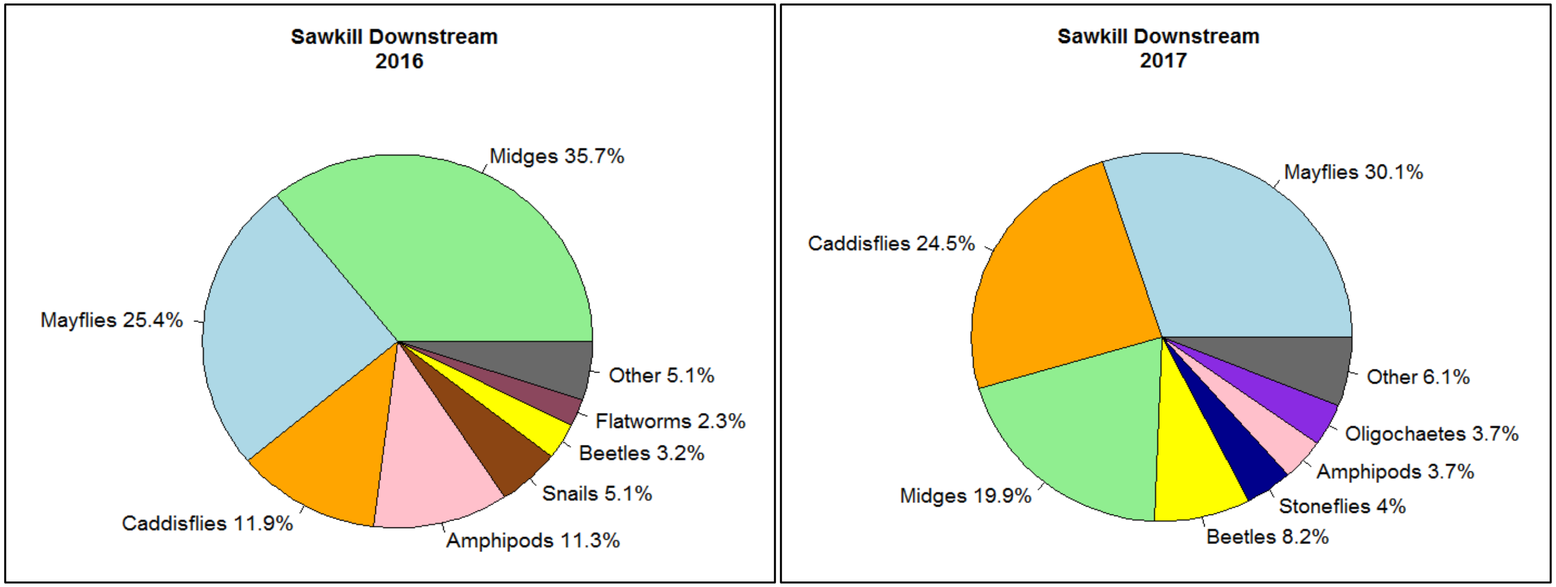


***Figure 7: Annual comparison of benthic macroinvertebrate community structure downstream on the Sawkill between 2016-2017.***

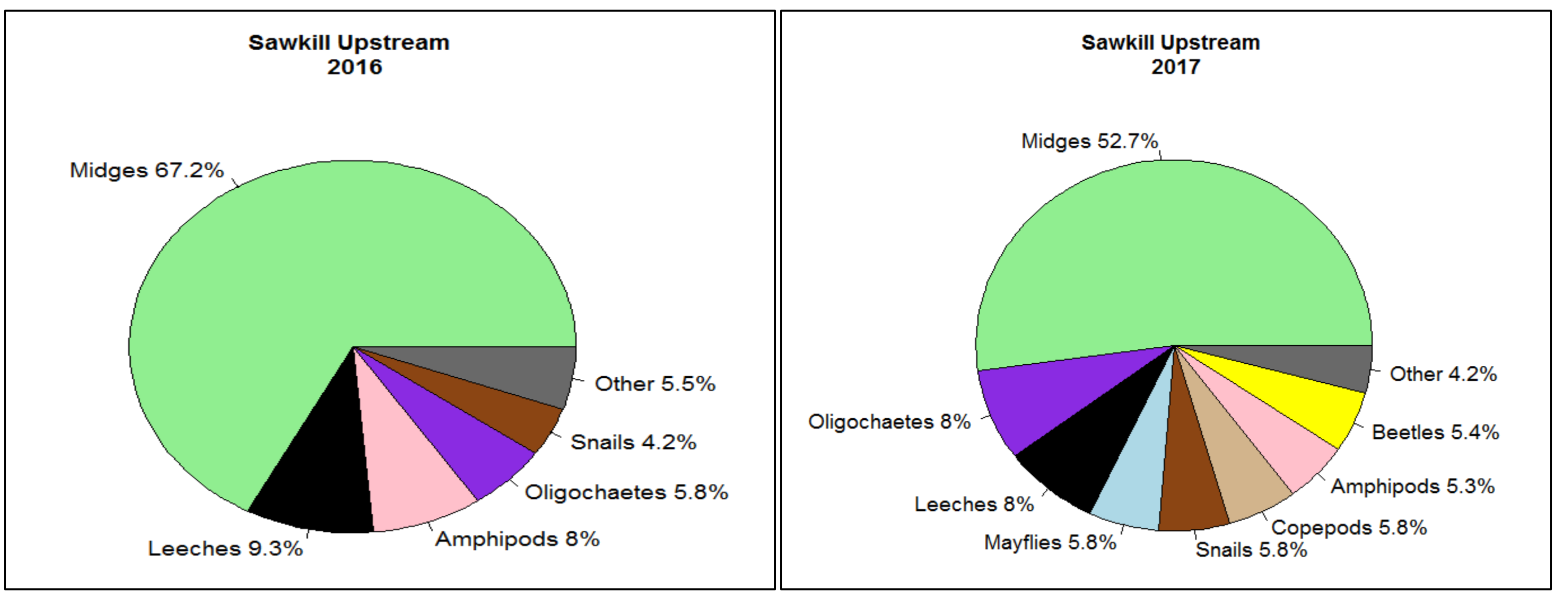


***Figure 8: Annual comparison of benthic macroinvertebrate community structure of Ponar Samples on the Sawkill between 2016-2017.***

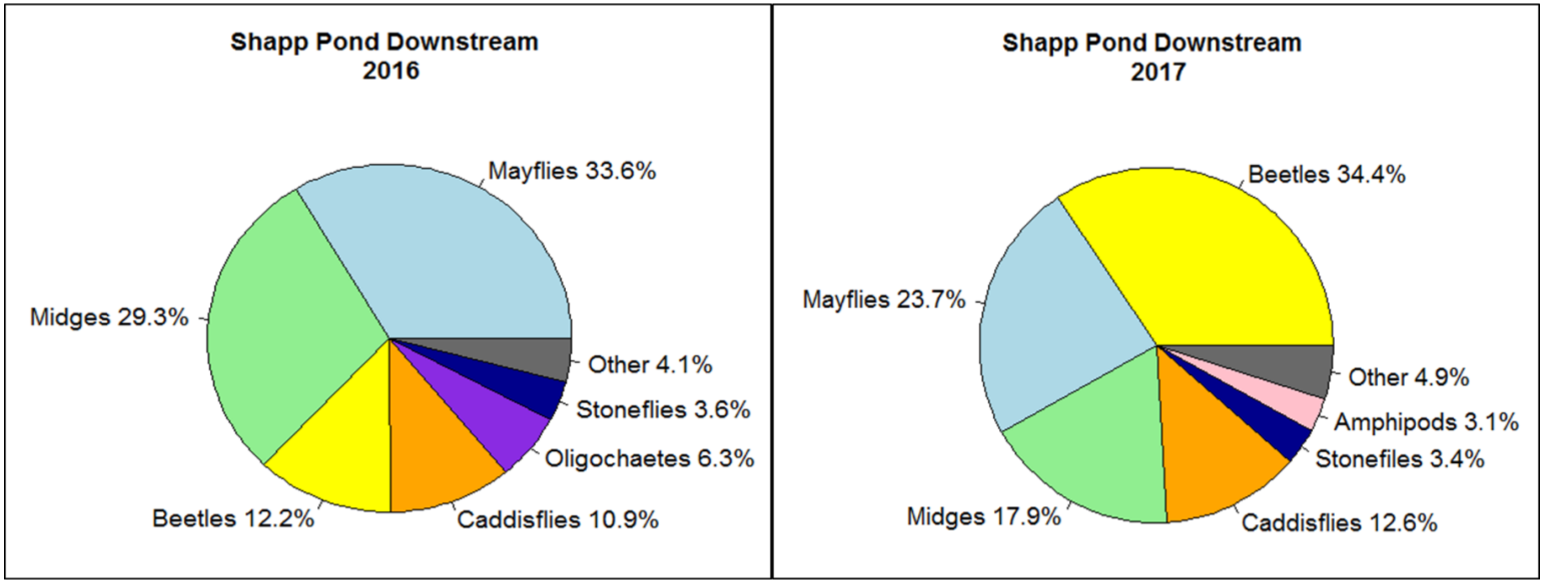


***Figure 9: Annual comparison of benthic macroinvertebrate community structure downstream on the E. Br. Wappingers between 2016-2017.***

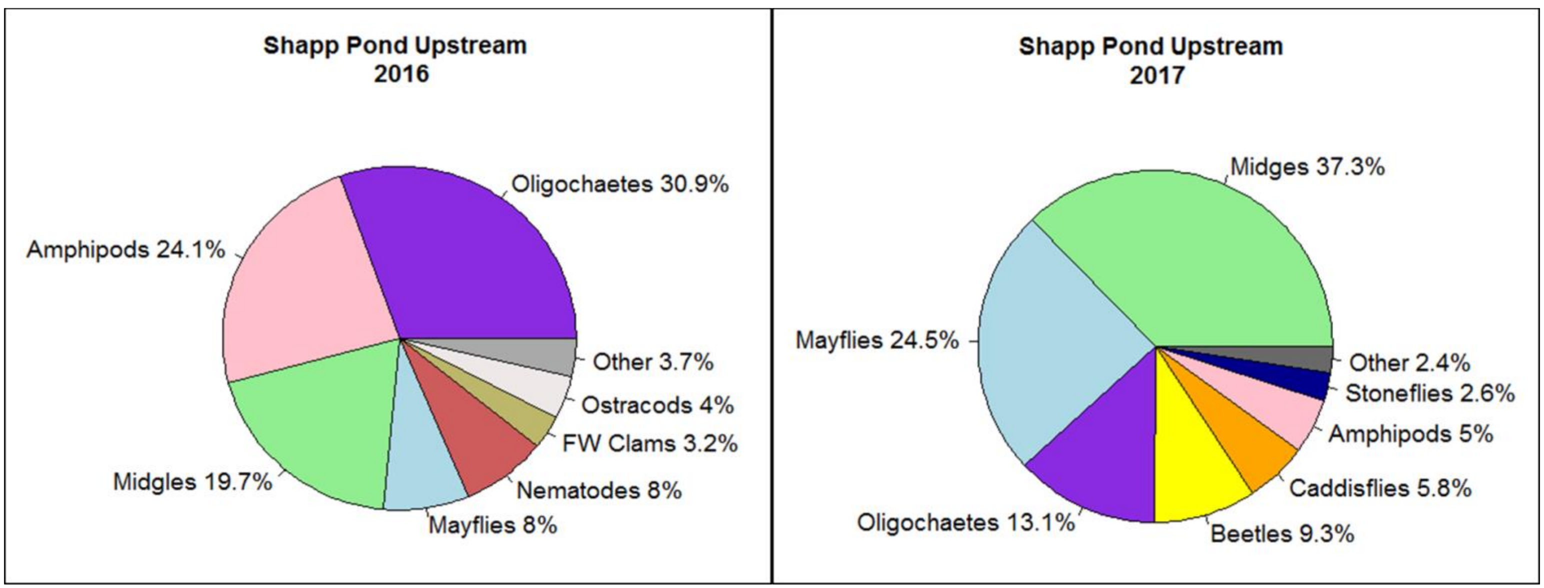


***Figure 10: Annual comparison of benthic macroinvertebrate community structure upstream on the E. Br. Wappingers between 2016-2017.***

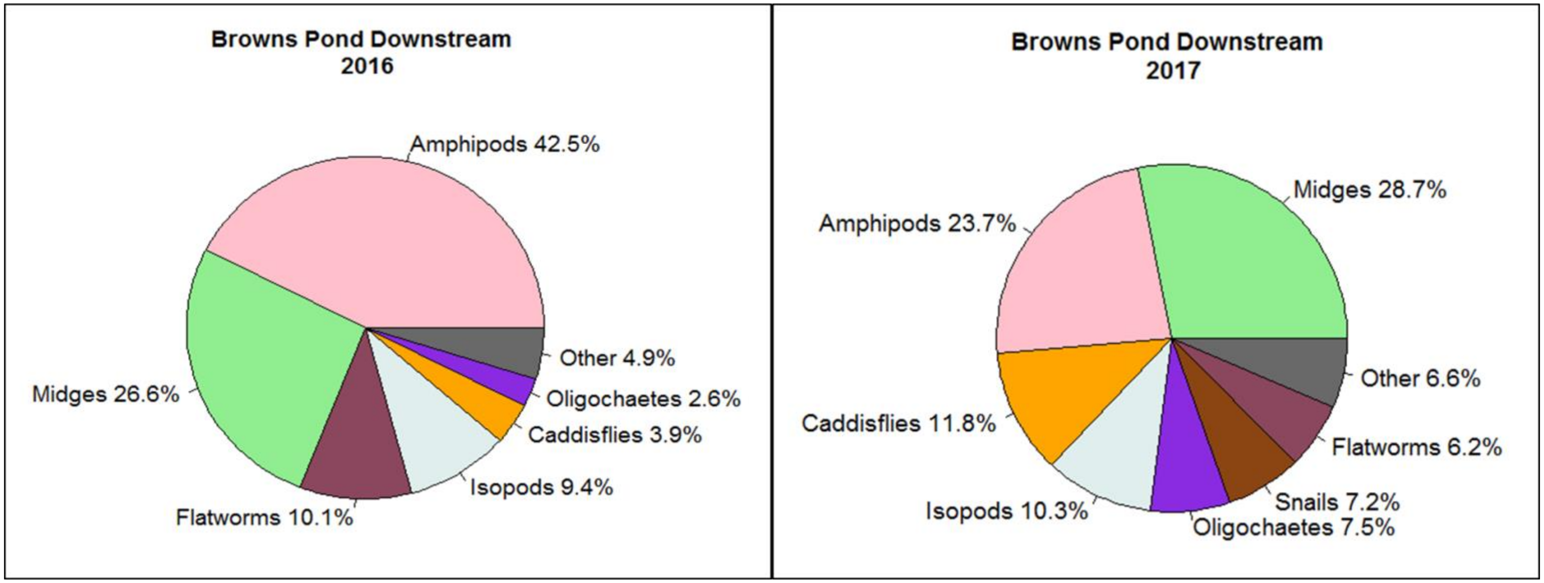


***Figure 11: Annual comparison of benthic macroinvertebrate community structure downstream on the Otterkill between 2016-2017.***

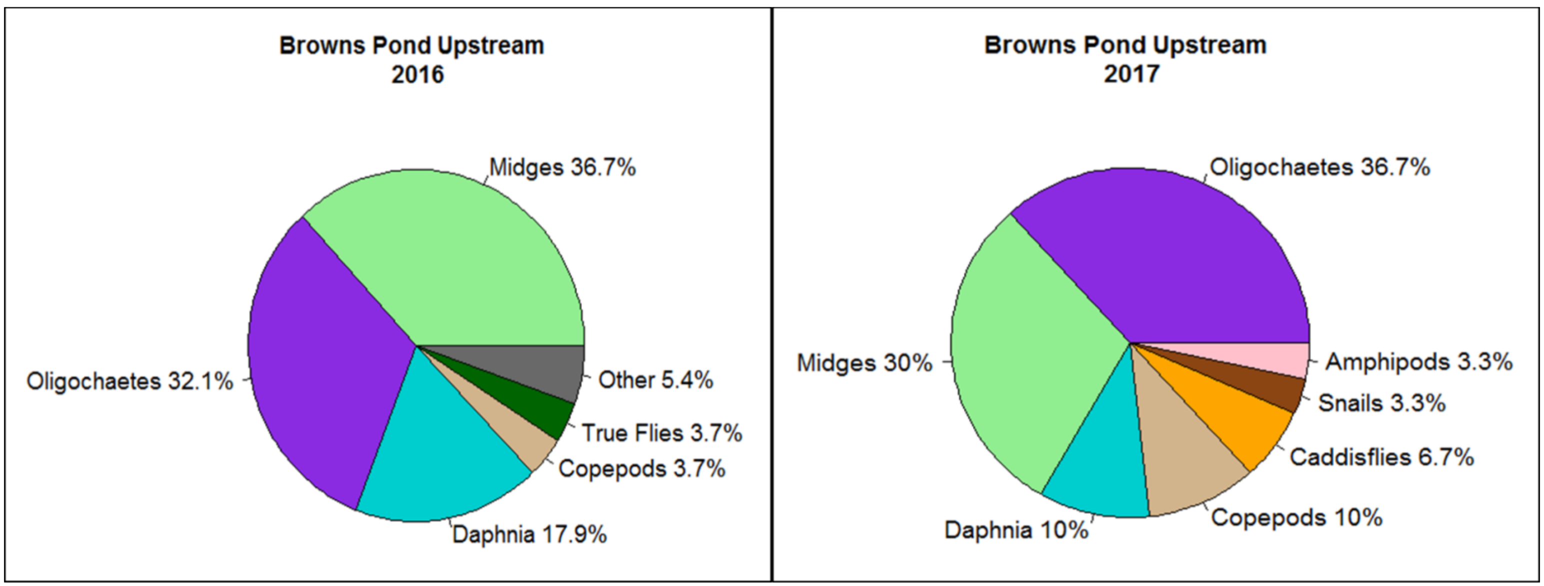


***Figure 12: Annual comparison of benthic macroinvertebrate community structure of Ponar Samples on the Otterkill between 2016-2017.***

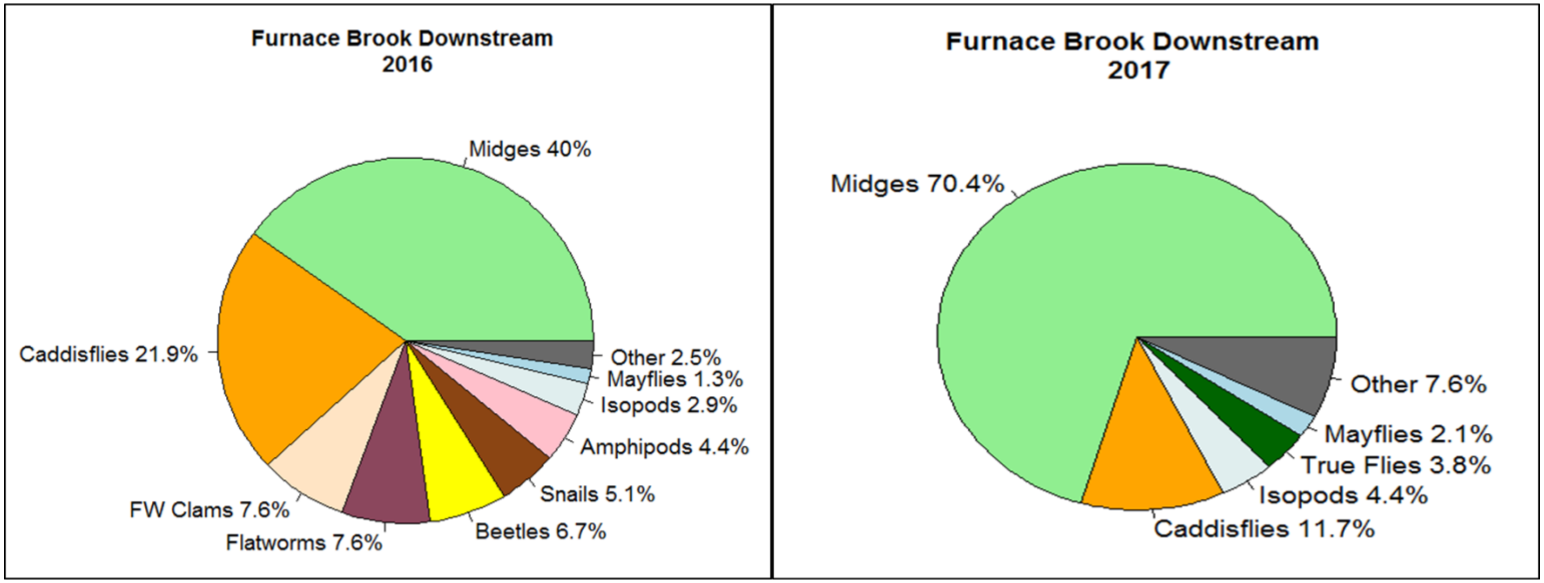


***Figure 13: Annual comparison of benthic macroinvertebrate community structure downstream on Furnace Brook between 2016-2017.***

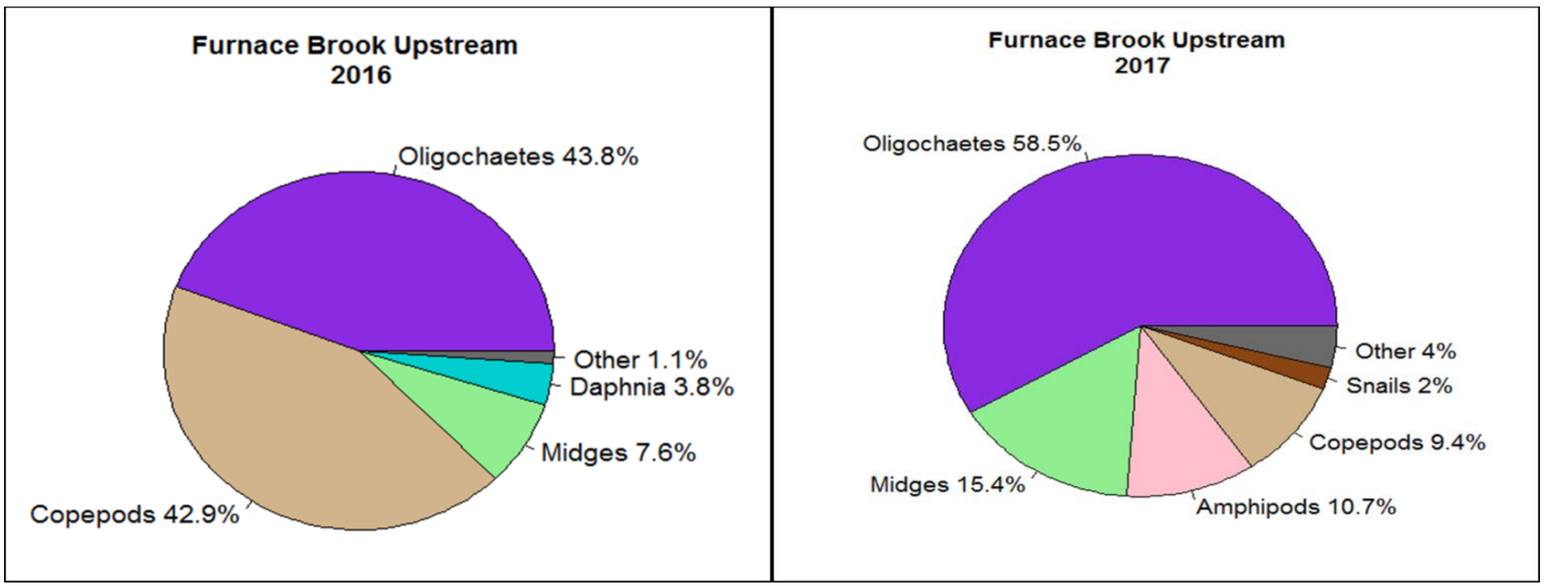


***Figure 14: Annual comparison of benthic macroinvertebrate community structure of Ponar Samples on Furnace Brook between 2016-2017.***

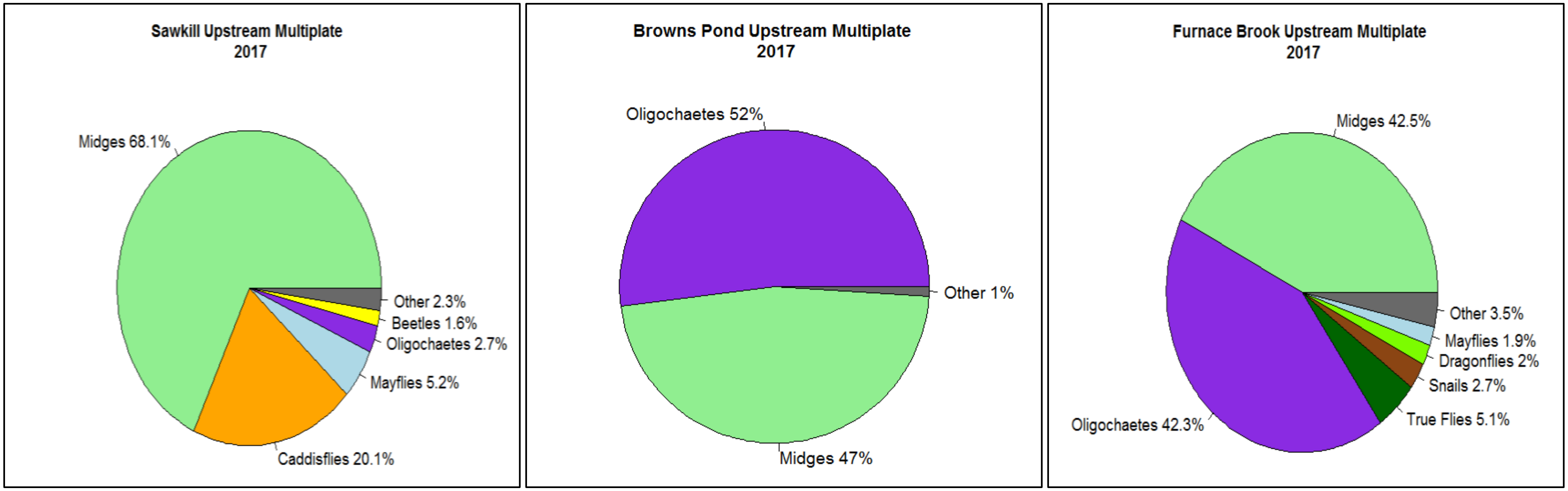


*Figure 15: Comparison of benthic macroinvertebrate community structure of multiplate samples across our impoundment sites during 2017.*

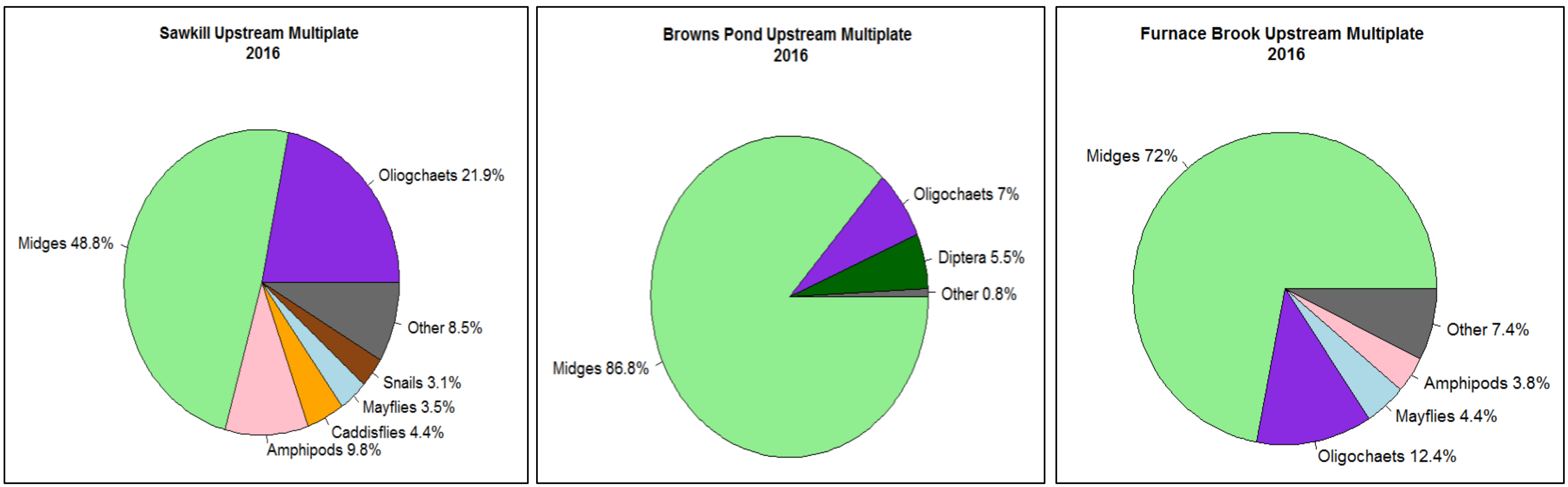


*Figure 16: Comparison of benthic macroinvertebrate community structure of multiplate samples across our impoundment sites during 2016.*

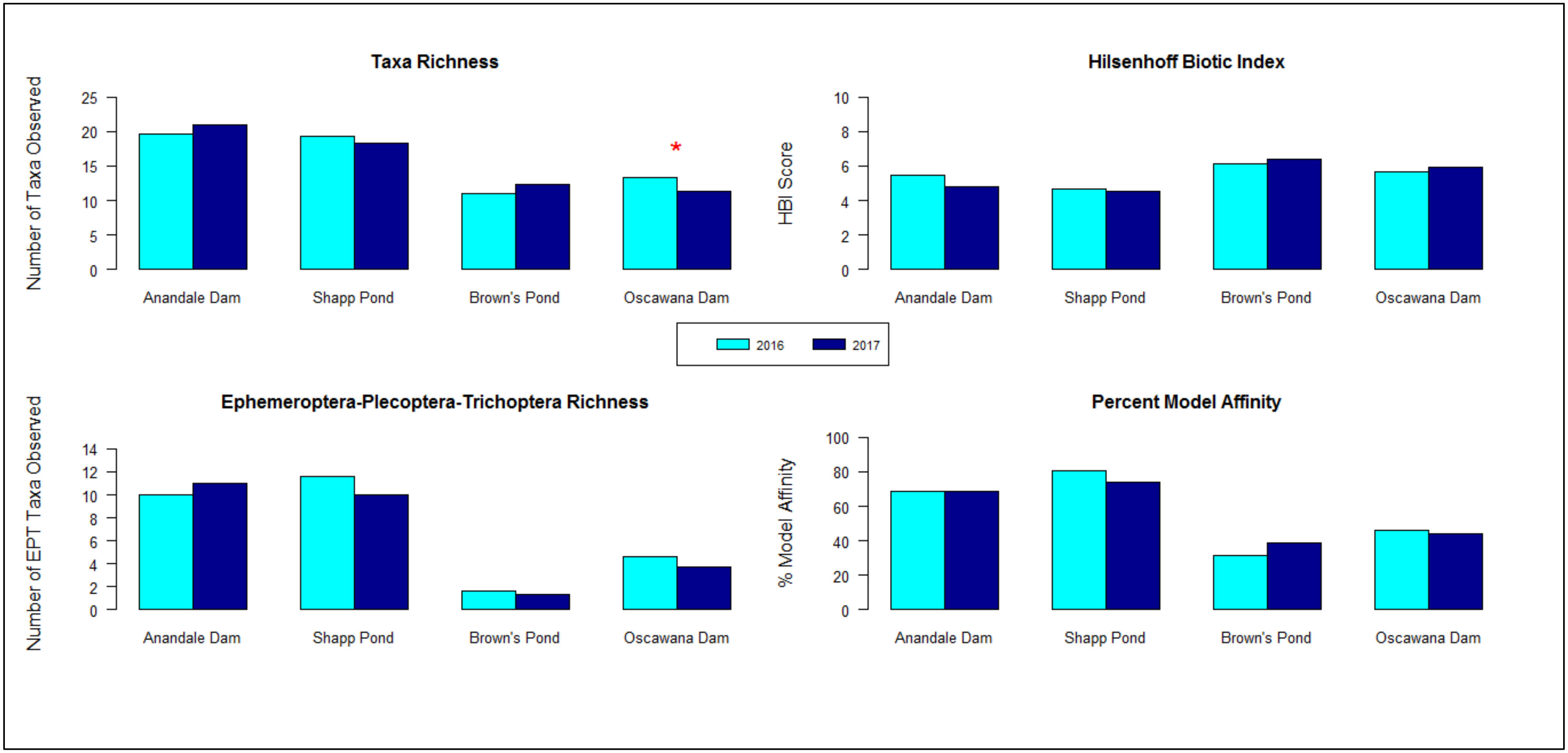


*Figure 17: Mean values of Bioindex metrics for kick-samples at downstream locations across sites. Significant differences between 2016 and 2017 are indicated with red asterisk(s).*

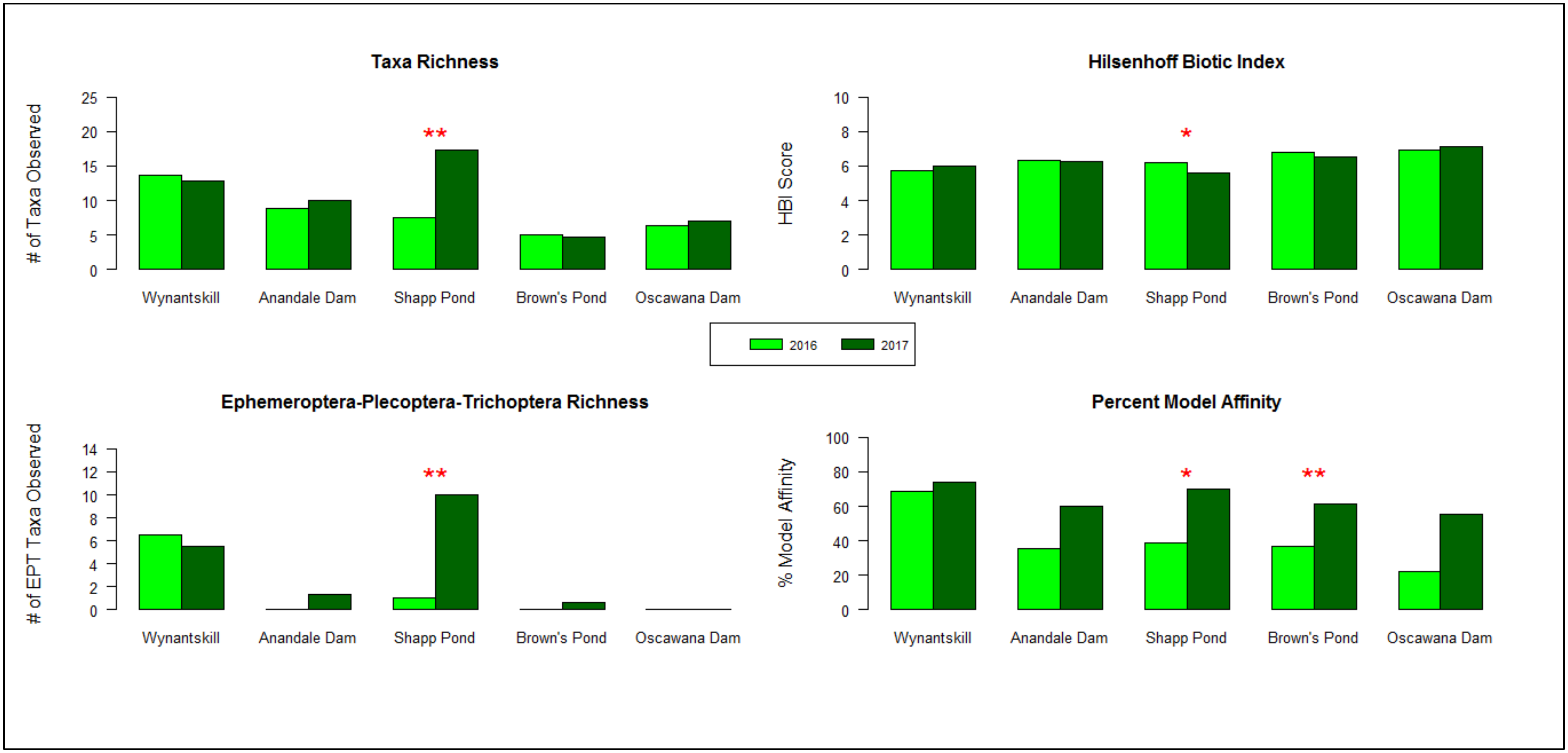


***Figure 18: Mean values of Bioindex metrics for ponar samples at upstream locations across sites. Sampling at Shapp Pond in conducted by ponar sample in 2016 and kick-sample in 2017. Significant differences between 2016 and 2017 are indicated with red asterisk(s).***

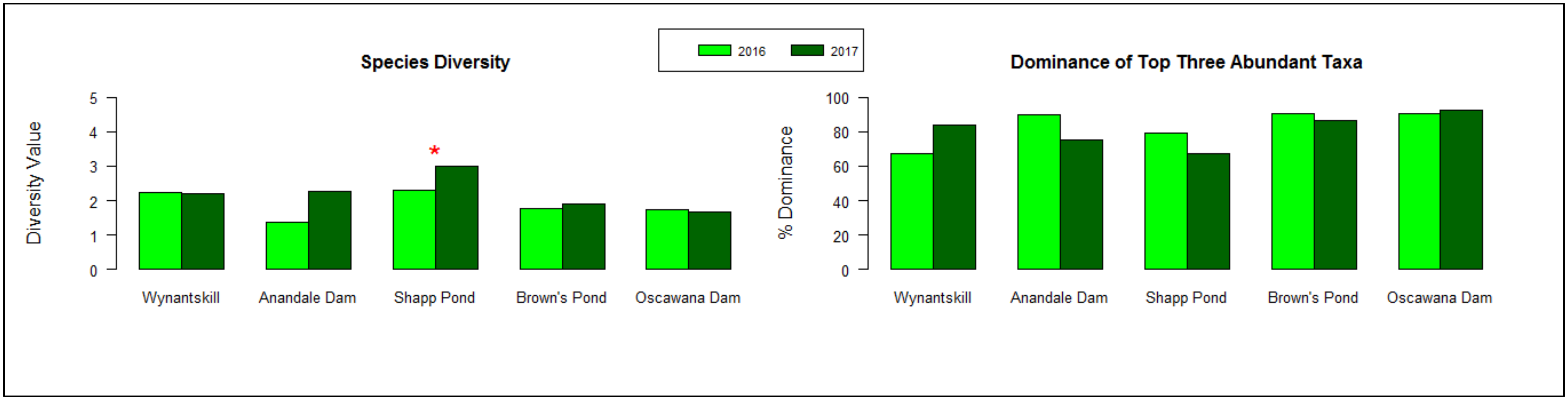


***Figure 19: Mean values of Bioindex metrics for ponar samples at upstream locations across sites. Sampling at Shapp Pond in conducted by ponar sample in 2016 and kick-sample in 2017. Significant differences between 2016 and 2017 are indicated with red asterisk(s).***

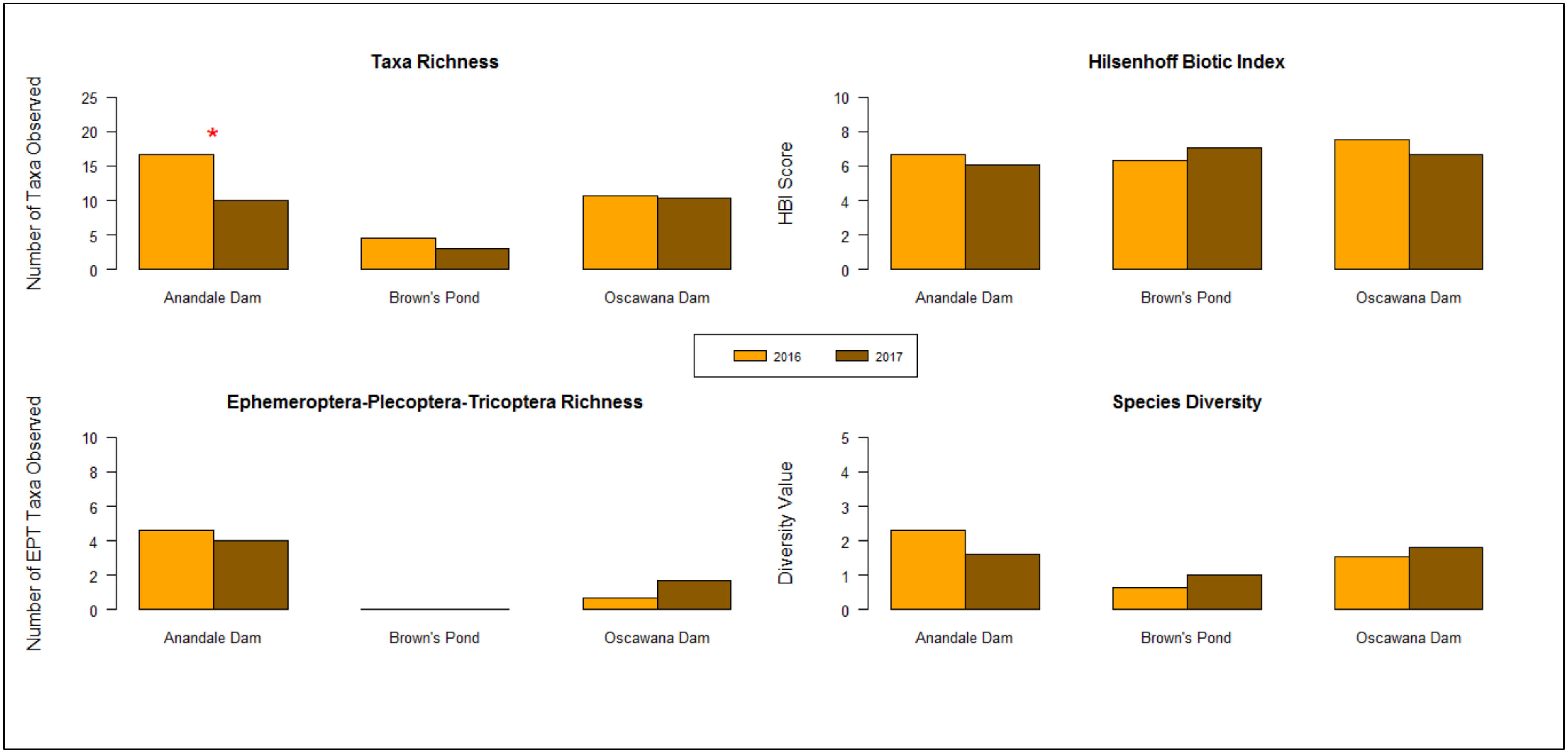


***Figure 20: Mean values of Bioindex metrics for multiplate samples at upstream locations across sites. Significant differences between 2016 and 2017 are indicated with red asterisk(s).***

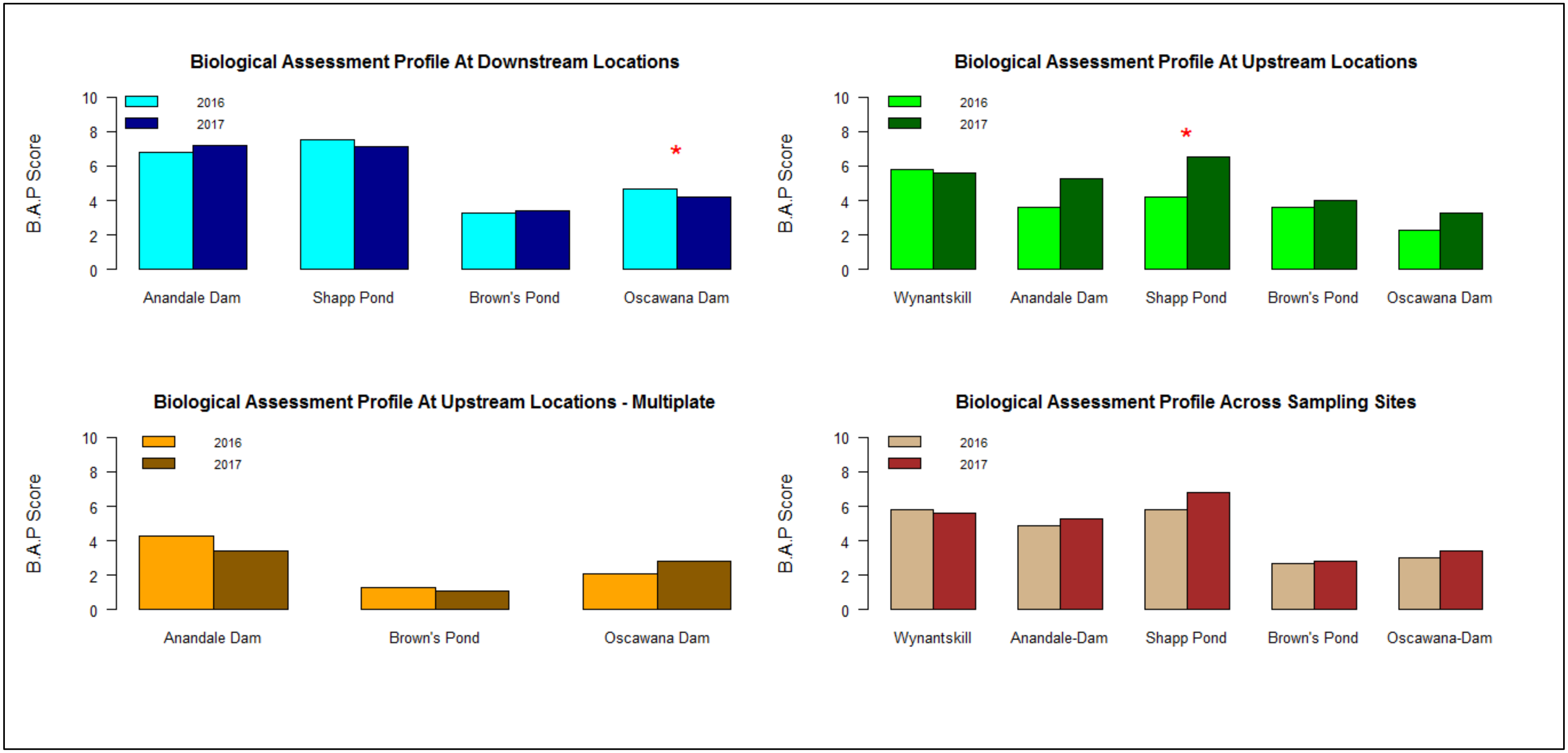


***Figure 21: Mean cumulative values of Biological Assessment Profile (B.A.P. score for kick, ponar, and multiplate samples at upstream and downstream locations across sites. Sampling at Shapp Pond in conducted by ponar sample in 2016 and kick-sample in 2017. B.A.P values at both upstream and downstream were pooled for whole across-site comparisons. Significant differences between 2016 and 2017 are indicated with red asterisk(s).***

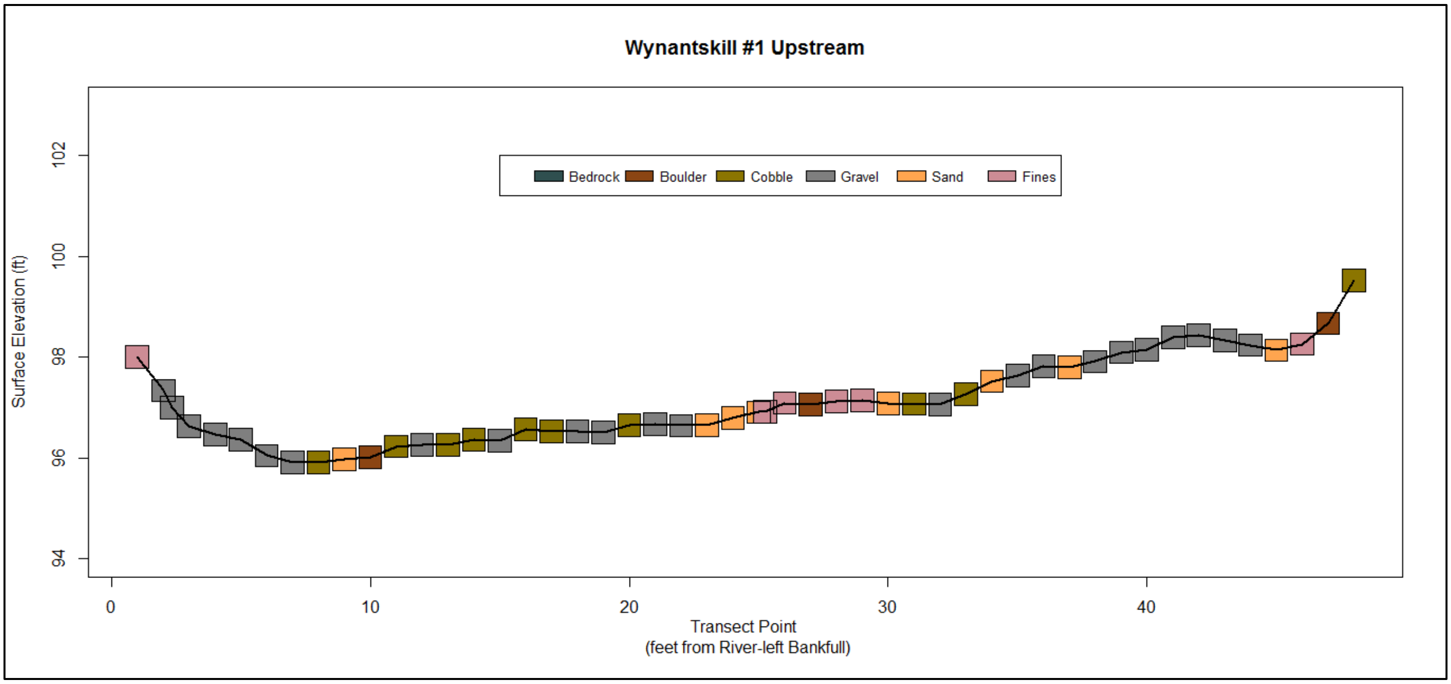


**Figure 22: Field surveyed channel morphology (black line) and substrate composition during August 2017 at upstream Wynantskill transect #1.**

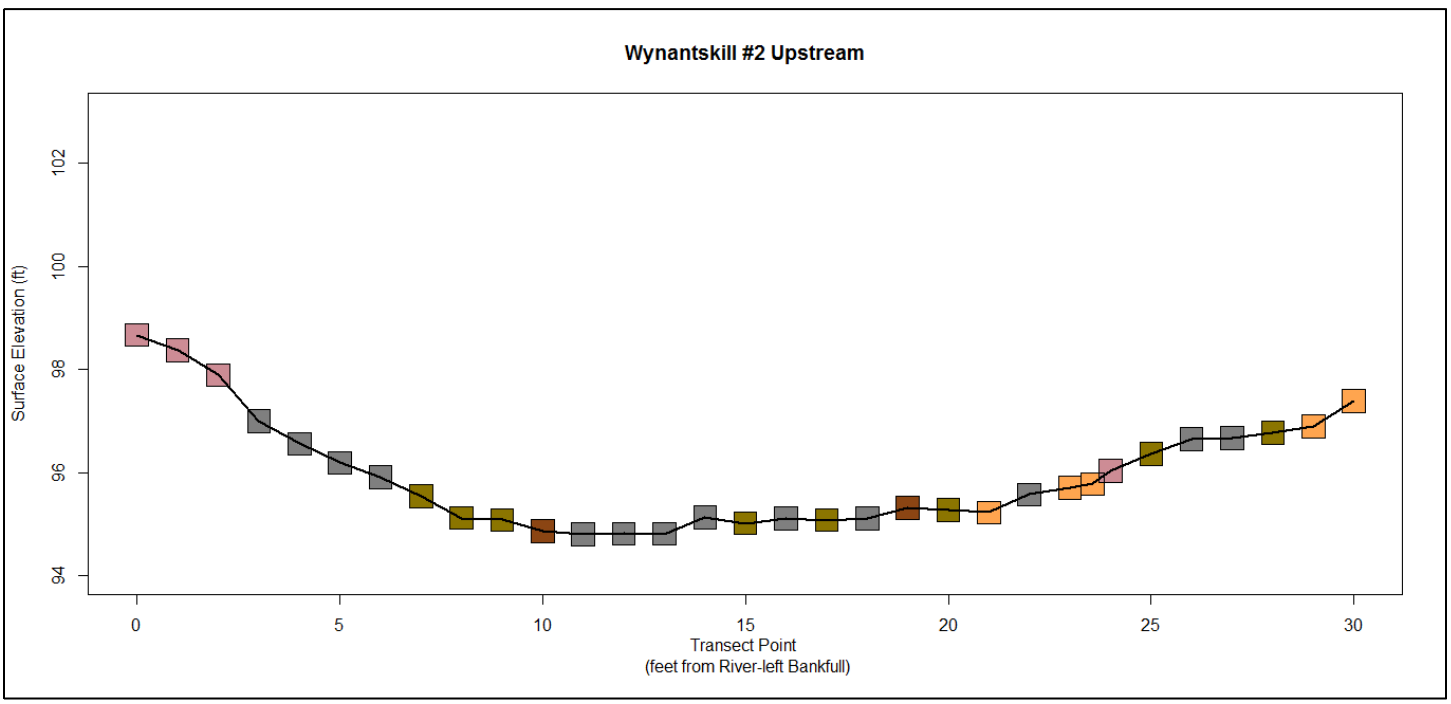


**Figure 23: Field surveyed channel morphology (black line) and substrate composition during August 2017 at upstream Wynantskill transect #2.**

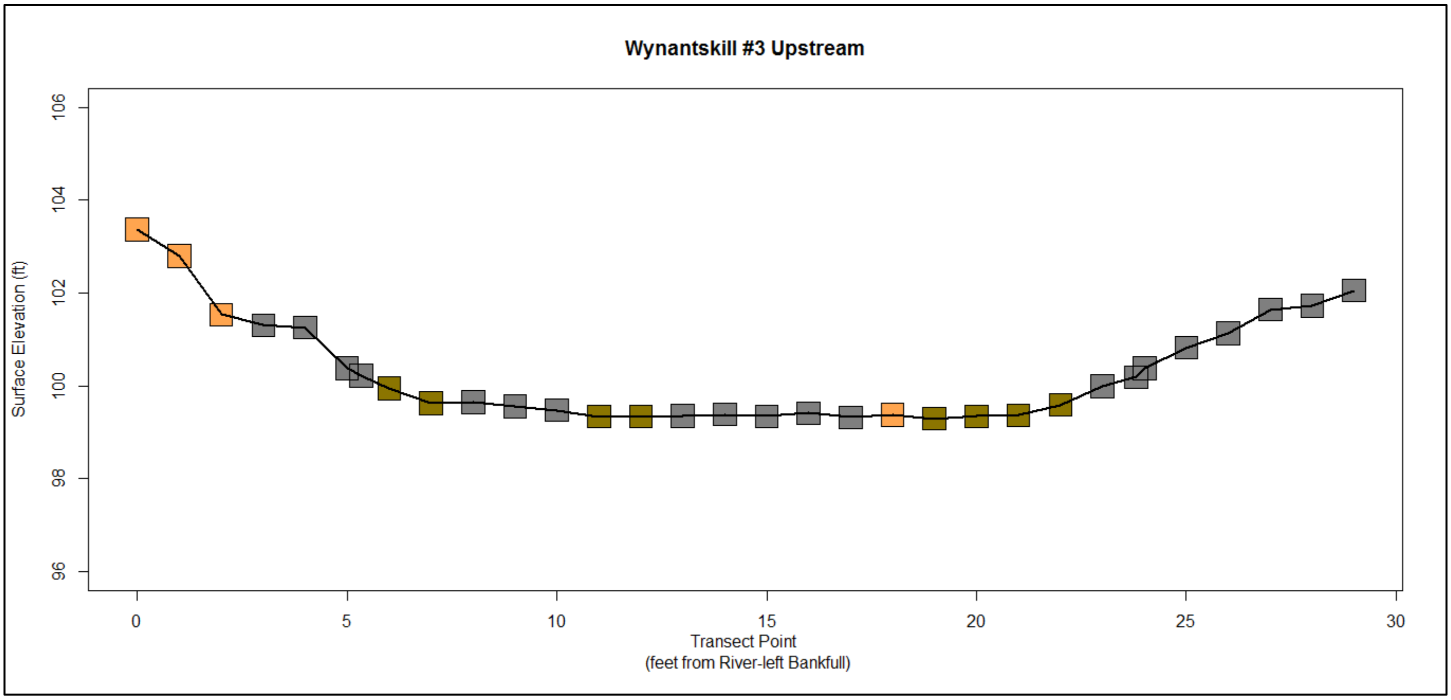


**Figure 24: Field surveyed channel morphology (black line) and substrate composition during August 2017 at upstream Wynantskill transect #3.**

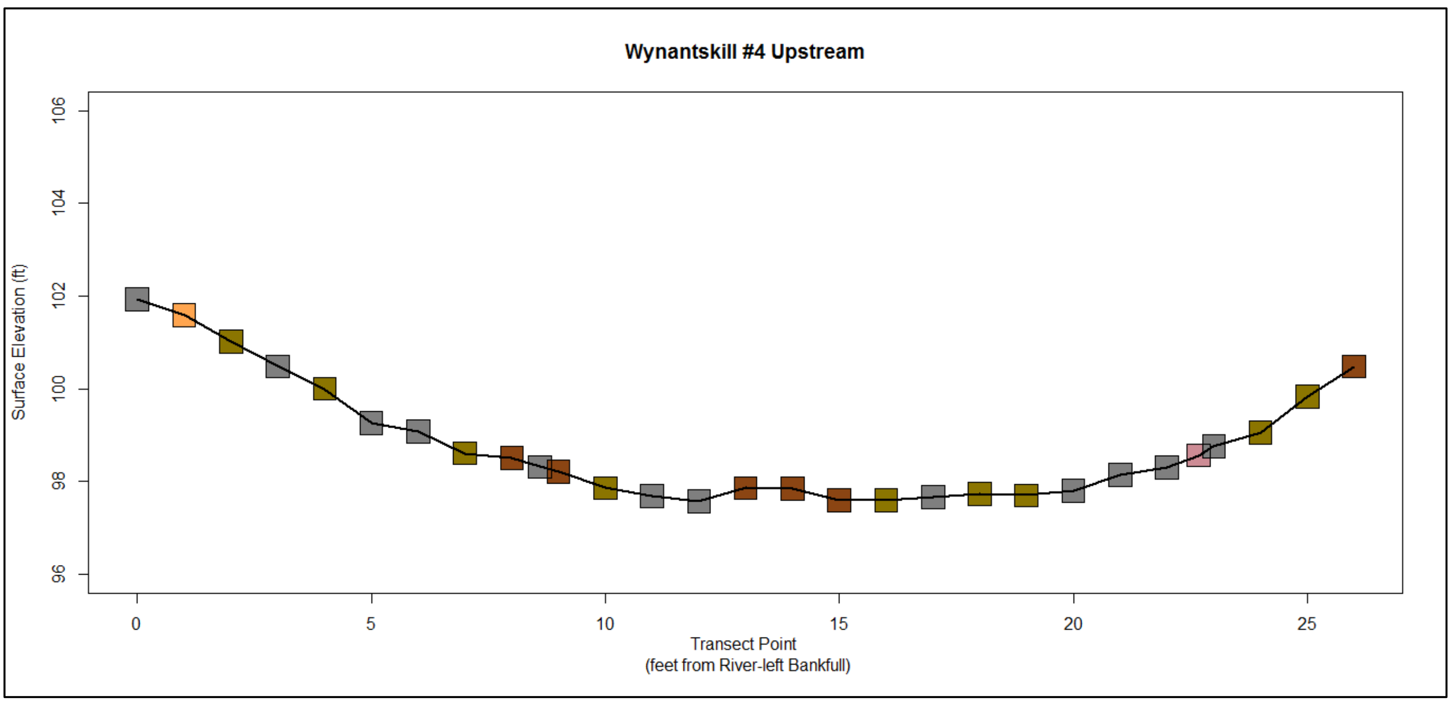


**Figure 25: Field surveyed channel morphology (black line) and substrate composition during August 2017 at upstream Wynantskill transect #4.**

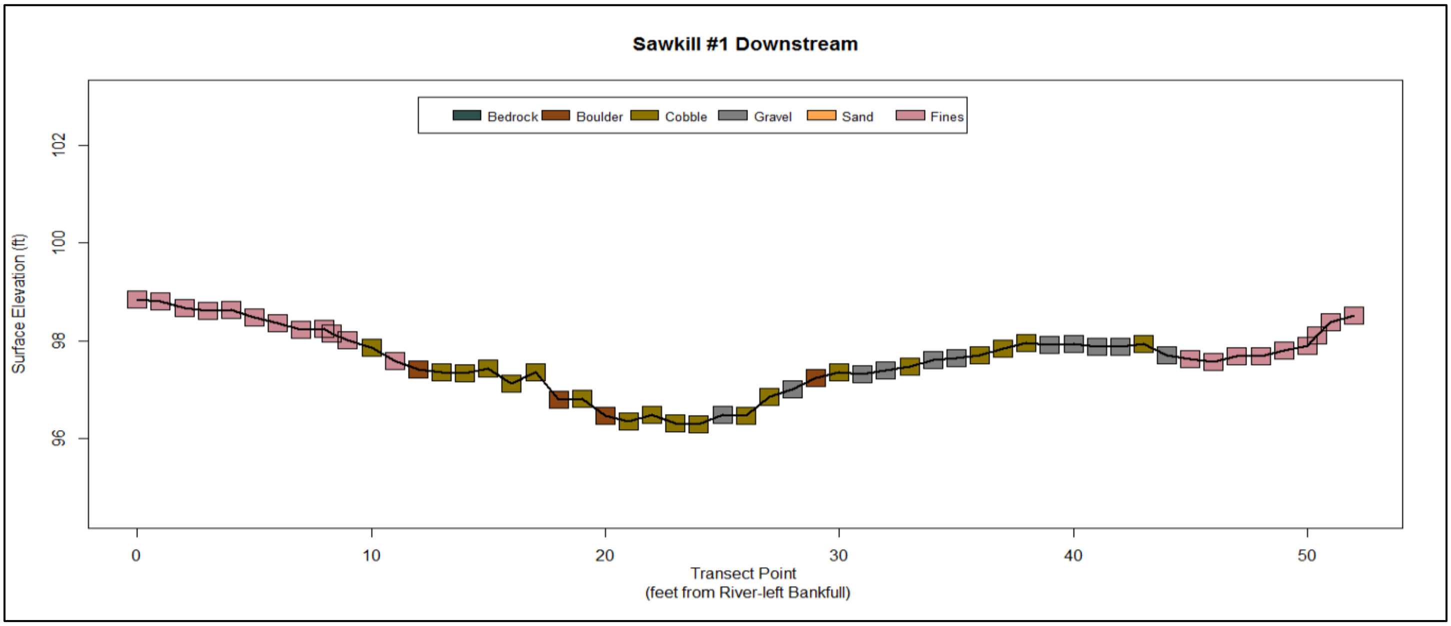


**Figure 26: Field surveyed channel morphology (black line) and substrate composition during August 2017 at downstream Sawkill transect #1.**

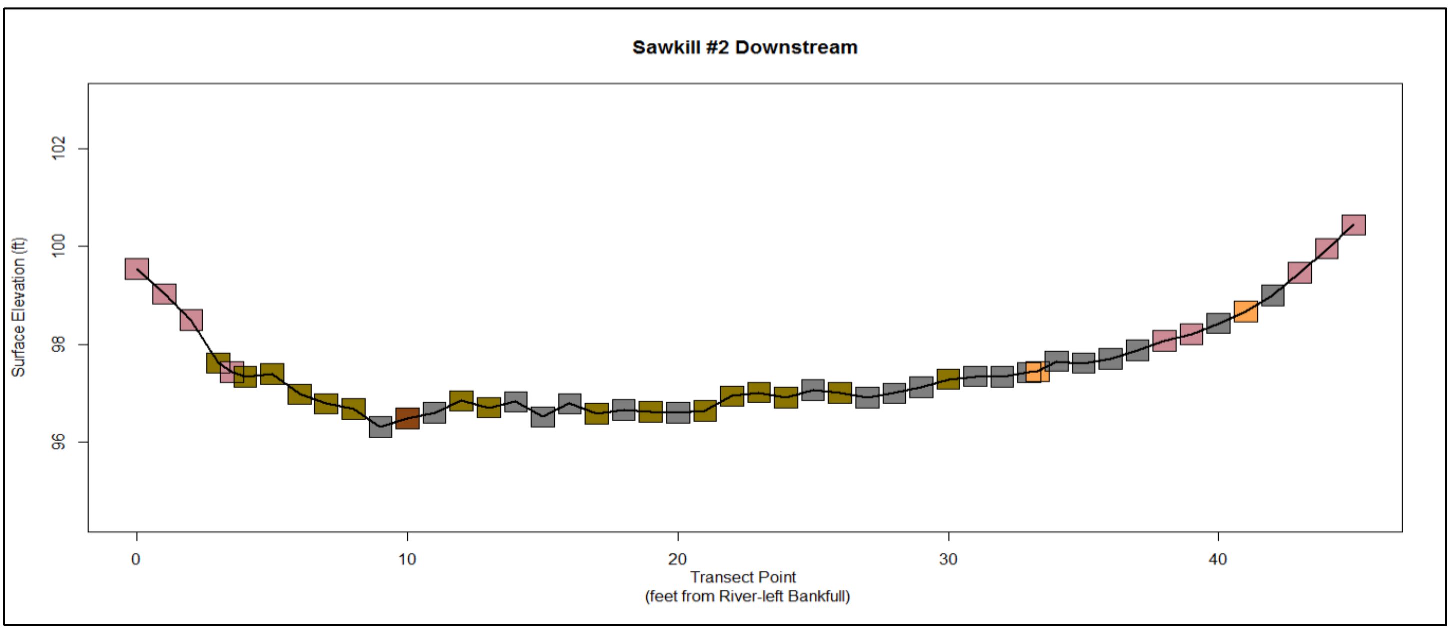


**Figure 27: Field surveyed channel morphology (black line) and substrate composition during August 2017 at downstream Sawkill transect #2.**

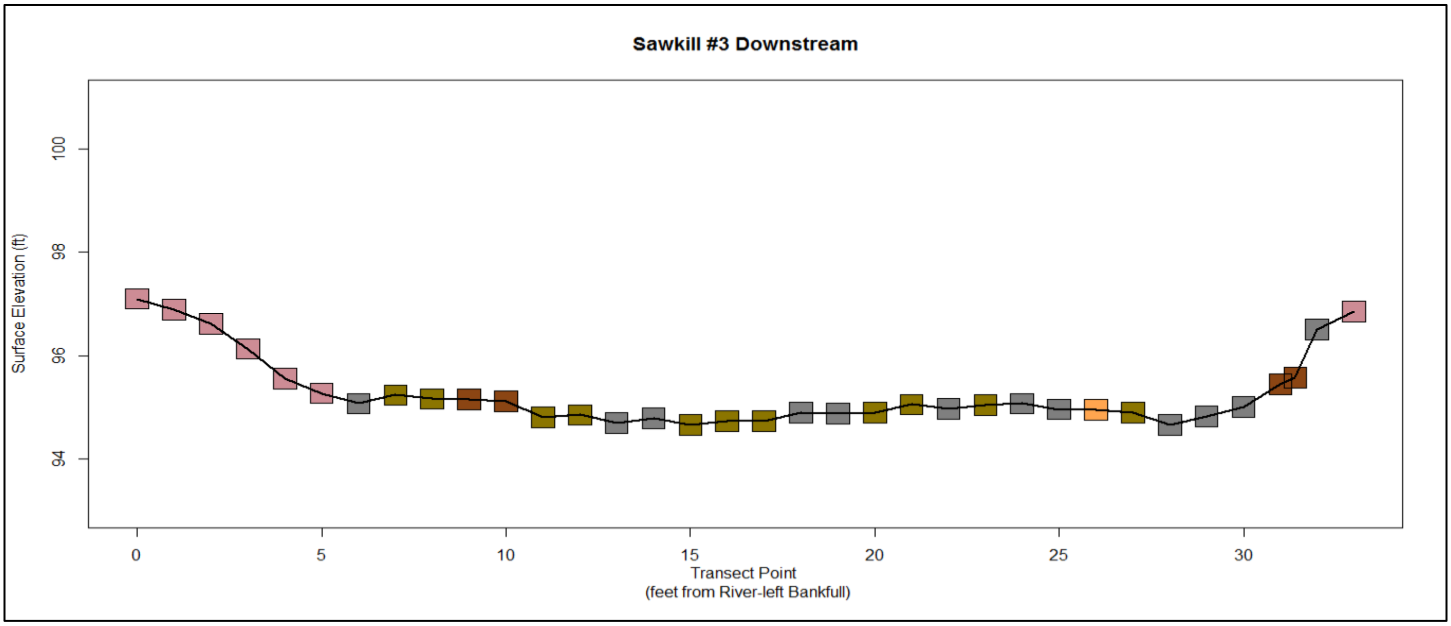


**Figure 28: Field surveyed channel morphology (black line) and substrate composition during August 2017 at downstream Sawkill transect #3.**

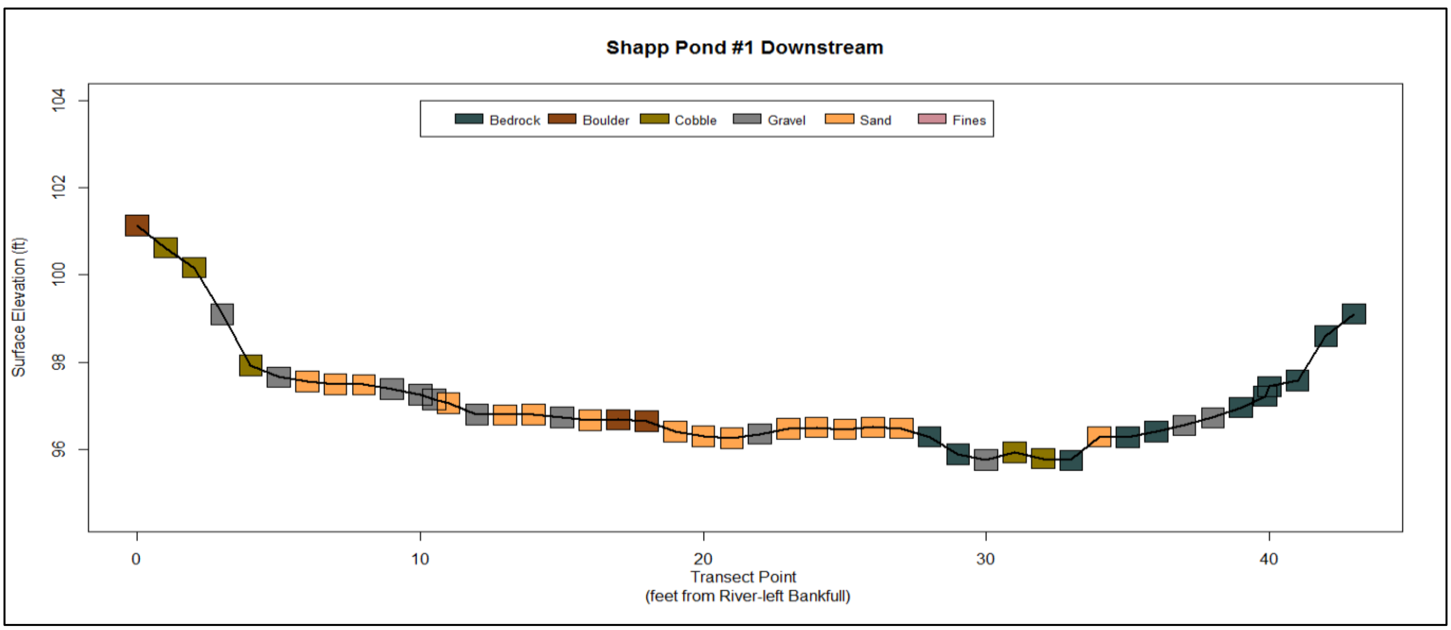


**Figure 29: Field surveyed channel morphology (black line) and substrate composition during August 2017 at downstream E. Br. Wappingers Creek transect #1.**

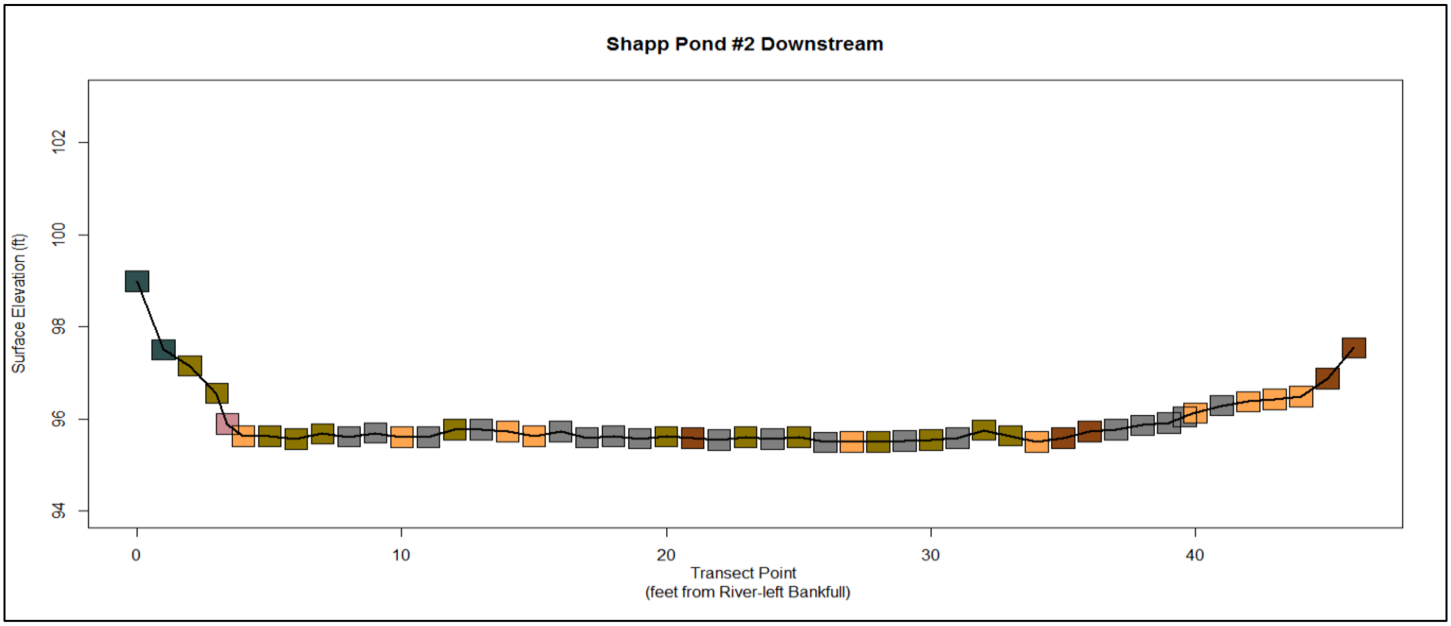


**Figure 30: Field surveyed channel morphology (black line) and substrate composition during August 2017 at downstream E. Br. Wappingers Creek transect #2.**

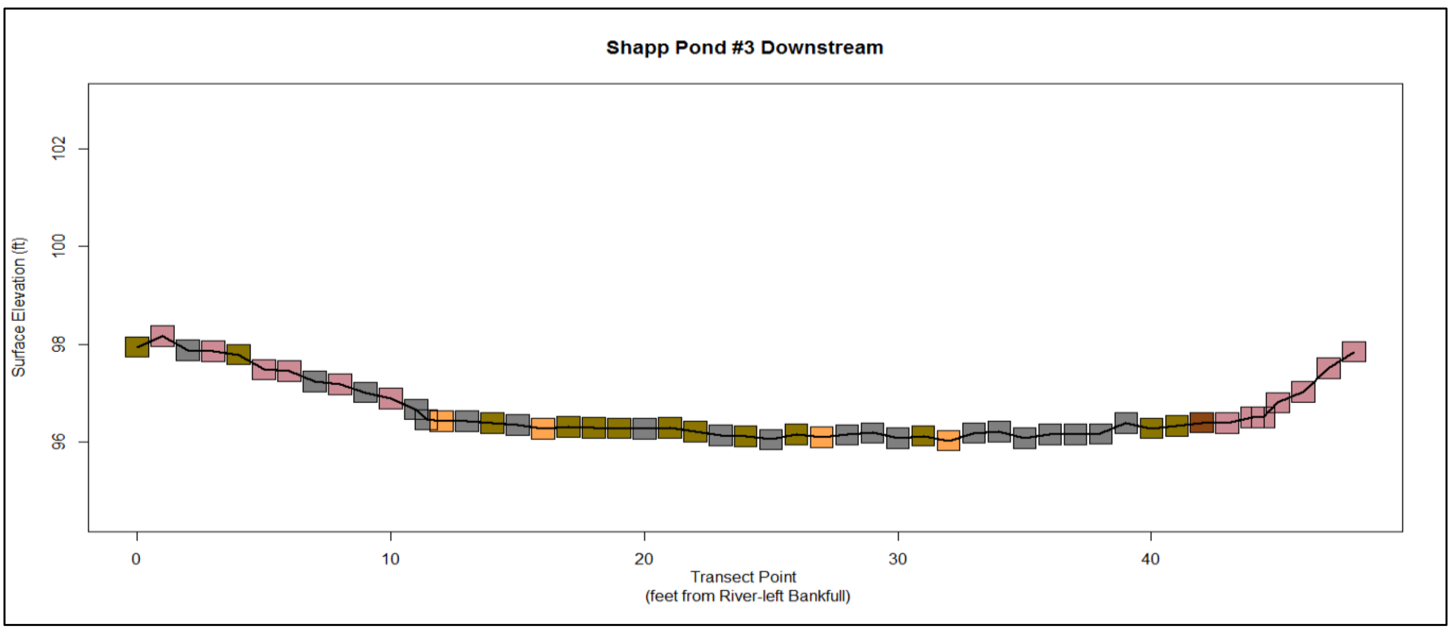


**Figure 31: Field surveyed channel morphology (black line) and substrate composition during August 2017 at downstream E. Br. Wappingers Creek transect #3.**

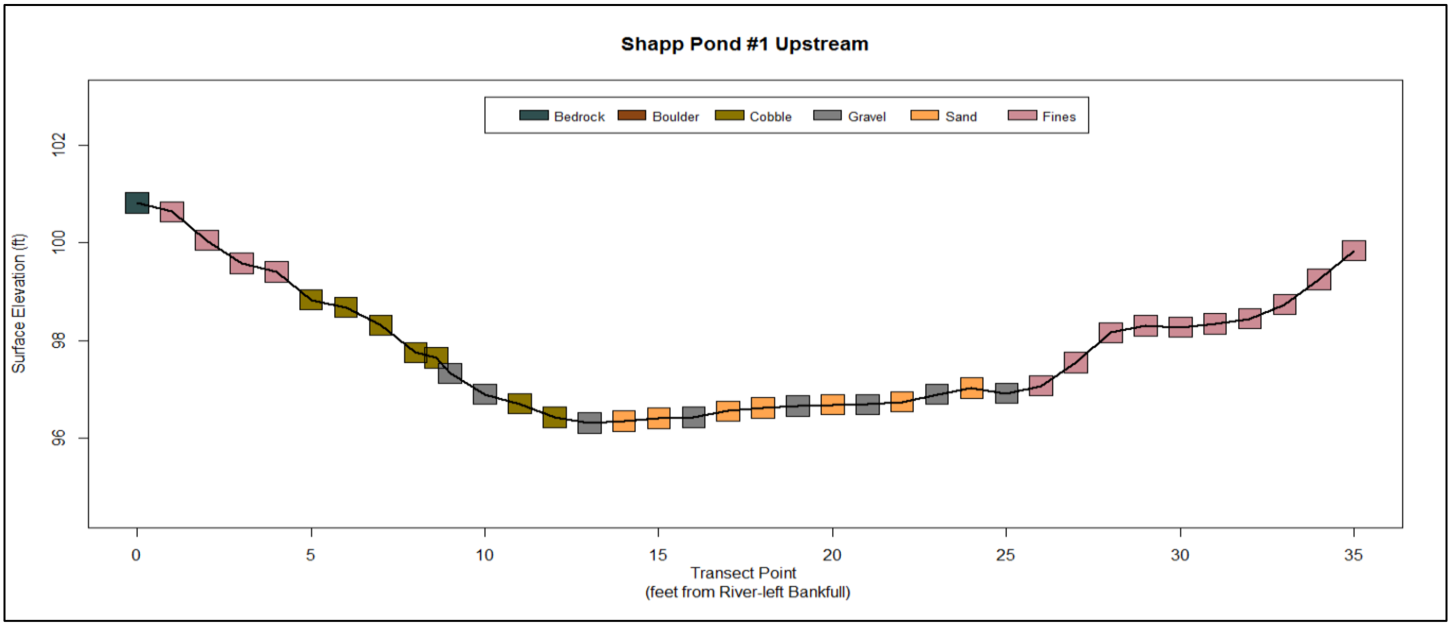


**Figure 32: Field surveyed channel morphology (black line) and substrate composition during August 2017 at upstream E. Br. Wappingers Creek transect #1.**

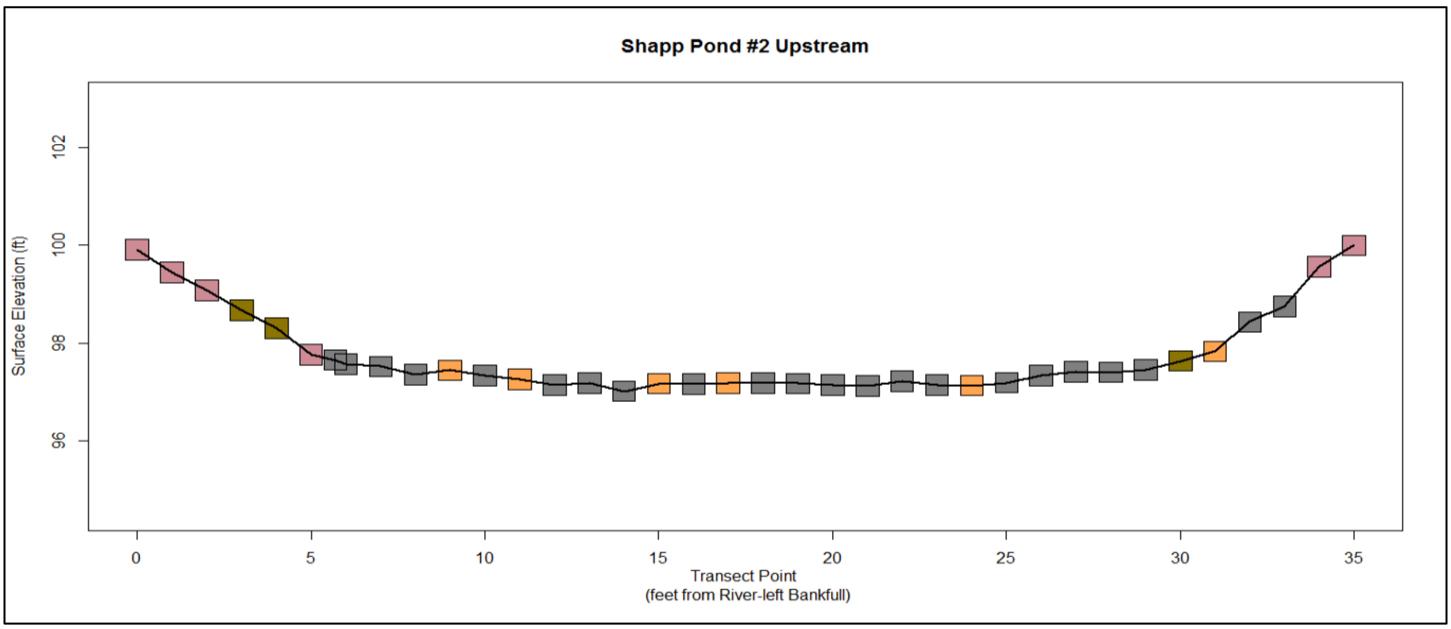


**Figure 33: Field surveyed channel morphology (black line) and substrate composition during August 2017 at upstream E. Br. Wappingers Creek transect #2.**

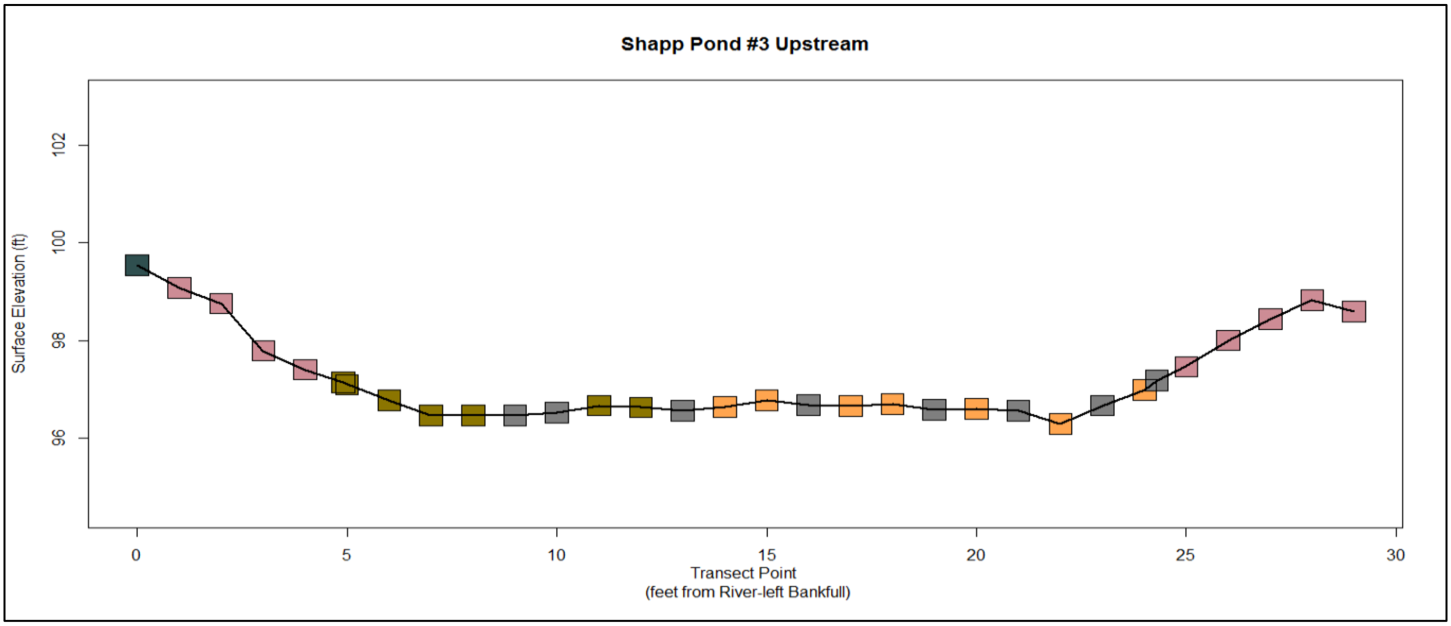


**Figure 34: Field surveyed channel morphology (black line) and substrate composition during August 2017 at upstream E. Br. Wappingers Creek transect #3.**

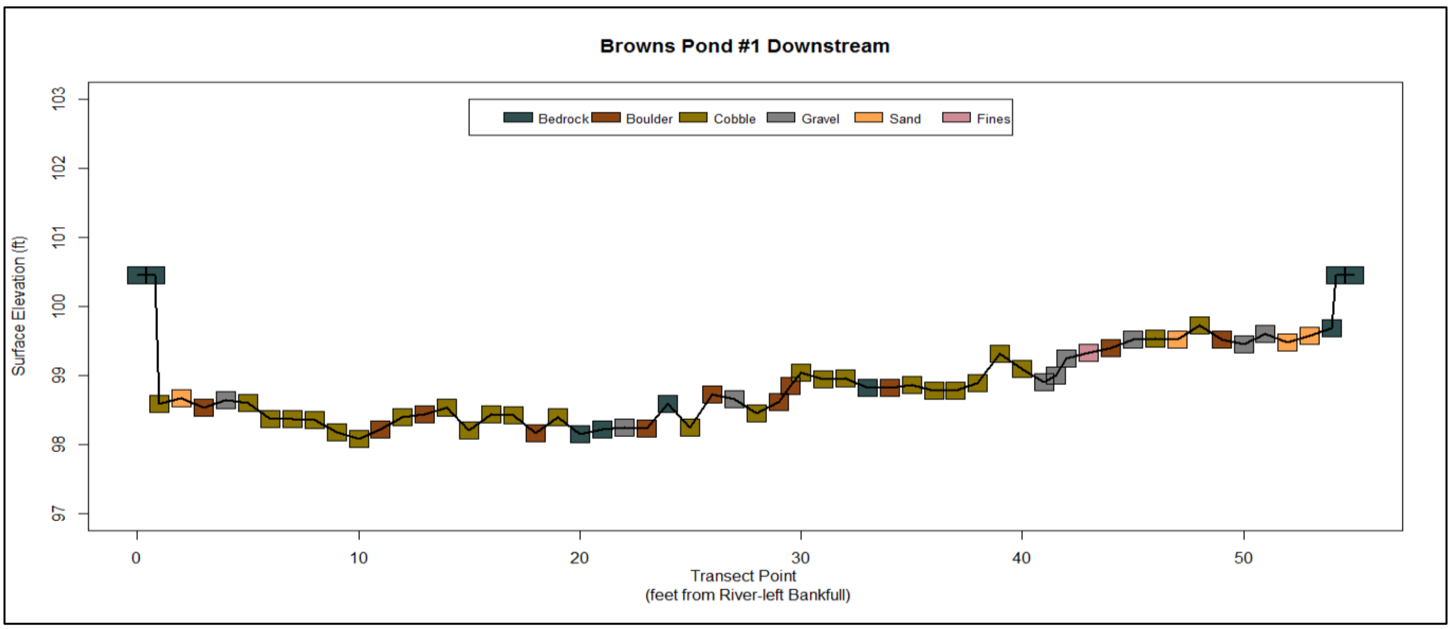


**Figure 35: Field surveyed channel morphology (black line) and substrate composition during August 2017 at downstream Otterkill transect #1.**

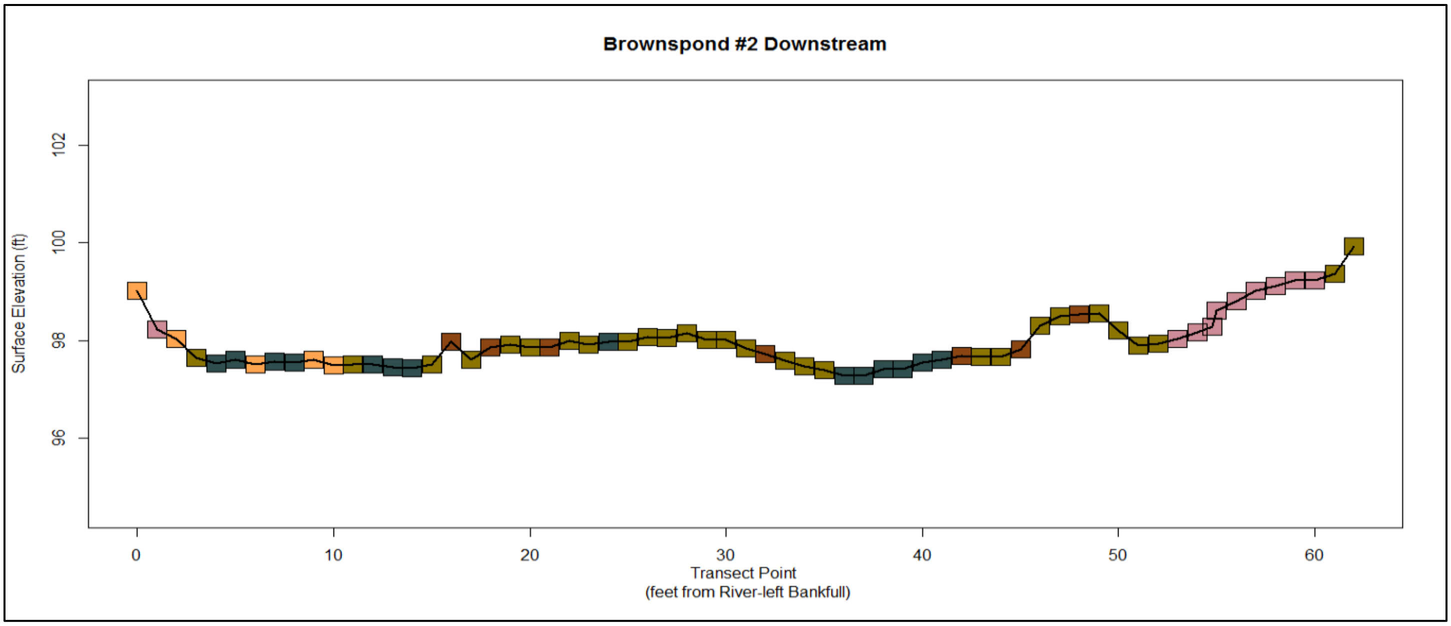


**Figure 36: Field surveyed channel morphology (black line) and substrate composition during August 2017 at downstream Otterkill transect #2.**

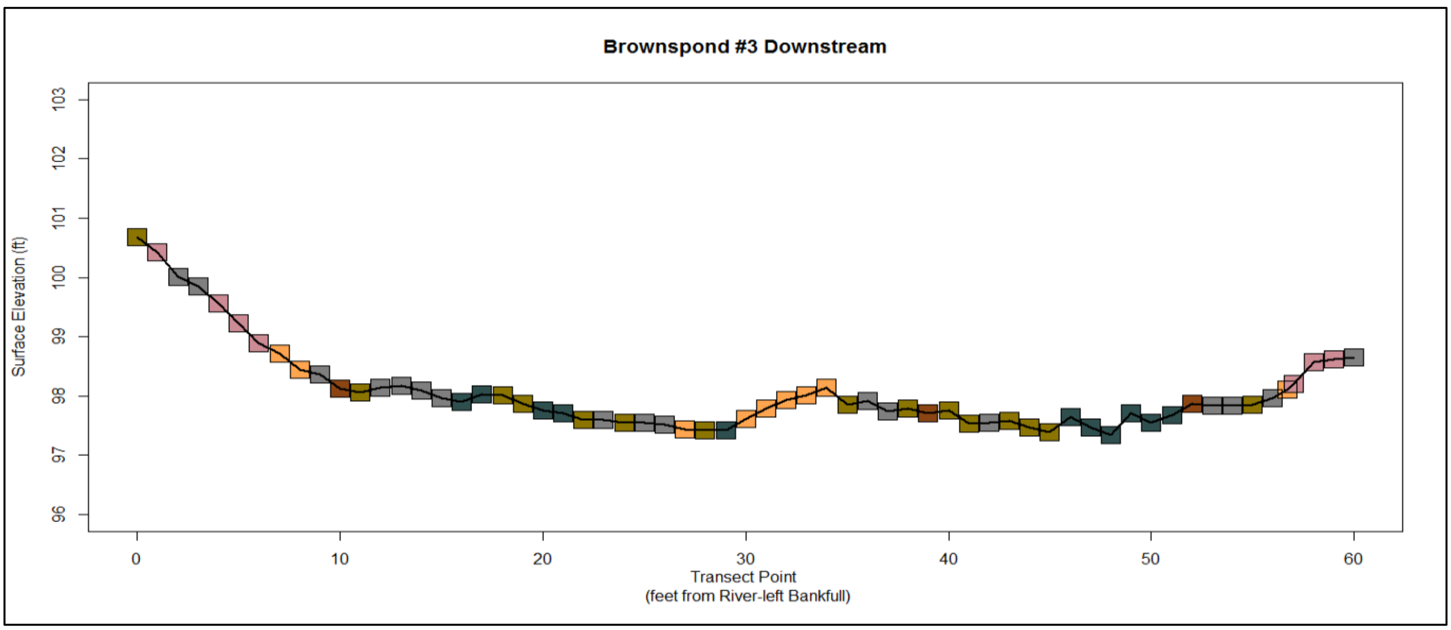


**Figure 37: Field surveyed channel morphology (black line) and substrate composition during August 2017 at downstream Otterkill transect #3.**

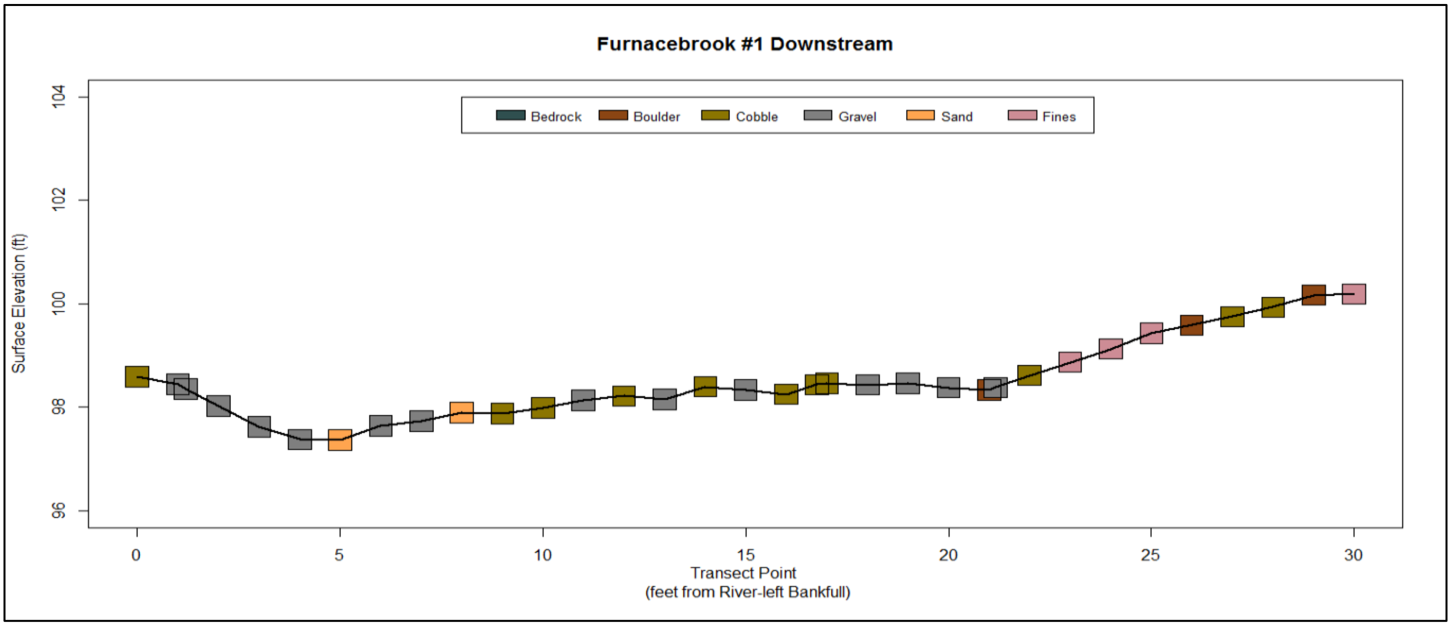


**Figure 38: Field surveyed channel morphology (black line) and substrate composition during August 2017 at downstream Furnace Brook transect #1.**

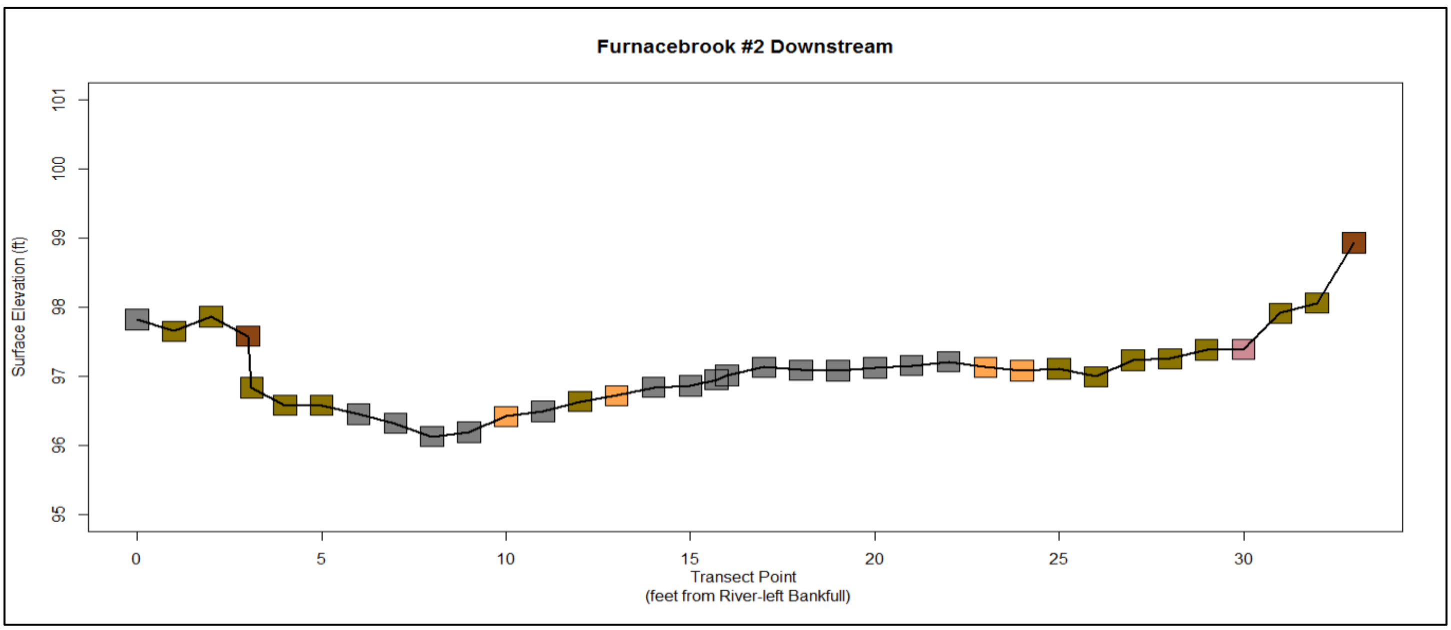


**Figure 39: Field surveyed channel morphology (black line) and substrate composition during August 2017 at downstream Furnace Brook transect #2.**

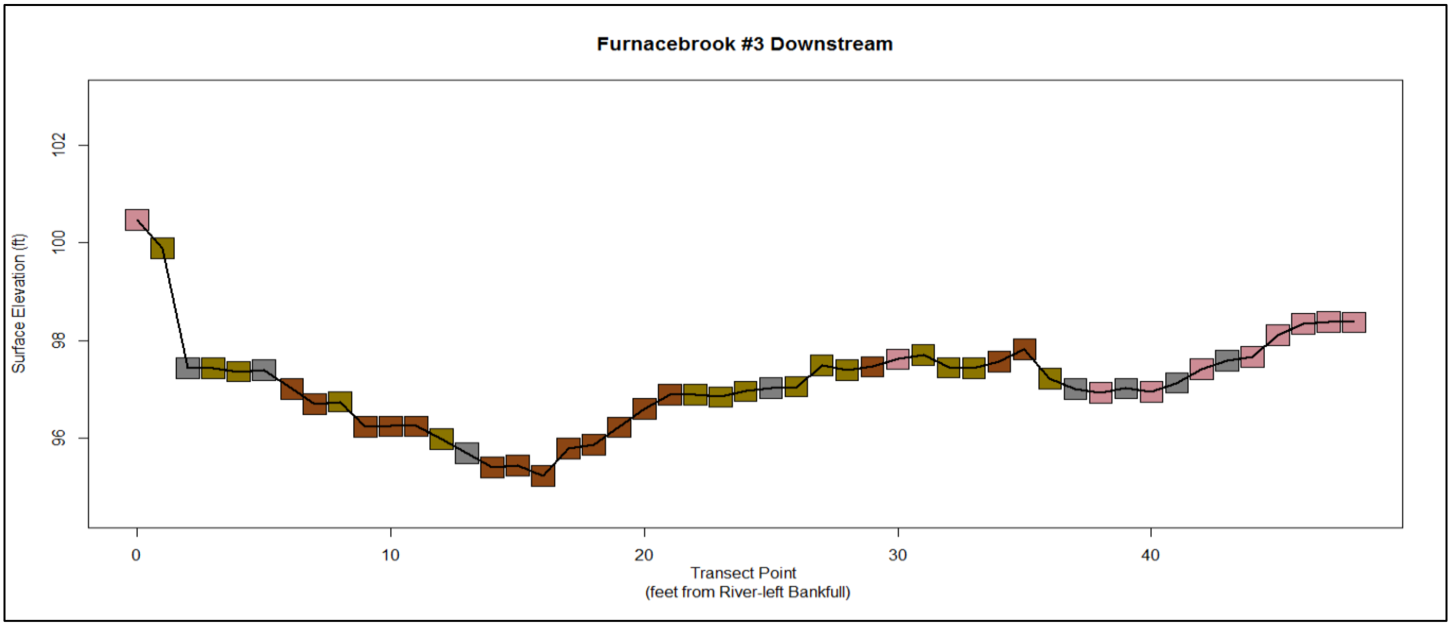


**Figure 40: Field surveyed channel morphology (black line) and substrate composition during August 2017 at downstream Furnace Brook transect #3.**