RESULTS OF THE AQUATIC MONITORING PROGRAM IN BIG DRY CREEK, 2016

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Cities of Northglenn and Westminster,
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EXECUTIVE SUMMMARY

Results of the 2016 biological monitoring program for Big Dry Creek (BDC) are presented in this report with references to the 1997-2010 study results as appropriate. The 2016 study effort was consistent with 2008 and was the fifth year of the reduced-scope program. The reduced program included discontinuing the spring sampling event as well as and sampling at sites bdc1.5 and bdc6.0. The current monitoring program included studies of physical habitat and fall surveys of fish and benthic macroinvertebrate populations at six study sites in Big Dry Creek with key findings discussed below.

Average streamflows in 2016 were close to normal as in 2014, compared to the 2012 drought year which was followed by the record flood event in September 2013. The Rapid Bioassessment Protocol (RBP) habitat analysis in 2014 showed some beneficial changes in habitat conditions since the 2013 flood. The post-flood habitat conditions remained similar in 2016 with only minimal habitat differences noted between 2016 and 2014. The flood-level flows caused significant scouring in the reach from site bdc1.5C downstream to site bdc5.0 washing away the accumulated soft sediments exposing buried gravel and cobble areas which improved substrate quality for macroinvertebrate colonization. The most noticeable improvement was at site bdc2.0. The 2014 as well as the 2016 RBP habitat scores were comparatively higher than scores for the 2008-2012 sampling years indicating an overall improvement in habitat conditions as evidenced by the improved health of the macroinvertebrate community.

In 2016, fish populations in Big Dry Creek continued to be healthy and abundant with typical year-to-year and site-to-site variability. The highest number of fish (1,772 individuals) collected in 2016 was at site bdc5.0. The total number of species collected was 14, with nine native species. Also notable in 2016 was that for the third consecutive sampling event, relatively high numbers of fish were again collected at site bdc2.0. Fathead minnows continued to be the most abundant species system-wide with white suckers, creek chubs, longnose dace, and sand shiners relatively abundant as well. The native longnose dace was the only intolerant species collected, and as usual they were most abundant at sites bdc0.5, bdc1.0, and bdc3.0. Sand shiners were mostly found at site bdc5.0 as in past years with some also collected at sites bdc1.0 and bdc3.0. Creek chubs were collected at all sites including the three downstream sites for the fourth consecutive year. Johnny darters were again scarce, but were more abundant in 2016 compared to 2012 and 2014. In fact, they have become more widely distributed throughout BDC study area in 2016 with 11 individuals collected at the most downstream site bdc5.0 with good numbers also at site bdc1.0. They were also collected for the second consecutive year at site bdc1.5C, while one darter was collected at bdc2.0 where they were last collected in 2001. Interestingly, 2016 was the first time johnny darters

were collected downstream from I-25. Because of the presence of the johnny darter, the CWQCC has assigned a *Warm Stream Tier I* (WS-I) water temperature standard to BDC Segment 1.

The 2016 fish Index of Biotic Integrity (IBI) scores were consistent with previous years with the best scores at sites bdc1.0 and bdc5.0. IBIs were lowest at sites bdc0.5, bdc1.5C and bdc3.0 in 2016. The 6-year mean IBIs (2006-2016) were highest and similar at sites bdc5.0 and bdc1.0; whereas site bdc2.0 had the lowest mean IBI with site bdc1.5C also the lowest of the upstream sites, indicating that the fish populations at these sites were not as healthy as noted at sites bdc5.0 and bdc1.0.

In 2016, the incidence of "black spot" disease in the fish population decreased at sites bdc0.5 and bdc5.0 compared to 2014, while increasing at the remaining sites. The increases at sites bdc2.0 and bdc3.0 in 2016 were substantial. Incidence at site bdc5.0 dropped to the typically low levels of past years after a spike in 2014. For the 10-year study period (2001-2016, 10-yr mean), the average incidence of disease was higher at the upstream sites compared to the downstream sites. Numbers of infected fish and disease severity have historically been higher at the upstream sites due to the predominance of susceptible fish species and the relatively higher density of snails, which are an intermediate host for the disease. Severity of disease was again low in 2016 as in 2014 and 2012, with only few *heavily* infected fish collected at sites bdc0.5 and bdc1.0. Over the study period, correlations between increases and/or decreases in snail numbers and incidence of disease have not been consistent, indicating the complexity of the black spot disease cycle that is further exacerbated by environmental conditions such as low flows, crowding and warm water temperatures. Nonetheless, the WWTP discharges from the Cities are more than likely not a contributing factor related to increases in disease incidence in the BDC system.

Macroinvertebrates were sampled by kick in fall of 2016. In general, the 2016 data continue to show that the benthic macroinvertebrate community of Big Dry Creek reflects the urban and agricultural characteristics of the watershed, especially the flashy nature of stream flows and predominance of shifting sand and silt substrates. However as in 2014, the mayfly population continued to be abundant in 2016 which is no doubt due to the scouring flows of the September 2013 flood event that improved the overall substrate conditions (exposed clean gravel and cobble). Mayflies were again most abundant at sites bdc0.5 and bdc1.0, and for the second year in row they were numerous at bdc2.0 reflecting the improved post-flood substrate conditions. The 2016 fall macroinvertebrate community was dominated by dipterans, mainly midges as usual, followed by oligochaetes, mayflies, amphipods, and caddisflies. A total of 14 macroinvertebrate orders were represented and a total of 71 unique taxa were collected. Taxa richness was highest at site bdc0.5 and lowest at bdc5.0. Densities were quite high in 2016 and notably greater than in 2014 with >18,000 organisms per square meter collected at all sites.

Mean scores for the key metrics including species diversity, the Index of Community Integrity (ICI) and the Hilsenhoff Biotic Index (HBI) were used to compare the overall health of the benthic community at upstream vs. downstream sites. Species diversity, ICI, and HBI mean scores in 2016 indicate that the downstream sites were again more stressed than the upstream sites especially at site bdc5.0, whereas in 2014 the upstream vs. downstream mean scores were similar. The ICI was lowest at site bdc5.0 with the score decreasing sufficiently to drop it from the *good* category in 2014 to *poor* in 2016.

Furthermore, the Rapid Bioassessment Protocol III (RBP) results for 2016 showed no impairment at site bdc2.0 but some degree of impairment at sites bdc3.0 and bdc5.0. The most impairment was at bdc5.0 in 2016. RBPs at site bdc2.0 were lowest indicating *slight* impairment in 2010 and 2012, but improved in 2014 and 2016 to *nonimpaired*. The 2016 RBP results also corresponded with the ICI results which is the expected trend, in contrast to 2012 and 2014 when the RBP and ICI results did not correlate between sites bdc3.0 and bdc5.0.

MMIs for the 2010-2016 period showed less impairment than the study's long-term key metrics (HBI, ICI, RBP, species diversity, total taxa, density) by indicating that the majority (18 of 24, 75.0%) of the MMI scores were in the High Scoring Water category and all sites met use attainment (all MMIs >22). MMIs, unlike the other key metrics, have been calibrated to stream conditions specific to the appropriate biotype (*biotype 3; plains/xeric*). In 2016, MMIs were lowest at site bdc5.0 and highest at site bdc0.5 which was also the trend for the 4-year mean MMIs and agrees with the key metrics analyses. The lowest MMIs were at site bdc5.0 in both 2014 and 2016 and indicated a total decrease of 41.9 points suggesting degradation at this site in recent years according to Policy 10-1. When the more-sensitive mayflies were abundant at study sites, the key metrics and MMI results were better in those years. Conversely, results were worse when the community was dominated by the more-tolerant aquatic worms.

The 2016 benthic macroinvertebrate community in Big Dry Creek, except for site bdc5.0, continues to be relatively healthy and typical of Front Range warm water streams that are influenced by the urban and agricultural characteristics of their watersheds. Notably, the benthic community at site bdc2.0 has shown an improvement in 2014 and 2016 in response to the improved substrate conditions since the 2013 flood.

1.0 INTRODUCTION

The Big Dry Creek biological monitoring program was initiated in 1997 for the Big Dry Creek Watershed Association (BDCWA), which was founded in 1997 by the City and County of Broomfield, the Cities of Northglenn and Westminster (the Cities) and the Rocky Flats Environmental Technology Site (RFETS). The purpose of this program is to document changes in the abundance and distribution of fish and benthic macroinvertebrate populations and to monitor physical habitat conditions at established study sites in Big Dry Creek (BDC). The results of biological monitoring performed in 2016 are presented in this report with historical comparisons, as in previous reports, made as appropriate. Results of biological and habitat monitoring efforts conducted from 1997 through 2014 are available in separate reports (Aquatics Associates, Inc. (AAI) 1998, 1999a, 1999b, 2002, 2005a, 2005b, 2007, 2010, 2012, 2014, and 2016). Objectives of this program have been to establish a biological data base that can be used to support appropriate water quality standards for Segment 1 of Big Dry Creek and to document the effects that changes in water quality and habitat conditions have on the aquatic community. For example, in 2017 at the request of the BDCWA, AAI provided the Big Dry Creek macroinvertebrate data set (2008-2016) to the Colorado Water Quality Control Division (CWQCD) for their use in the recalibration of the Multi-Metric Index (MMI) and Policy 10-1 that was approved on August 7, 2017 (CWQCC 2017). This continues to show the usefulness and importance of the biological data set for establishing appropriate water quality standards for Big Dry Creek.

The 2016 monitoring program was consistent with the reduced program that was implemented in 2008 (AAI 2016). The key changes of the reduced program were the discontinuation of the spring sampling event and elimination of sites bdc1.5 and bdc6.0 from the program resulting in six sites being sampled in the fall (three sites upstream and downstream from the WWTPs).

The scope of this project was somewhat limited during the initial three years (1997-1999) of the program because of the Cities' budget considerations. Grant funding provided by DOE (Rocky Flats) from 2000 through 2004 allowed for the continuation of the program. Although DOE funding for the 2004 monitoring year was substantially reduced and then eliminated in 2006, additional funding from the Woman Creek Reservoir Authority (WCRA) since 2004 has helped the BDCWA sustain this program at previous levels. This financial support continues to ensure the integrity of the biological monitoring program over a longer term to the benefit of the Cities, the WCRA, and other concerned parties.

Temperature criteria for the South Platte River Basin (including Big Dry Creek) were approved by the Colorado Water Quality Control Commission (CWQCC) during the June 8-9, 2009 hearing which went into effect on June 30, 2010. Accordingly, Segment 1 of Big Dry Creek was designated as *Aquatic Life*

Warm 2 with a temperature standard of *Warm Stream Tier I* (WS-I), which is considered protective of the johnny darter (CWQCD 2010a). The WS-I temperature criteria are as follows: Maximum Weekly Average Temperature (MWAT) from March to November (summer) is 24.2 ^{o}C, while for December to February (winter) it is 12.1 ^{o}C; Daily Maximum (DM) for March to November is 29.0 ^{o}C vs. 14.5 ^{o}C for December to February. The CWQCD's rationale for the temperature standard designation of WS-I (rather that WS-II) is based on the presence of the johnny darter in this case (i.e., common shiner and orange throated darter are also listed for WS-I but have not been collected in BDC Segment 1). During the BDC study period from 1997 through 2014, johnny darters have been collected by AAI at several sites including bdc0.5, bdc1.0, bdc1.5, bdc1.5C, and bdc2.0, but have yet to be collected at sites downstream from I-25 (bdc3.0 and bdc5.0).

The CWQCC adopted Policy 10-1 on October 12, 2010 (CWQCC 2010b), which provides for the evaluation of the biotic integrity of streams through use of a MMI calibrated for the State of Colorado, with the BDC data set (2000-2006) being included in the calibration process. Application of this method requires the collection and analysis of benthic macroinvertebrate samples. Use attainment thresholds have been established for three separate stream biotypes and Big Dry Creek is designated as a *biotype 3* (Plains and Xeric) stream. Failure to meet use attainment thresholds for streams in their particular the biotype may result in the affected segment(s) being listed as impaired for aquatic life. Because of the importance of the MMI analysis as a regulatory tool for the CWQCD, this analysis was performed for the BDC macroinvertebrate data set with results of the most recent four sampling years (2010, 2012, 2014, and 2016) presented herein.

Storm events in the summer of 2012 were of insufficient magnitude to affect stream flows and impact aquatic life in Big Dry Creek. The dry precipitation patterns in 2012 were severe causing a region-wide drought with the lower flows resulting in higher water temperatures in Big Dry Creek. In fact, average streamflows during 2012 were among the lowest in the period of record for both stream gages on Big Dry Creek (BDCWA 2013). The drought persisted, to a lesser extent, until September 11 and 12, 2013, when Big Dry Creek experienced a record flood event as did most drainages along the northern Front Range. In 2014, weather patterns were more normal, but slightly wetter from May to October (USGS 2017). The 2015 summer flows were higher than in 2014 and 2016, with three or more major storm events. Streamflow in 2016 was closer to normal with low flows at the time of the sampling in late September and late October.

The project study area in Big Dry Creek currently extends from approximately 1.5 miles downstream from the Standley Lake dam to site bdc5.0 immediately downstream from the Yoxall Ditch at Weld County Road 4, which is 8.2 miles downstream from site bdc3.0 and in agricultural land. The total length of the study area is currently ~17 miles including the six sites (bdc0.5 through bdc5.0). The project study area and locations of study sites and WWTPs are depicted in Figure 1. Locations of the study sites on Big Dry Creek with distances between the sites and cumulative distances downstream (from Standley Lake dam to the lowest site) are provided in Table 1. Sampling frequency and the types of samples collected are presented in Table 2 for the 2016 monitoring period.

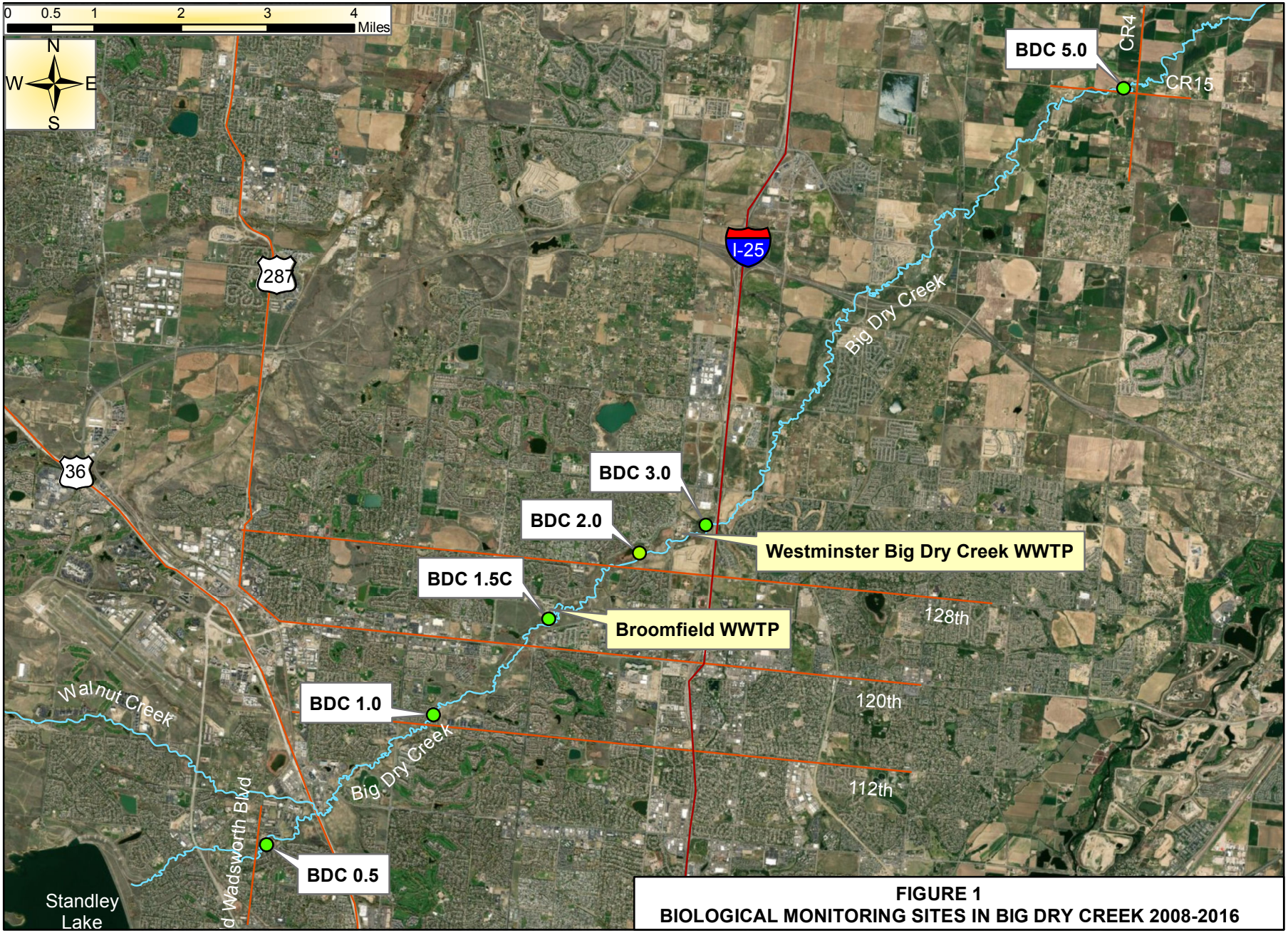


FIGURE 1
BIOLOGICAL MONITORING SITES IN BIG DRY CREEK 2008-2016

TABLE 1

BIOLOGICAL MONITORING SITES
IN BIG DRY CREEK, 2008-2016 1/

Study Site	Location	Distance Between Sites	Cumulative Distance
BIG DRY CREEK			
UPSTREAM FROM TREATMENT PLANTS		*Distance from Standley Lake dam*	
bdc0.5	Church Ranch Open Space, downstream from Old Wadsworth Boulevard	1.5 mi.	1.5 mi.
bdc1.0	Downstream from 112th Avenue	2.8 mi.	4.3 mi.
bdc1.5C	Immediately upstream from Broomfield WWTP 2/	0.4 mi.	6.2 mi.
DOWNSTREAM FROM TREATMENT PLANTS			
bdc2.0	Upstream from 128th Avenue, downstream from Broomfield WWTP	1.5 mi.	7.7 mi.
bdc3.0	At Interstate-25, downstream from Westminster Big Dry Creek WWTP	1.0 mi.	8.7 mi.
bdc5.0	Downstream from Weld County Road 4	8.2 mi.	16.9 mi.

1/ Sites bdc1.5 and bdc6.0 were eliminated in 2008.
2/ Site bdc1.5C was added to the program in the spring 2000.

TABLE 2

SAMPLING DATES AND TYPES OF SAMPLES COLLECTED AT
BIG DRY CREEK MONITORING SITES, 2016 1/

Study Site	2016 fall
BIG DRY CREEK	
Upstream from WWTPs	
bdc0.5	*F, M, H*
bdc1.0	*F, M, H*
bdc1.5C	*F, M, H*
Downstream from WWTPs	
bdc2.0	*F, M H*
bdc3.0	*F,M, H*
bdc5.0	*F, M, H*

1/ Fish, macroinvertebrate, and habitat sampling are denoted by *F, M,* and *H*, respectively.

2.0 METHODS

2.1 PHYSICAL HABITAT

Physical habitat characteristics were measured rigorously in the fall of 2000 during the low flow period to establish baseline conditions. Physical data were collected within the same stream reaches sampled for the fish population surveys. The assessment of habitat characteristics was performed primarily to provide supplemental data for distinguishing between habitat and water quality effects on fish and macroinvertebrate communities inhabiting the various study sites. Subsequent habitat evaluations have been conducted in the fall each year concurrent with the biological sampling and consisted of visual observations with measurements being made only when obvious changes were observed such as increased bank erosion and collapse, sediment deposition and movement within the channel due to flow changes and fluctuations which are often significant in this system, and/or changes in the relative amounts of pool (vs. run and riffle) habitat resulting from fallen trees and beaver activity.

Physical parameters were evaluated according to the most recent methods outlined for the Rapid Bioassessment Protocol (RBP) habitat assessment for low gradient streams. This analysis allows for determining habitat differences between sites and documenting yearly changes at individual sites (Barbour et al. 1999). The RBP analysis incorporates ten habitat parameters including available cover, pool substrate characterization, pool variability, sediment deposition, channel flow status, channel alteration, sinuosity, bank stability (erosion), bank vegetation protection, and riparian vegetation zone width. These habitat variables were measured in the field, and each parameter was rated as *optimal*, *suboptimal*, *marginal*, or *poor* based the data collected and scoring ranges designated for the RBP habitat assessment (Barbour et al. 1999). A total habitat assessment score was then calculated for each site by adding the ten habitat parameter scores. Habitat assessment scores may potentially range between 0 and 200, with higher scores generally indicating better habitat quality. The RBP habitat assessment scores were calculated primarily to document observed habitat changes and trends at individual sites from year-to-year and over time.

The presence and abundance of most fish and benthic macroinvertebrate species inhabiting a given stream reach are in part influenced by substrate composition and the relative amounts of macro-habitat (riffle, run, pool) available. Consequently, substrate composition and macro-habitat were also measured at study sites to supplement the RBP habitat analysis. Substrate particle size distribution was quantitatively measured at each site using the Wolman pebble count technique (Wolman 1954) in previous years (2000 and 2004), although subsequent sampling has not been necessary since 2004 because substrate composition changes at study sites remained relatively constant. Photographs of study sites were taken to

document habitat conditions, and general habitat descriptions and observed changes were also recorded on all sampling occasions.

2.2 FISH POPULATIONS

Fish populations were sampled at the six study sites in the fall with assistance provided by the Cities on two of the three sampling days. Sampling methods were consistent with previous years. Shoreline electroshocking equipment with one stationary negative and three to five mobile positive electrodes were used, depending on stream width and water volume at each station. Fish were collected at all sites using two-pass removal techniques. Fish were collected in two consecutive passes with fish from each pass kept separate for processing. All fish captured were identified, counted, measured, and released to the stream. For each species, lengths and weights were measured for all individuals collected. When a large number of a single species was collected, specimens were counted and weighed collectively after a representative sample of individual fish was measured. Individuals were visually examined and the incidence of disease was recorded. In addition, the level of disease severity was also rated on a scale of 0 to 3, with ratings of 0, 1, 2, or 3 denoting either no, slight, moderate, or heavy disease levels recorded for individuals examined.

Fish sampling was performed in the same stream reaches sampled on previous occasions. Sampling areas were representative of the stream reach and were of sufficient length to include all macro-habitats (riffle, run, pool) present. In most cases, natural physical barriers (very shallow depths over the riffle) prevented fish from moving into or out of the study reach. Study sites boundaries were permanently marked with rebar. The length of study areas ranged from approximately 105 to 192 meters (345 to 630 feet) at the six BDC sites. Stream widths were measured at either 9 or 15-meter intervals throughout each study section depending on stream size. Average stream widths ranged from approximately 4 to 7 meters (12 to 22 feet) at BDC sites. Average stream width and total station length were used to calculate the area sampled. General site characteristics encountered at the time of sampling were recorded.

A list of fish species collected including mean lengths and weights, number collected, relative abundance, and percent disease were calculated for all study sites. The Index of Biotic Integrity (IBI) was also calculated for the population at each site based on the methods outlined in Karr (1981), Karr et al. (1986), and the EPA Rapid Bioassessment Protocols (Barbour et al. 1999, Plafkin et al. 1989). The EPA has developed different sets of metrics that are specific for the various regions of North America based on the original IBI developed by Karr (1981), which provide a consistent assessment methodology for analyzing fish assemblage data. Metrics developed specifically for Colorado Front Range streams were used to

assess fish data collected from Big Dry Creek. The eleven metrics incorporated in IBI analysis include: 1) total number of native species, 2) number of darter species, 3) number of sunfish species, 4) number of minnow species, 5) number of intolerant species, 6) percent white suckers, 7) percent omnivores, 8) percent specialized insectivores, 9) total number of individuals collected, 10) percent introduced species, and 11) percent diseased individuals. Each metric value was calculated and scored based on the data collected. Metric values approximating, deviating slightly from, or deviating greatly from values for reference sites are scored as 5, 3, or 1, respectively. Species tolerance and trophic designations used in the IBI analysis are defined in Barbour et al. (1999). Site-specific fish abundance data for the 1997-2004 sampling period were used to determine scoring ranges for the total number of individuals metric. The final IBI scores calculated for each site are the sum of the eleven individual metric scores. Final IBI scores may range from 11 to 55, with higher scores indicating better community condition. Integrity categories and their corresponding numerical ranges were determined by modifying the numerical ranges provided in Karr (1981) and Plafkin et al. (1989). IBI score ranges and corresponding condition categories for the BDC fish data are: *excellent* (53-55), *good* (44-52), *fair* (37-43), *poor* (29-36), and *very poor* (11-28) as calculated per EPA RBP guidance documents (Barbour et al. 1999, Plafkin et al. 1989).

The IBI condition categories defined by the EPA should not be interpreted as comparative of some pristine or reference condition, but rather as general descriptors for the lower to higher scoring sites. It is important to note that the fish IBI as originally developed by Karr (1981) was for assessing degradation in mesic midwestern streams that are relatively rich in fish fauna, and furthermore, recent literature by Bramblett and Fausch (1991) cautions against a strict interpretation of fish IBI scores and respective condition categories when assessing western Great Plains streams which comparatively are depauperate in fish fauna and those species present are largely habitat generalists. Because of these limitations, which represent the most recent research on the applicability of the IBI to western Great Plains streams, the BDC fish IBI scores (rather than the condition categories) will be used as a point of reference for monitoring changes in the fish community at and among the study sites over time.

2.3 MACROINVERTEBRATES

Macroinvertebrate sampling was conducted in the fall. Sampling was performed according to methods outlined by Klemm et al. (1990) and the CWQCC (2010b) and was consistent with previous years. Benthic macroinvertebrates were collected from representative aquatic habitats (riffle, run, pool, and bank) found at each site using a kick net with a mesh size of 425 microns (*um)*. Kick net samples were collected from approximately one-square meter areas from representative habitats and were combined into one composite sample for analysis. The material collected from each sample was carefully placed

into labeled sample containers and preserved with 10% formalin in the field. Samples were transported to the laboratory for analysis.

Identification of macroinvertebrates and laboratory techniques were performed according to the methods outlined in Klemm et al. (1990). In the laboratory, samples were thoroughly rinsed of excess preservative and debris in a 500 *u*m sieve before being placed in a white tray for processing. All macroinvertebrates were removed from the debris with forceps and placed in labeled vials filled with 80% ethanol. Macroinvertebrates were identified to the lowest taxonomic level possible with the aid of both binocular dissecting and compound microscopes using appropriate taxonomic literature (AAI 1999b). Any new taxa encountered in the 2008 collections were added to the project macroinvertebrate reference collection, which contains representative specimens of each taxon in vials of 80% ethanol or on permanent slide mounts with Euparal or PVA (polyvinyl alcohol) when necessary.

Following identification and enumeration, a species list including the number of organisms collected, total density (organisms per square meter), total number of taxa, relative abundance, and diversity were calculated for each sample. Other community parameters were also calculated according to methods outlined for the Rapid Bioassessment Protocol III (RBP) analysis (Barbour et al. 1999, Plafkin et al. 1989). The RBP analysis incorporates several benthic community metrics and provides a standardized method for evaluating spatial, seasonal, and annual differences. The eight metrics calculated and incorporated in the RBP analysis include taxa richness, the modified Hilsenhoff Biotic Index (HBI), percent dominant taxon, the EPT Index (number of Ephemeroptera, Plecoptera, and Trichoptera taxa), ratio of EPT to Chironomidae abundances, ratio of scrapers to filtering collector feeding groups, ratio of the shredder feeding group to the total number of individuals collected, and the Community Loss Index. Tolerance values used in the HBI incorporate values presented by Barbour et al. (1999), with other references occasionally used as needed (MDEQ 1996, Bode 1988, and Winget and Mangum 1979). The HBI measures macroinvertebrate community responses to organic pollution. HBI values may range from 0 to 10, with higher values (generally >6) indicating higher degrees of organic pollution. Final RBP scores were calculated for each site based on the eight individual metrics, with the resulting scores compared to the upstream reference sites and expressed as a percent. RBP score ranges and corresponding condition categories are: *nonimpaired* (>83%), *slightly* impaired (54-79%), *moderately* impaired (21-50%), and *severely* impaired (<17%) (Plafkin et al. 1989).

The RBP analyses was performed with comparisons made using reference site bdc1.5C to assess benthic community condition at sites downstream from WWTPs. Site bdc1.5C was selected as the RBP reference site because habitat conditions at this site are most representative of and similar to the sites downstream from the WWTPs based on the various RBP comparisons made in previous years (AAI 2016).

The Invertebrate Community Index (ICI) was also included in the evaluation of macroinvertebrate data to provide an additional objective measure of biological condition at BDC study sites. The ICI values were calculated according to methods outlined by DeShon (1995), which provide the detailed methodology used by the Ohio EPA for assessing the biological condition of streams in Ohio and the surrounding region. The Ohio EPA approach for calculating ICI community ratings was appropriate for this project since general environmental conditions in Big Dry Creek were sufficiently similar to those of the streams in Ohio and the Midwest (meandering, slow moving, and generally turbid streams with predominantly silty, muddy substrates). The ICI analysis involves scoring ten different metrics with the sum of these metrics providing the final index score. The metrics used include: 1) total number of taxa, 2) number of mayfly taxa, 3) number of caddisfly taxa, 4) number of dipteran taxa, 5) percent mayflies, 6) percent caddisflies, 7) percent of tribe Tanytarsini midges, 8) percent other dipterans and non-insects, 9) percent tolerant organisms, and 10) number of qualitative ET (Ephemeroptera and Trichoptera) taxa. Each of these metrics is given a score of 6, 4, 2, or 0 depending on the value derived from macroinvertebrate data for each station. For tolerant species designations, any species with an HBI rating of 8 or higher was considered tolerant. Individual metric scores were determined by comparing derived values with species area plots for the reference data versus drainage area. A score of 6 for a given metric indicates the metric value is within the range exhibited by very good or exceptional aquatic communities, a score of 4 indicates that the value is characteristic of more typical or good communities, a score of 2 indicates the value is moderately deviating from the expected range of good to exceptional values, and a score of 0 indicates the value is strongly deviating from expected good or exceptional values. Final ICI scores were calculated for each site, and may range from 0 to 60 with higher ICI scores indicating better community condition. Corresponding benthic community condition ratings developed for the ICI are: *exceptional* (46-60), *good* (36-45), *fair* (13-35), and *poor* (0-12) (DeShon 1995). Calculation of the ICI/HBI ratio was added in 2008 to further aid in discerning relative degrees of impairment between the BDC study sites.

The Multi-Metric Index (MMI) analysis was performed for the BDC macroinvertebrate data 4-year data set for 2010, 2012, 2014, and 2016 according to methods outlined in CWQCC's Policy 10-1 (CWQCC 2010b), which provides for the evaluation of the biotic integrity of streams through use of a MMI calibrated for the State of Colorado (Jessup 2010), with the BDC data set (2000-2006) being included in the calibration process. The CWQCD's Ecological Data Application System (EDAS, Version 3.3H.2k CO) data base was used to calculate MMI and other metrics for this analysis. Application of this method requires the collection and analysis of benthic macroinvertebrate samples according to WQCD protocols (CWQCC 2010b). Use attainment thresholds have been established for three separate stream biotypes which include Transition (*biotype 1*), Mountain (*biotype 2*), and Plains & Xeric (*biotype 3*). The Big Dry

Creek study sites are all designated as *biotype 3* per EDAS, and BDC Segment 1 is a Class 2 warm water stream. The thresholds for *biotype 3*, Class 2 streams are: MMI >22 for meeting use attainment (nonimpairment) and MMI scores >44 indicate a high scoring water (HSW). Any drop in HSW scores of 22 points or more for samples collected twelve or more months apart within a 5-year span of time may indicate impairment.

3.0 RESULTS

3.1 PHYSICAL HABITAT

Physical habitat assessment results for Big Dry Creek are summarized in Table 3 for 2016 with total RBP habitat assessment scores for the previous years also presented for comparison. A comparison of RBP habitat assessment scores for 2014 and 2016 vs. the mean score for 2000-2012 is graphically presented in Figure 2. Physical habitat characteristics of the BDC sites have been described in detail in previous reports (AAI 1999a, 1999b, 2002, 2005a, 2005b, 2007, 2010, 2012, 2014, and 2016). Consequently, this report will focus on changes observed at the six sites during the 2016 physical habitat assessment follow-up survey. Photographs of notable habitat conditions observed are presented in Appendix A.

Streamflow data for the last four years (2013-2016) are graphically presented in Appendix A (USGS 2017). The record flood event that occurred in September 2013 on Big Dry Creek resulted in some notable habitat changes such as substrate scouring, washout of snags, bank erosion and other impacts which were previously discussed in the 2014 report (AAI 2016). Average streamflows during 2016 were close to normal as they were in 2014. In 2015 however, the summer flows were somewhat higher with three or more storm events. Post-flood habitat conditions at the BDC sites reflect the more normalized stream conditions during the last three years which are described for each site below.

Gravel and cobble substrates continued to be clean and scoured in 2016 like in 2014, when effects of the 2013 flood were observed, with mud and soft sediments scoured and washed away leaving a more uniform bottom at all sites. More exposed gravel and cobble has also been observed since the flood. Overall habitat conditions were similar to 2014 (residual effects of 2013 flood) except for the lower flows during the 2016 event. Compared to 2014, there was more algae and aquatic weed growth at site bdc0.5 because of the lower flows. At site bdc1.0, the gravel and cobble substrates continued to be clean with minimal algae growth and no aquatic weeds. At site bdc1.5C, the bottom remained scoured with some exposed areas of gravel and small cobble, periphytic algae was present on the cobble in shallows riffles, and the channel was clear of fallen trees. At site bdc2.0, the stream bottom in 2016 was also clean and uniform with no anoxic mud deposits in backwaters. Areas of exposed gravel with slight amounts of stringy algae were still present providing good habitat for macroinvertebrate colonization. Algae growth in 2016 however was less than observed in 2014, whereas little or no algae was noted at bdc2.0 (or bdc1.5C) in past years due to the scarcity of suitable substrates (i.e., exposed gravel and cobble). In the channelized reach of site bdc3.0, the hard clay stream bottom continued to be clean of anoxic mud deposits in backwater areas in 2016. As usual, stringy green algae was abundant on the cobble and

concrete surfaces near the I-25 bridge. The 2016 habitat conditions at site bdc5.0 also remained similar to 2014 since the 2013 flood exposed new cobble bars and washed out and deepened the upper pool. Dense growth of stringy green algae on the cobble in riffle areas were again observed although algal growth was not as prolific as in 2014. The pool at top of reach that was deepened by floodwaters and the concrete structure (old weir) that sits adjacent to the pool provide cover for fish. At the time of sampling in 2016, flows were about normal since the diversions to the Yoxall Ditch were minimal with slightly less flow than in 2014. In some years when most of the creek's flow is diverted for irrigation, flows become reduced to a trickle with only isolated pools remaining in study reach which was the case in 2012 and 2006.

The Rapid Bioassessment Protocol (RBP) habitat analysis scores for 2016 were relatively similar to 2014 with scores overall higher compared to previous years because of the improved habitat conditions noted since the 2013 flood (Table 3, Figure 2). Only slight changes in habitat scores were recorded in 2016 vs. 2014, at sites bdc0.5, bdc1.5C, bdc2.0, and bdc5.0 while scores remained the same at sites bdc1.0 and bdc3.0. The total score increased by one point at site bdc0.5 due to the slight increase in the bottom substrate/available cover parameter (more algae and aquatic weeds), while scores decreased by one point at sites bdc1.5C, bdc2.0, and bdc5.0 since there was less bottom cover (algae) at these sites in 2016 vs. 2014. For the ten individual habitat parameters assessed, the condition category changed for the bottom substrate parameter at sites bdc2.0 and bdc5.0 as a result of the scores decreases in 2016; otherwise there were no other changes in condition categories. The 2016 RBP habitat assessment scores were highest for the three upstream sites ranging from 130 to 135, whereas scores ranged from 81 to 122 for the downstream sites (of a possible maximum score 200) (Table 3). As in previous years, scores were lower at downstream sites bdc3.0 and bdc5.0 in the channelized section of Big Dry Creek (97 and 81) and at site bdc2.0 but to a lesser extent indicating a gradual downstream decrease in habitat quality as reported in previous years (Figure 2). Habitat scores have consistently been the lowest (poorest) at site bdc5.0 due to the extreme flow fluctuations and resulting disturbances that are ongoing within the narrow incised channel. Overall, the RBP results indicate habitat changes were relatively minimal in 2016 compared to 2014.

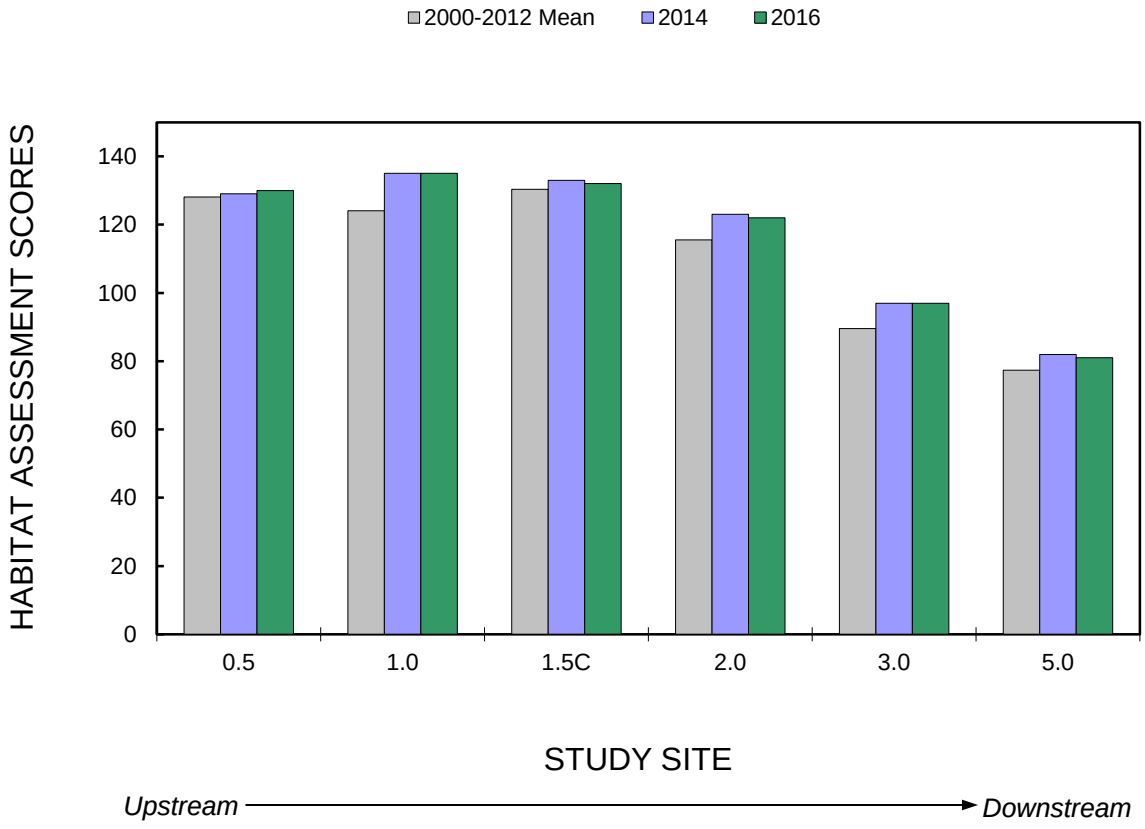
TABLE 3

SUMMARY OF RAPID BIOASSESSMENT PROTOCOL (RBP) HABITAT ASSESSMENT SCORES
FOR BIG DRY CREEK SITES UPSTREAM AND DOWNSTREAM FROM WWTPs, FALL 2016 VS. 2000-2014

		UPSTREAM FROM TREATMENT PLANTS						DOWNSTREAM FROM TREATMENT PLANTS					
		BDC-0.5		**BDC-1.0**		**BDC-1.5C**		**BDC-2.0**		**BDC-3.0**		**BDC-5.0**	
Habitat Parameter		Score	Condition Category	Score	Condition Category	Score	Condition Category	Score	Condition Category	Score	Condition Category	Score	Condition Category
Bottom Substrate/ Available Cover		14	Suboptimal	10	Marginal	11	Suboptimal	10	Marginal	11	Suboptimal	10	Marginal
Pool Substrate Characterization		16	Optimal	14	Suboptimal	13	Suboptimal	13	Suboptimal	12	Suboptimal	10	Marginal
Pool Variability		8	Marginal	10	Marginal	7	Marginal	8	Marginal	8	Marginal	6	Marginal
Sediment Deposition		9	Marginal	10	Marginal	10	Marginal	8	Marginal	7	Marginal	8	Marginal
Channel Flow Status		10	Marginal	13	Suboptimal	14	Suboptimal	12	Suboptimal	16	Optimal	10	Marginal
Channel Alteration		19	Optimal	19	Optimal	18	Optimal	18	Optimal	2	Poor	2	Poor
Channel Sinuosity		9	Marginal	14	Suboptimal	14	Suboptimal	8	Marginal	7	Marginal	7	Marginal
Bank Stability		7	L-Suboptimal	7	L-Suboptimal	5	L-Marginal	6	L-Suboptimal	5	L-Marginal	1	L-Poor
		7	R-Suboptimal	6	R-Suboptimal	7	R-Suboptimal	5	R-Marginal	5	R-Marginal	1	R-Poor
Bank Vegetative Protection		7	L-Suboptimal	9	L-Optimal	7	L-Suboptimal	9	L-Optimal	8	L-Suboptimal	9	L-Optimal
		8	R-Suboptimal	9	R-Optimal	8	R-Optimal	9	R-Optimal	8	R-Suboptimal	9	R-Optimal
Riparian Vegetation Zone Width		8	L-Suboptimal	6	L-Suboptimal	9	L-Optimal	8	L-Suboptimal	4	L-Marginal	4	L-Marginal
		8	R-Suboptimal	8	R-Suboptimal	9	R-Optimal	8	R-Suboptimal	4	R-Marginal	4	R-Marginal
Total Score	2016	130		135		132		122		97		81	
	2014	129		135		133		123		97		82	
	2012	127		128		125		117		92		72	
	2010	129		130		128		118		92		74	
	2008	129		130		131		118		92		73	
	2006	127		113		129		108		88		74	
	2004	127		122		128		110		86		78	
	2003	127		121		131		113		86		79	
	2002	128		121		131		118		87		78	
	2001	128		125		135		115		87		82	
	2000	131		127		135		123		96		86	

FIGURE 2

COMPARISON OF RAPID BIOASSESSMENT PROTOCOL (RBP) HABITAT ASSESSMENT SCORES FOR BIG DRY CREEK SITES, 2000-2012 MEAN VS. 2014 AND 2016



3.2 FISH

Fish monitoring in Big Dry Creek in 2016 included the fall population survey at the six sites on September 28, 29, and 30. Survey results for 2016 including percent abundance, the total number and species of fish collected, number of native species, and the Index of Biotic Integrity (IBI) scores for the BDC sites are presented in Table 4. Percent relative abundance of numerically dominant and important native fish species collected in the six years sampled from 2006 through 2016 is presented in Figure 3. Comparisons of the total number and species of fish collected in 2016 vs. previous years (2006-2014) are depicted in Figure 4. Fish IBI scores for 2016 with comparisons to previous years are presented in Figure 5. Fish population data including numbers and percent composition for the species collected in 2016 are summarized in Appendix B. Summaries of total fish numbers collected, johnny darter collections, and fish IBI scores for the 12 years sampled during the 1999-2016 study period are also provided in Appendix B. The fish population results are discussed in Section 3.2.1 with tables and figures provided at the end of this section. The fish disease results and supporting tables and figures are discussed separately in Section 3.2.2.

3.2.1 Populations

The 2016 fish populations in Big Dry Creek continued to be healthy and abundant with typical year-to-year and site-to-site variability. The highest number of fish, 1,772 individuals, was collected at site bdc5.0 where the highest numbers of fish have been historically collected, rather than site bdc0.5 in 2014 (N=1,474). Results for site bdc5.0 show the high variability in fish abundance in 2012 and 2010 when the highest number of fish were collected (2,849 and 3,833) while in 2014 this site had its lowest number of fish (419) over the study period (12 sampling events). The lower numbers in 2014 were likely due to washout from the upper pool during the September 2013 flood. Furthermore, the flow diversions from the Yoxall Ditch result in reduced flows leaving isolated pools (fish trapped and easy to collect) in some sampling years which can also influence fish numbers at bdc5.0. The fewest fish collected in 2016 was at site bdc3.0 (N=225) which was notably lower than the previous three sampling events when 691, 1,118, and 416 individuals were collected in 2014, 2012, and 2010, respectively (Appendix B).

The distribution and abundance of the fish in 2016 was similar to 2012 and 2008 in that fathead minnows, white suckers, creek chubs, and longnose dace were common and relatively abundant at most sites. Creek chubs were again collected at the three downstream sites having been absent prior to 2010, and for the fourth consecutive year (2010, 2012, 2014, and 2016) were collected at all six sites. In fact, they were numerically more abundant at downstream sites bdc2.0 (203) and bdc5.0 (340) than at upstream sites

bdc0.5 (176) and bdc1.0 (113). In 2016, longnose dace were the most abundant species at sites bdc1.0 (48.4%) and bdc3.0 (29.3%) where they have been dominant in the past with good numbers also at site bdc0.5.

As usual, in the study area fathead minnows and white suckers were the most abundant species system-wide at 24.7 and 25.6%, respectively. Creek chubs were third in abundance at 19.5%. Longnose dace comprised 17.0% of the overall population, while sand shiners were at 8.6%.

At site bdc5.0, creek chubs, fathead minnows, and white suckers were mainly responsible for the high numbers. Sand shiners, which have often been the most abundant fish at site bdc5.0, were also relatively numerous with considerably fewer in 2010 and 2012 (264 vs. 1,632 and 1,550, respectively). Wash out during the 2013 flood was probably the main cause. In comparison, in 2016 at bdc0.5 (which had the highest number of fish in 2014) only 648 total fish were caught with the predominant species being creek chubs, fathead minnows, and longnose dace. At site bdc3.0 where the fewest fish were caught in 2016, the predominant fish collected were longnose dace, fathead minnows, and white suckers.

Notably, for the third consecutive sampling event fish numbers at site bdc2.0, which prior to 2012 typically had the fewest fish collected for all sites, were relatively high with 716 individuals in 2016 compared to 629 and 1,394 fish in 2014 and 2012, respectively. In 2016 as in 2014, relatively large numbers of creek chubs, fathead minnows, and white suckers (203, 220, and 281, respectively) contributed to the higher numbers at site bdc2.0 indicating continued recovery in recent years.

A total of 14 fish species were collected in 2016. As in 2014, the highest number of species in 2016 was at site bdc5.0 (13 total species, eight natives) and the lowest was at site bdc0.5 with only five species collected (all natives). For the study to date, 10 of the 20 total fish species collected in Big Dry Creek are native to the South Platte River Basin in Colorado (1997-2016). The number of native species collected has varied between seven and ten since 1997, with total of nine native species collected in 2016 (5-8 natives at individual sites). Several non-native fishes were also found but were always represented by fewer species and included largemouth bass, common carp, mosquitofish, black crappie, and bluegill in 2016. Of the native species, the longnose dace was the only intolerant species collected.

A summary of johnny darter collections for the entire 1997-2016 study period is provided in Appendix B. In 2016, johnny darters were not collected at site bdc0.5 where historically they have been most abundant. Instead nine darters were collected at site bdc1.0 where since 2002 they have been either absent or only one or two had been collected. Most interesting was the collection of 11 individuals at site bdc5.0 where

none have been collected before, which is a good distance downstream of sites bdc0.5 and bdc1.0 (where most usually collected). Likewise, at site bdc2.0 one individual was collected where none have been collected since 2001 (one specimen). At site bdc1.5C, four individuals were collected in 2016, with the first specimen collected at this site in 2014. This species appears to be especially sensitive to stream conditions brought on by droughts (2002 and 2012). In the earlier study years, johnny darters were confined to upper reaches of Big Dry Creek downstream from Standley Lake with a few also at site bdc2.0 in 1997-2001. After essentially being absent from 2002 to 2006, they have returned in good numbers at the upper two sites and their range has expanded into downstream areas in 2014 and 2016 (since the 2013 flood). The status of the johnny darter population in Big Dry Creek is an important issue for the Cities because of the CWQCC's designation for Segment 1 as *Aquatic Life Warm 2* with a temperature standard of *Warm Stream Tier I* (WS-I) due to the presence of johnny darters, which have now been collected at all sites except site bdc3.0.

For fish IBIs, the overall trend in 2016 remains consistent with previous years with highest IBIs at sites bdc1.0 and bdc5.0 (39 and 35) (vs. 31 and 37 in 2014). The lowest IBI of 29 was calculated at three of the sites: bdc0.5, 1.5C and 3.0, all of which were lower than in 2014 when IBIs were 33, 31 and 37, respectively (Figure 5, Appendix B). The 6-year mean data show that site bdc5.0 had the highest mean IBI score of 36.0, while the lowest mean score was 26.3 at site bdc2.0. The 6-year means also show IBIs highest and similar at bdc1.0 and bdc5.0 (IBI 35.7 and 36.0), while bdc0.5 and 3.0 are similar (IBI 32.3 and 32.7).

Factors contributing to the highest IBIs at site bdc1.0 in 2016 were: 1) lower % omnivores [fathead minnows, white suckers, and common carp]; 2) high % insectivores [johnny darter, longnose dace, sand shiners, and bluegills]; and 3) high total numbers of fish [N=754]; 4) fewer % suckers; and 5) johnny darter presence. Factors contributing to the higher IBIs at site bdc5.0 in 2016 were: 1) high total numbers of fish [N=1,772]; 2) more sunfish species; 3) fewer % suckers; and 4) johnny darter presence. Conversely, the lowest IBI score of 29 at sites bdc0.5, bdc1.5C and bdc3.0 and reasons varied from site to site but generally were due to: 1) low % insectivores at bdc0.5 and bdc1.5C; 2) high % omnivores at all three sites; 3) number of darter or sunfish species at bdc0.5; 4) no darters at sites bdc0.5 and bdc3.0; and 5) low total fish numbers at bdc1.5C and bdc3.0 [N=319 and 225].

Despite site differences, the overall mean IBIs for the upstream vs. downstream sites were similar at 32.2 and 31.7, respectively, which suggests that the biotic integrity of fish populations in Big Dry Creek is essentially the same in the upstream and downstream reaches.

TABLE 4

PERCENT ABUNDANCE OF FISH SPECIES, TOTAL NUMBER COLLECTED, NUMBER OF NATIVE SPECIES, AND INDEX OF BIOTIC INTEGRITY (IBI) SCORES AT BIG DRY CREEK SITES, FALL 2016

	STUDY SITES					
SPECIES	bdc0.5	bdc1.0	bdc1.5C	bdc2.0	bdc3.0	bdc5.0
Longnose dace *Rhinichthys cataractae*	16.7	48.4	6.3	0.3	29.3	0.9
Creek chub *Semotilus atromaculatus*	27.2	15.0	26.7	28.4	0.9	19.2
Fathead minnow *Pimephales promelas*	41.5	9.2	25.7	30.7	20.0	20.9
Sand shiner *Notropis stramineus*	--	11.5	0.3	--	7.6	14.9
White sucker *Catostomus commersoni*	11.6	14.5	37.6	39.3	28.0	22.8
Longnose sucker *Catostomus catostomus*	3.1	--	--	--	--	--
Johnny darter *Etheostoma nigrum*	--	1.2	1.3	0.1	--	0.6
Green sunfish *Lepomis cyanellus*	--	--	2.2	1.1	5.3	0.5
Mosquitofish *Gambusia affinis*	--	--	--	--	--	8.2
Largemouth bass *Micropterus salmoides*	--	--	--	--	--	1.3
Common carp *Cyprinus carpio*	--	0.1	--	0.1	7.6	10.3
Black Crappie *Ameiurus melas*	--	--	--	--	0.4	0.1
Bluegill *Pomoxis nigromaculatus*	--	0.1	--	--	--	0.1
Black bullhead *Ameiurus melas*	--	--	--	--	0.9	0.3
TOTAL COLLECTED	648	754	319	716	225	1,772
TOTAL SPECIES	5	8	7	7	9	13
NATIVE SPECIES	5	6	7	6	7	8
IBI SCORE	29	39	29	31	29	35

* Bold indicates native to South Platte River.

FIGURE 3

PERCENT RELATIVE ABUNDANCE OF NUMERICALLY DOMINANT AND IMPORTANT NATIVE FISH SPECIES COLLECTED AT BIG DRY CREEK SITES, FALL 2006-2016

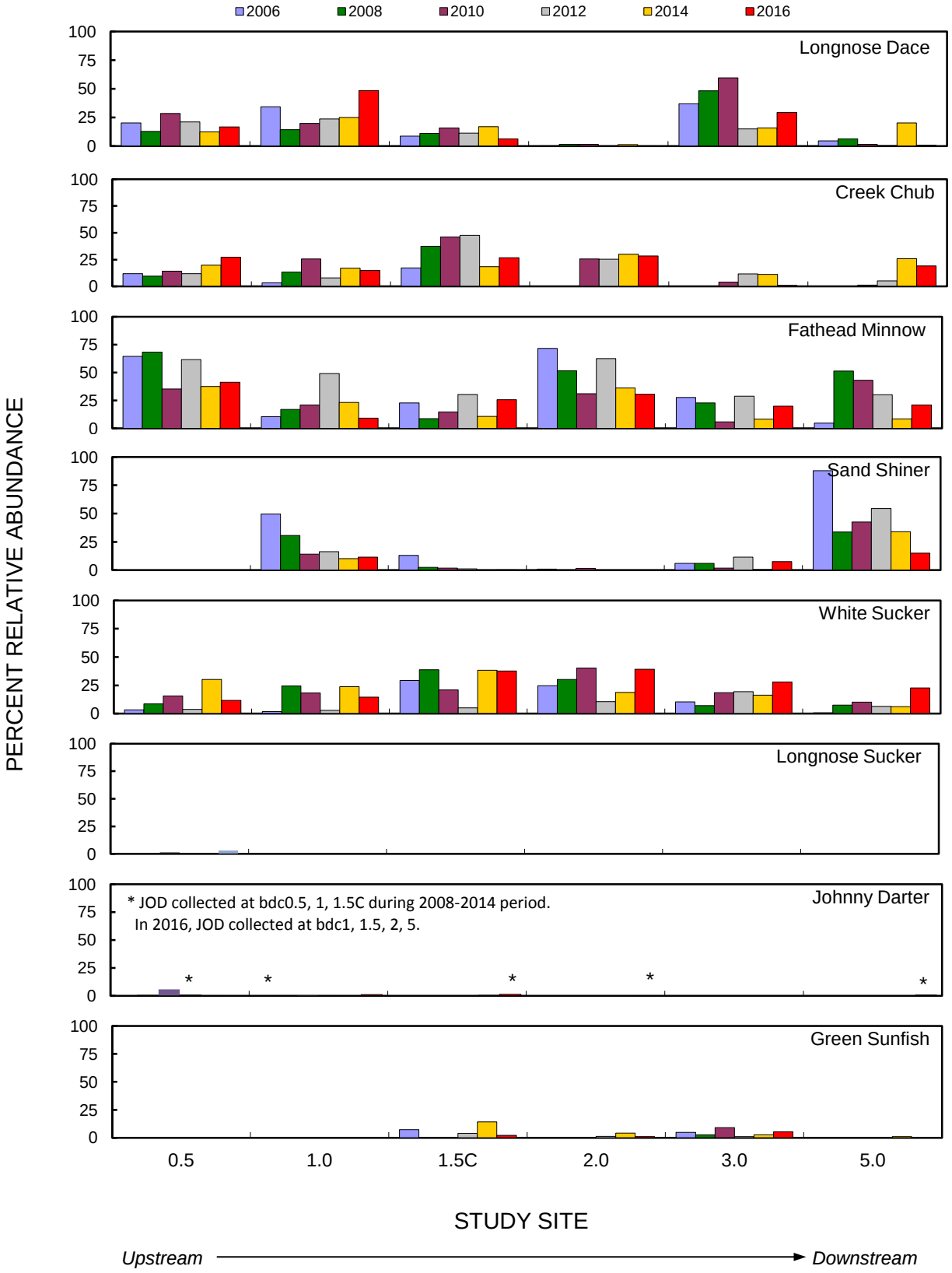


FIGURE 4
COMPARISONS OF NUMBERS OF FISH AND SPECIES COLLECTED AT
BIG DRY CREEK SITES, 2006-2016

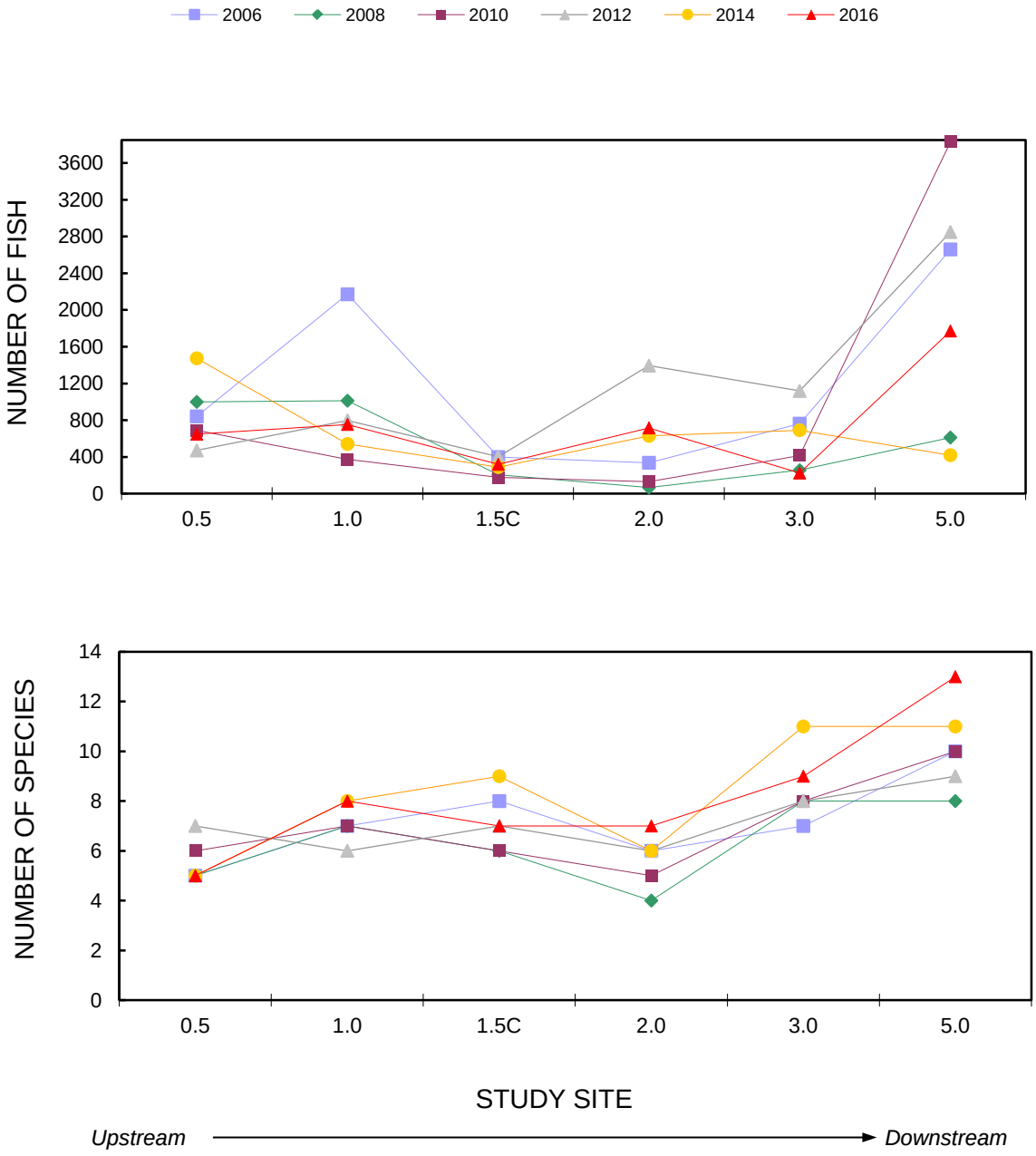
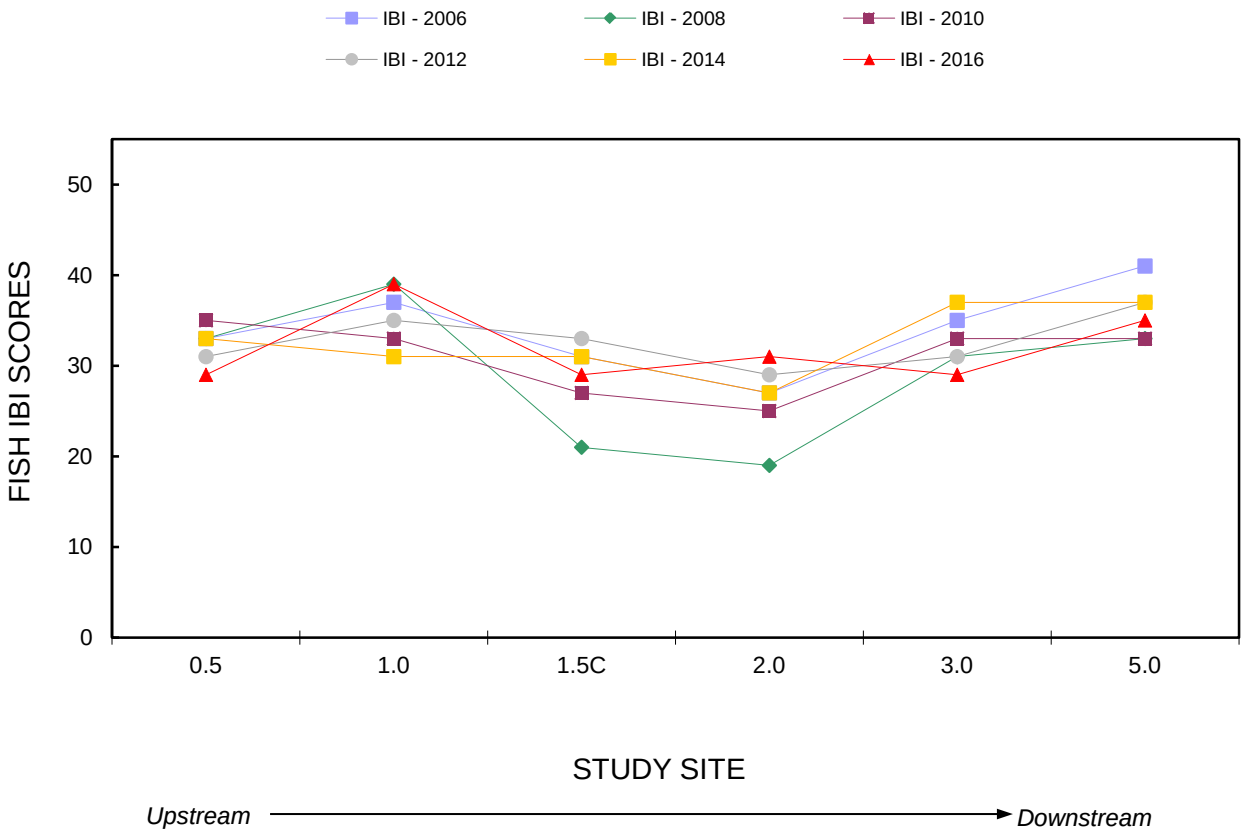


FIGURE 5

COMPARISONS OF FISH INDEX OF BIOTIC INTEGRITY (IBI) SCORES
FOR BIG DRY CREEK, 2006-2016



3.2.2 Fish Disease

Comparisons of percent disease by site and at upstream vs. downstream sites in BDC are provided in Table 5 for 2016 vs. years sampled since 2000. Mean disease ratings and percent abundance of *heavily* infected fish for the last six sampling years (2006-2016) are summarized in Table 6. Fish disease occurrence is also graphically depicted in Figure 6 including the number of diseased fish compared to the total fish collected by site and year for the 11 years studied (2000-2016). Fish disease Tables 5 and 6 and Figure 6 are provided at the end of this section.

Figure 6 shows the incidence and distribution of "black spot disease" in fish, which increased dramatically between 2000 and 2001 and remained high through 2006, and has remained more prevalent at the upstream sites than at the downstream sites. Compared to the 2001 to 2006 period, disease rates have been generally lower the last five sampling years (2008-2016) especially at the upstream sites. In 2016, disease incidence decreased at sites bdc0.5 and bdc5.0 compared to 2014, while increasing at all of the other sites.

At upstream site bdc0.5, disease gradually decreased from 2006 to 2012, but increased notably in 2014 and 2016 (up 80.9% then down 66.4%) (Table 5). At site bdc1.0, however the disease rate remained relatively high (>65%) except in 2010 (48.6%), then increased from 76.0% in 2014 to 89.0% in 2016. At site bdc1.5C, disease gradually decreased from 2006 to 2010 but since then has fluctuated being up and down each sampling year at 44.7, 71.9, 32.9, and 74.2% from 2012 through 2016, respectively.

At the downstream sites, disease incidence at sites bdc2.0 and bdc3.0 increased substantially in 2016 vs. 2014 as disease incidence went from 49.0 to 67.6% and 29.2 to 57.1%, respectively. At site bdc5.0 disease spiked to 29.9% in 2014 but decreased to 6.0% in 2016 which was similar to the overall low incidence levels of past years. The notable increase at site bdc2.0 is likely due to the abundance of disease-susceptible fathead minnows and white suckers which comprised 70.0% of the fish population. The 2016 increase at site bdc3.0 was due to the predominance longnose dace as well as fathead minnows and white suckers which together comprised 77.3% of population. The lower disease incidence at bdc5.0 in 2016 can most likely be attributed to higher numbers of disease-resistant creek chub and sand shiners even though relatively high numbers of fathead minnows and white suckers were present. The unexpected high incidence at bdc5.0 in 2014 may have been due to an unusually high relative abundance (20.3%) of highly susceptible longnose dace.

The overall mean disease incidence (2001-2016, 10-year mean) for the downstream sites in 2016 was higher than in 2014 (43.6% vs. 36.0%). For the 10-year period, the average incidence of disease is currently 71.8% for the upstream sites compared to 42.2% for the downstream sites, and when only sites bdc2.0 and bdc3.0 are compared (bdc5.0 excluded), the mean incidence is higher at 54.7%.

In 2016, the average severity of disease (% *heavy*) remained considerably lower (0.8% and 0% *heavy* infected at the upstream and downstream sites, respectively). The highest degree of severity was in 2006 when the *heavy* infection rate was at its highest (average 19.2% *heavy* for the upstream sites), especially at sites bdc0.5 and bdc1.0 (34.3 and 23.8%) (Table 6). In 2016, the highest level of *heavily* infected fish was again at site bdc1.0 at 1.8%, which is slightly less than in 2014 (2.1%) but notably less than in 2012 and 2006 (9.3% and 23.8%). Except for site bdc0.5 (0.5%), none of the other sites had any *heavy* disease ratings in either 2016 or 2014.

As noted above, numbers of infected fish and disease severity have historically been higher at the upstream sites than at the downstream sites due both to the predominance of susceptible fish species and the comparatively higher density of snails, the intermediate host for the disease. In 2016, snails were only collected at sites bdc0.5 and bdc1.5C (331 and 1,323, respectively), with only 55 collected downstream at site bdc2.0. The disease incidence at bdc1.5C may be correlated to the high number of snails in 2016 (vs. none the in 2014 and 2012). The high number of snails may also be linked to the large 41.3% increase in disease at bdc1.5C in 2016 (32.9 to 74.2% in 2014 vs. 2016). In contrast, at site bdc2.0 snails numbers decreased from 110 to 55 but disease incidence increased from 49.0% to 67.6%. In 2016, there was no correlation between snail numbers vs. disease incidence at sites bdc2.0, bdc1.0, and bdc3.0.

The comparison of snail numbers to disease incidence and severity does not correlate consistently which indicates the complexity of the black spot disease cycle (bird to snail to fish) that is undoubtedly further exacerbated by environmental conditions such as low flows, warm water temperatures, and crowding. Nevertheless, the disease analyses continue to indicate that the WWTP discharges do not appear to worsen the fish disease rate and may in fact help decrease the infection rate due to increased dilution flows as concluded in previous reports (AAI 2005b, 2007, 2010, 2012, 2014, and 2016).

TABLE 5

COMPARISONS OF PERCENT DISEASE BY SITE AND UPSTREAM VS. DOWNSTREAM AT SITES IN BIG DRY CREEK, 2000-2016

	Big Dry Creek							
	upstream sites				downstream sites			
	bdc0.5	bdc1.0	bdc1.5	bdc1.5C	bdc2.0	bdc3.0	bdc5.0	bdc6.0
Percent Disease by site								
2000	7.8	6.4	1.8	6.2	19.6	5.3	2.1	6.4
2001	69.4	90.3	79.0	26.8	46.4	70.4	6.8	28.2
2002	95.2	85.6	57.6	68.0	71.2	56.8	3.8	13.1
2003	66.6	75.6	76.5	94.4	66.7	50.0	5.2	37.2
2004	85.8	91.0	84.3	91.7	92.1	38.8	31.5	20.3
2006	99.8	65.4	80.6	81.5	92.9	57.4	7.5	21.1
2008	59.2	75.7	ns	70.9	39.4	63.0	8.0	ns
2010	50.0	48.6	ns	44.7	48.8	83.0	14.8	ns
2012	45.5	80.3	ns	71.9	41.0	28.1	3.6	ns
2014	80.9	76.0	ns	32.9	49.0	29.2	29.9	ns
2016	66.4	89.0	ns	74.2	67.6	57.1	6.0	ns
10-yr Mean 2001-2016	71.9	77.8		65.7	61.5	53.4	11.7	

Annual Mean Percent Disease

	all sites	upstream sites	downstream sites	
2000	7.0	5.6	8.4	
2001	52.2	66.4	38.0	
2002	56.4	76.6	36.2	
2003	59.0	78.3	39.8	
2004	66.9	88.2	45.7	
2006	63.3	81.8	44.7	
2008	52.7	68.6	36.8	
2010	48.3	47.8	48.9	
2012	45.1	65.9	24.2	
2014	49.7	63.3	36.0	
2016	60.1	76.5	43.6	
10-yr Mean 2001-2016	57.0	71.8	42.2	
			57.4	for d/s sites when bdc2.0 & bdc3.0 only

* ns indicates not sampled.

TABLE 6

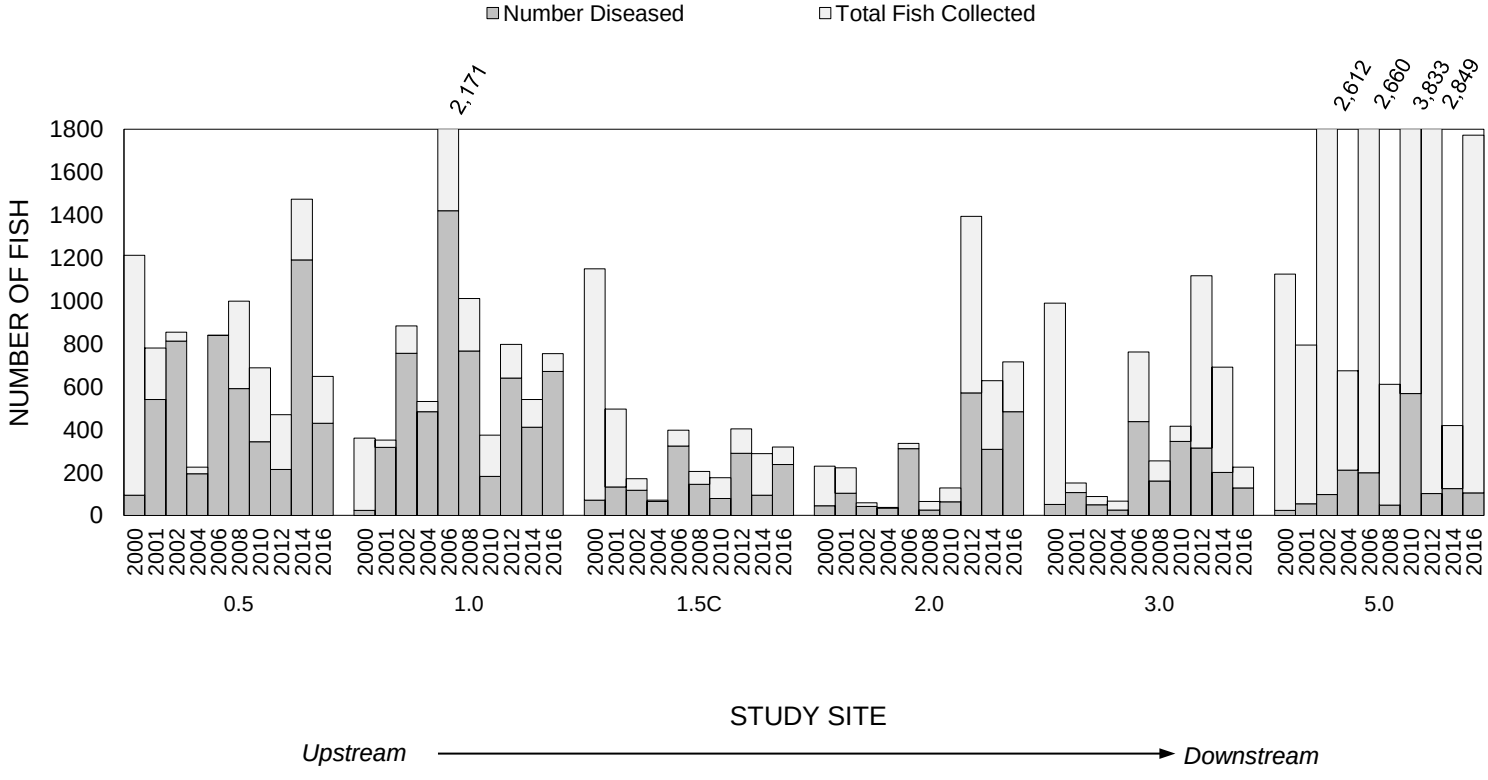
MEAN DISEASE RATINGS AND PERCENT OF HEAVY INFECTED FISH COLLECTED AT BIG DRY CREEK SITES, FALL 2006-2016

	Big Dry Creek							
	upstream sites				downstream sites			
Year Sampled	bdc0.5	bdc1.0	bdc1.5	bdc1.5C	bdc2.0	bdc3.0	bdc5.0	bdc6.0
Fall 2006								
Mean Disease Rating	2.1	1.5	1.4	0.9	1.1	0.6	0.4	0.2
upstream sites	1.5							
downstream sites	0.6							
Percent Heavy	34.3	23.8	14.8	4.0	2.9	0.0	0.0	0.0
upstream sites	19.2							
downstream sites	0.7							
Fall 2008								
Mean Disease Rating	0.8	1.1	ns	0.8	0.4	0.6	0.1	ns
upstream sites	0.9							
downstream sites	0.4							
Percent Heavy	1.2	2.8	ns	2.4	0.0	0.0	0.0	ns
upstream sites	2.1							
downstream sites	0.0							
Fall 2010								
Mean Disease Rating	0.5	0.5	ns	0.5	0.5	0.6	0.1	ns
upstream sites	0.5							
downstream sites	0.4							
Percent Heavy	0.0	0.0	ns	0.6	0.0	0.0	0.0	ns
upstream sites	0.2							
downstream sites	0.0							
Fall 2012								
Mean Disease Rating	0.5	1.1	ns	0.7	0.6	0.3	0.05	ns
upstream sites	0.8							
downstream sites	0.3							
Percent Heavy	0.4	9.3	ns	0.7	0.4	0.0	0.0	ns
upstream sites	3.5							
downstream sites	0.1							
Fall 2014								
Mean Disease Rating	0.8	0.8	ns	0.3	0.4	0.4	0.3	ns
upstream sites	0.6							
downstream sites	0.4							
Percent Heavy	1.2	2.1	ns	0.0	0.0	0.0	0.0	ns
upstream sites	1.1							
downstream sites	0.0							
Fall 2016								
Mean Disease Rating	0.7	1.0	ns	0.7	0.6	0.6	0.04	ns
upstream sites	0.8							
downstream sites	0.4							
Percent Heavy	0.5	1.8	ns	0.0	0.0	0.0	0.0	ns
upstream sites	0.8							
downstream sites	0.0							

1/ Mean disease rating is the level of disease for the entire population sampled at each site on scale of 0-3, with ratings of 0, 1, 2, or 3 denoting either no, slight, moderate, or heavy level of disease for individuals collected.

2/ Percent of diseased fish that were rated as heavily infected.

FIGURE 6
FISH DISEASE OCCURRENCE AT
BIG DRY CREEK SITES, 2000-2016



3.3 MACROINVERTEBRATES

The fall macroinvertebrate sampling was conducted at the six sites on Big Dry Creek on October 26, 2016 (Table 2). Sampling results are summarized in Appendices C and D for the 2016 sampling period. Summaries of community metrics as well as the Rapid Bioassessment Protocol III (RBP) and Invertebrate Community Index (ICI) results are provided in Appendix C. Detailed data for individual sites are provided in Appendix D including a list of species collected, relative abundance, total density, number of taxa, and other community parameters. A summary of mean percent abundance for predominant and other important macroinvertebrate species for sites upstream and downstream from WWTPs are presented in Table 7 for the fall of 2016 vs. 2010, 2012, and 2014. A summary of key community metrics for sites upstream and downstream from the WWTPs is presented in Table 8 for sampling years 2010, 2012, 2014, and 2016. The percent abundance of the major taxonomic groups collected in kick samples is presented graphically in Figure 7, while a comparison of total taxa and density data is provided in Figure 8 for the last four sampling years (2010, 2012, 2014, and 2016). Comparisons of the annual ICI scores for 2012, 2014, and 2016 vs. the mean ICI score for the 1997-2010 period are graphically presented in Figure 9. The RBP and ICI scores for the 2016 sampling event are summarized and compared in Figure 10. Multi-Metric Index (MMI) results for the 4-year data set including 2010, 2012, 2014, and 2016 are summarized in Table 9.

The results include discussions of mean percent abundance for predominant and other important macroinvertebrate species, total taxa and densities, key community metrics including species diversity, HBI, ICI, and RBP for sites upstream and downstream from WWTPs, as well as the MMI results. The macroinvertebrate population results are discussed in Section 3.3.1 and the community metrics are discussed in Section 3.3.2 with all tables and figures provided at the end of the Macroinvertebrate section.

3.3.1 Populations

In 2016 as in past years, the BDC study area was dominated by dipterans (true flies, mostly midges) followed by (in order of abundance): aquatic worms (Oligochaeta), mayflies (Ephemeroptera), scuds (Amphipoda), and caddisflies (Trichoptera). Dipterans were dominant at sites bdc0.5, 1.0, 1.5C and 2.0, whereas oligochaetes dominated sites bdc3.0 and bdc5.0. In 2014, mayflies were dominant at sites bdc0.5 and bdc1.0, which represents a slight shift the predominant groups in 2016. “Other groups” collected in 2016 included flatworms (Turbellaria), round worms (Nematoda), leaches (Hirudinea), damselflies and dragonflies (Odonata), true bugs (Hemiptera), beetles (Coleoptera), snails (Gastropoda), and clams (Bivalvia) with the most abundant of these being flatworms and snails. Groups not collected in

2016 were water mites (Acari), isopods (Isopoda), and springtails (Collembola). In 2016 organisms from 14 orders were collected comprising a total of 71 unique taxa.

While dipterans have consistently dominated the BDC macroinvertebrate fauna, the order of abundance of the other major groups has varied year to year. For example, oligochaetes were second in abundance in 2010, 2012, 2016, with mayflies second in 2014. Then either scuds or caddisflies comprised the next most abundant groups. In 2010, the high abundance of aquatic worms was due to the unusually high numbers of the species group, *Nais* spp. (~45K organisms per square meter [N/m^2], 58.3%) at site bdc5.0; mayflies were third followed by caddisflies and amphipods. In 2012, worms were also second largely because of their high abundance at site bdc3.0 (~9K/m^2, 54.6%) with mayflies again third in abundance, followed by scuds and caddisflies. In 2014, mayflies were the second most abundant group and worms were third. In 2016, worms were again the second most abundant group and mayflies were third as in 2010 and 2012 (Figure 7). These differences continue to indicate the variable nature of macroinvertebrate populations with year-to-year shifts in the predominant groups which are rarely the same.

Dipteran abundance in 2016 was again highest at bdc1.5C (53.8 vs. 66.5% in 2014) with percent relative abundance (%RA) of 41.4%, 45.6% and 45.0% at sites bdc0.5, bdc1.0 and bdc2.0, respectively, although actual numbers were somewhat lower at bdc2.0. Since 2010 the macroinvertebrate populations at sites bdc1.5C and bdc2.0 have been dominated by dipterans (53.8% to 91.5%). Dipterans have generally dominated these two sites since project inception in 1997.

As in past years, dipterans, mainly midges (Chironomidae), were largely comprised of the moderately tolerant, *Stictochironomus* sp. (6.0% overall; tolerance value 6 [t=6]) and *Cricotopus* sp. (12.0% overall; t=7) (Table7). These two species are ubiquitous and found at every site. In 2016 as in 2014, *Stictochironomus* sp. was most abundant at the upstream sites with 10.0% vs. 2.0% downstream, while *Cricotopus* sp. showed no preference for either upstream or downstream sites (12.2% vs. 11.9%) except in 2014 and 2012 when more were collected at the downstream sites. Interestingly, the midge *Rheotanytarsus* sp. (t=6; predator) which has been sparsely collected in the past was, by far the most abundant midge at bdc0.5 where it comprised 22.4% of the population (20,617/m^2). It was however, only collected at bdc3.0 (110/m^2) and not found at any of the other sites. The black fly, *Simulium vittatum* (t=6), was more numerous at the downstream sites (3.4 vs. 1.1%) in 2016, as they were in 2012 and 2014, with notably fewer collected in 2012. In 2016, the most black flies were collected at sites bdc2.0 and bdc3.0 (1,378 and 1,764/m^2) (Appendix D).

Mayflies were collected at all sites in 2016, and as usual their abundance (as in 2010, 2012 and 2014) was highest upstream at sites bdc0.5 and 1.0 (vs. other sites) with mayflies comprising 32.9% and 34.2% of the populations, respectively. Sites bdc3.0 and bdc5.0 had the fewest (11.2 and 3.6%, respectively). Increases in mayfly abundance were evident in both 2014 and 2016. Interestingly, mayfly abundance (numbers and %RA) at bdc5.0 decreased dramatically from 38.1% (2014) to only 3.6% (2016). Of the six sites, mayfly populations have been most erratic at site bdc5.0. The decrease in 2016 is possibly related to changes in habitat conditions (less periphytic algae and flow fluctuations from Yoxall Ditch diversions). Notably, good numbers were also collected at site bdc2.0 in 2016 and 2014 (22.9 and 17.3%). Mayfly populations appear to be the most stable at bdc1.5C (12.0 to 15.0%).

Mayflies were again comprised of three slightly sensitive species that have predominated over the sampling years. *Baetis tricaudatus* (t=5) has tended to prefer the upstream sites, especially site bdc1.0 where it comprised about 14.3% of the population in 2016 (vs. 29.9% in 2014). This species has only been collected once at site bdc5.0 (1,378/m^2 in 2014). *Fallceon quilleri* (t=4) which was also most abundant at site bdc1.0 (13.3%) in 2016, has in general shown no preference for either the upstream or downstream sites over the study years, except in 2016 when it represented 7.8% vs. 3.4% of the upstream vs. downstream populations. *Tricorythodes explicatis* (t=4) however, appears to prefer the upstream sites, and especially site bdc0.5 in 2016 when it comprised over 23% of the population.

Caddisflies were also low in abundance in 2016 as in 2012 and 2014, especially compared to 2010 when caddisfly abundance was highest (6.0% to 25.6% at the upstream sites). As in previous years, they were most abundant at upstream sites bdc0.5 and 1.0 (1.7% and 4.7%) with good numbers also at bdc3.0 (2.0%) in 2016. At bdc2.0 abundance was only 0.3% (55/m^2) which was similar to 2014 (0.2%), while they were absent at this site in 2010 and 2012. They were also scarce at bdc1.5C (0.8%) in 2016. The general predominance of sifting-sand substrates (sites bdc1.5C and downstream) makes it difficult for these species to become established. Similar to previous years the dominant taxon was moderately tolerant, *Cheumatopsyche* sp. (t=5).

In 2016, oligochaetes, mainly tolerant naidid worms (t=10) were most abundant at sites bdc3.0 and bdc5.0. At site bdc5.0, oligochaete abundance was 68.0% (35,611/m^2), of which 33,516/m^2 were naidid worms. Abundance was also high at bdc5.0 in 2010 at 60.1% (46,610/m^2) compared to <1.4% at the rest of the sites. However in 2014, at site bdc5.0 naidid worms accounted for only 1.2% (276/m^2) of the population, which shows how highly variable worm populations can be, both in numbers and species, which is largely related to their reproductive biology that allows them to proliferate faster than the aquatic insects. Interestingly in 2016, naidid and tubificid worms were co-dominant with their respective

abundances nearly equal at sites bdc1.0, bdc1.5C, and bdc3.0 (4.7 and 6.7%; 9.5 and 7.7%; 29.1 and 33.1%, respectively). Whereas in 2014, tubificids were more abundant than naidids throughout the study area.

Amphipods have been fairly abundant at most sites and study years since 1997 with abundances of generally <10% and have been most abundant at bdc0.5 and bdc5.0. However, in 2016 and 2014 they were most abundant at site bdc2.0 (11.3 and 11.8%, respectively). The most abundant amphipod in 2016 was *Crangonyx* sp. (t=6) which was found to be most numerous at site bdc0.5. Its related taxon, *Hyallela azteca* (t=8) was fairly abundant at site bdc5.0.

Total densities in 2016 ranged from a high of 91,864/m^2 at site bdc0.5 to low of 18,511/m^2 at bdc2.0 (Figure 8). Densities were very high (~45K/m^2 or more) at sites bdc0.5, bdc1.0, bdc3.0, and bdc5.0. The lower densities at bdc1.5C and bdc2.0 were also high (i.e., >10K/m^2) compared to previous years. The high densities at site bdc0.5 and relatively so at bdc1.0 (44,762/m^2) were largely due to the high abundances of mayflies and dipterans (mainly midges), which when combined represented 74.3% and 79.8% of the benthic community, respectively. The high densities at downstream sites bdc3.0 and bdc5.0 (71,119 and 52,369 orgs/m^2, respectively) on the other hand were due to high abundances of oligochaetes and dipterans which had combined relative abundances of 82.5% and 89.5%, respectively.

For the last four events (2010-2016), the 4-year mean densities have been highest at bdc0.5 at 46,042/m^2 with mean densities also rather high at sites bdc3.0 and 5.0 (35,398 and 37,598/m^2, respectively). In 2016, mayflies continued to contribute significantly to the overall high densities at all the sites except bdc5.0. Mean densities continued to be lowest at sites bdc1.5C and bdc2.0 at ~16K/m^2.

At site bdc2.0 total density in 2016 was 18,511orgs/m^2 and was very similar to those in 2014 and 2012 (19,190 and 18,963/m^2). Densities have improved at bdc2.0 since 2010, which in 2012 was attributable to large numbers of naidid and tubificid worms, the midges *Cricotopus* sp. and especially *Stictochironomus* sp. (7,773/m^2), and black flies (simuliids), while in 2016 and 2014 it was due to mayflies, oligochaetes, and dipterans.

Taxa richness in 2016 ranged from 46 taxa at site bdc0.5 to 24 taxa at bdc5.0. The highest 4-year mean taxa richness (40) was at bdc0.5, while the lowest was 28 taxa at site bdc2.0.

3.3.2 Community Metrics

Selected key metrics were used to determine the relative degrees of impairment for the BDC sites for the fall 2016 monitoring event with comparisons to 2010 through 2016. In the past, the key metrics discussed in the report included total taxa, EPT taxa, species diversity, ICI, HBI, RBPs, % Chironomidae, and MMIs (Tables 8 and 9, Appendix C). However, for purposes of this report, only ICIs, HBIs, species diversity, RBPs, and MMIs are discussed herein.

Site bdc2.0 has usually had lowest ICI over the entire study period. However, recently (2010-2016 study years) ICIs were lowest at site bdc5.0 in 2016 and site bdc1.5C in 2014. In 2016, the lowest ICI score at site bdc5.0 was 12 and in the *poor* category (Figure 9, Appendix C). The major reasons for the low score at bdc5.0 were the lack of caddisflies, the lower mayfly abundance, and the abundance of tolerant organisms (mainly of naidid worms and dipterans). While ICIs varied each year, they were generally the highest at sites bdc0.5 and bdc1.0. ICIs were most similar at bdc1.5C, bdc2.0, and bdc3.0 in 2014 and 2016. One ICI score was in the *good* category (42 at site bdc0.5) in 2016, and in the previous three years, the only other ICIs in the *good* category occurred in 2010 (36 and 42 at bdc0.5 and bdc1.0), 2012 (38 at bdc0.5), and 2014 (36 at bdc5.0). Site bdc0.5 has had scores in the *good* category in three of the last four sampling years. While scores in the *poor* category have been rare, it is interesting how at site bdc5.0 the ICI dropped substantially from the *good* category in 2014 (36) to *poor* in 2016 (12). Otherwise the majority of ICIs were in the *fair* category. In addition, the 4-year mean ICIs (2010-2016) ranged from 22.0 to 37.0. The highest mean ICIs were at upstream sites bdc0.5 and bdc1.0. The lowest mean ICI was again at bdc2.0 (22.0) with bdc5.0 also low at 24.5.

The mean ICIs for the upstream vs. downstream sites in 2016 were notably different with 34.0 upstream and only 20.7 downstream (13.3 points lower) which is in good agreement with the HBI. Usually the higher the ICI score the lower the HBI (higher ICI=better, lower HBI= better). The mean HBI for the upstream sites was lower than the downstream mean (6.38 vs. 7.77; 1.39 points higher) indicating the downstream macroinvertebrate populations are more stressed from organic sources. In general, both the ICI and HBI scores in past study years have indicated greater degradation at the downstream sites, except in 2014 when upstream vs. downstream differences were slight.

The 2016 RBP scores were 87%, 78% and 52% at sites bdc2.0, bdc3.0, and bdc5.0 (*nonimpaired*, *slightly* impaired, and *slight* to *moderately* impaired, respectively). The RBP was lowest at site bdc5.0 in 2016 as

well as in 2014. However, RBPs were lowest at site bdc2.0 in 2010 and 2012 (65% and 62%) but improved to 87% in both 2014 and 2016 indicating nonimpairment.

Unlike in 2012 and 2014, in 2016 decreases in ICIs correlated with decreases in RBP values between sites bdc2.0 vs. bdc3.0 as well as between sites bdc3.0 vs. bdc5.0. In 2012 and 2014, the expected correlation did not occur between sites bdc3.0 vs. bdc5.0 in either year as the ICIs increased while the RBPs decreased (i.e., the expected trend is that when ICIs drop, RBPs also drop or vice versa).

In 2016 the species diversity values at individual sites ranged from a low of 2.27, again at bdc5.0 (3.30 in 2014) to a high of 4.11 at bdc1.0. Except for the low diversity at bdc5.0, all values were >3.00 which generally indicates a well-diversified population. Mean diversity for the downstream sites was less than the upstream site mean, which also corresponds to the ICI and HBI means.

MMI scores were calculated for the 2010, 2012, 2014 and 2016 benthic macroinvertebrate data sets per guidance in CWQCC's Policy 10-1 (CWQCC 2010b). Accordingly, Big Dry Creek Segment 1 is in the *biotype 3, plains/xeric* category and classified as a Class 2 warm water stream (auxiliary metrics not considered). Thresholds for *biotype 3, plains/xeric* streams are: MMI scores $\leq$22 indicate impairment and scores >22 indicate use attainment; MMI scores $\geq$44 are considered high scoring waters (HSW).

For the 4-year data set, MMI scores ranged from 24.8 to 66.7 and all sites met use attainment (no score $\leq$22). In 2016, the lowest MMI score was at site bdc5.0 with the lowest annual MMI in 2014 also at bdc5.0. For 2010 and 2012, the lowest MMIs were at sites bdc3.0 and bdc2.0, respectively. For the four years (2010-2016) evaluated 18 of the 24 scores (75.0%) were in the HSW category. Notably, in 2012, 2014 and 2016, there was only one site in each year that was not a HSW, which were the lowest annual scores in these years (bdc2.0 in 2012 and bdc5.0 in both 2014 and 2016).

The highest 4-year mean score was at site bdc0.5 (59.9), while the lowest mean MMI was at bdc5.0 (42.9). These scores were generally consistent with the key metrics analyses. The highest annual mean of the four years was in 2012 and 2014 (both 54.0) while the lowest was in 2010 (43.4).

In 2016, the lowest MMI score of 24.8 was at site bdc5.0 as it was in 2014 (39.2). This represents two decreases in a row at this site with a 14.4 drop from 2014 to 2016 and a 27.5 drop in between 2012 and 2014, resulting in a total decrease of 41.9 between 2012 and 2016. Although its MMI score is still just above the 22 point threshold for impairment, this site appears to be showing signs of degradation according to its MMI scores and Policy 10-1. Impairment at site bdc5.0 is further supported by the

findings of the key metrics analyses in 2014 and 2016, which all indicate that this site is lately the most stressed of the six monitoring sites.

Based on MMI analysis for 2010-2016, all sites met the use attainment criteria for the State's Class 2 warm water streams. It appears that the benthic community, except at site bdc5.0 (rather than bdc2.0) was the most stressed in 2016, while the remaining sites were quite healthy with each having two or more MMI scores above the HSW threshold. In fact, sites bdc0.5, bdc1.0, and bdc1.5C were ranked as HSW for all four sampling events from 2010 to 2016. Furthermore, at site bdc2.0, MMIs have gradually improved during the last four years with HSW in 2014 and 2016. In summary, all community metrics analyses including the MMI indicate that the macroinvertebrate populations at all sites except site bdc5.0 are healthy.

TABLE 7

MEAN PERCENT RELATIVE ABUNDANCE FOR PREDOMINANT AND IMPORTANT MACROINVERTEBRATE SPECIES COLLECTED AT BIG DRY CREEK SITES UPSTREAM AND DOWSTREAM FROM WWTPs, FALL 2016 VS. 2010-2014 1/

	2010		2012		2014		2016	
Taxa	Up	Down	Up	Down	Up	Down	Up	Down
TURBELLARIA (flatworms)								
Dugesia sp.	2.9	0.2	0.4	0.1	1.3	1.2	0.1	0.5
OLIGOCHAETA (aquatic worms)								
Nais spp.	0.2	19.5	1.9	14.1	1.0	3.7	5.0	31.5
Tubificidae	0.6	0.9	10.1	16.8	11.6	10.5	9.5	18.2
AMPHIPODS (scuds)								
Crangonyx sp.	6.1	1.1	6.2	1.2	1.7	1.2	4.2	4.4
Hyalella azteca	3.6	3.2	3.8	2.3	3.5	4.0	1.2	2.6
EPHEMEROPTERA (mayflies)								
Acentrella insignificans	1.1	0.1	0.2	0.7	nc 2/	5.8	nc	0.2
Baetis tricaudatus	9.4	0.3	1.1	0.0	15.5	4.3	7.0	0.6
Fallceon quilleri	1.9	4	10.0	4.4	4.2	7.8	7.8	3.4
Tricorythodes explicatus	7.9	0.9	8.1	2.8	11.9	4.6	12.2	7.5
TRICHOPTERA (caddisflies)								
Cheumatopsyche sp.	14.1	1.4	3.2	0.5	3.6	0.8	1.4	0.4
Hydropsyche sp.	1.9	<0.1	0.2	0.1	0.1	nc	0.6	0.2
Hydroptila sp.	0.3	0.1	1.2	1.0	0.5	0.3	0.4	0.3
DIPTERA								
Chironomidae (midges)								
Chironomus sp.	4.2	4.2	0.2	1.0	0.6	0.3	2.2	3.0
Cladotanytarsus sp.	0.3	0.3	0.1	0.6	0.5	1.9	0.2	1.3
Cricotopus sp.	13.2	11.2	4.0	10.2	6.3	15.9	12.2	11.9
Cryptochironomus sp.	0.6	0.4	2.2	1.3	1.4	0.5	2.9	0.5
Eukiefferiella sp.	<0.1	0.1	0.5	0.0	0.1	0.2	0.1	0.2
Hydrobaenus sp.	0.6	0.1	5.6	1.4	4.5	2.1	0.6	0.1
Micropsectra sp.	0.4	0.4	0.7	4.7	0.1	3.1	1.6	3.1
Parakiefferiella sp.	1.1	0.2	0.2	0.6	1.8	1.4	1.2	0.4
Paratanytarsus sp.	0.1	<0.1	1.3	0.0	0.8	nc	2.1	0.1
Polypedilum sp.	nc	nc	0.3	0.4	1.5	0.5	1.1	0.3
Rheotanytarsus sp.	nc	nc	0.4	nc	0.3	nc	7.5	0.1
Saetheria tylus	nc	0.1	0.1	nc	0.3	2.9	1.0	0.2
Stictochironomus sp.	12.6	38.4	26.1	17.4	17.2	3.9	10.0	2.0
Thienemanniella sp.	1.2	0.3	1.5	6.7	0.9	0.6	nc	0.5
Thienemannimyia group	0.4	<0.1	1.5	0.8	0.8	0.3	1.0	0.2
Simuliidae (black flies)								
Simulium vittatum complex	9	8.8	0.6	3.6	2.7	16.8	1.1	3.4
GASTROPODA (snails)								
Ferrissia sp.	1.1	0.1	0.5	0.1	0.4	0.2	1.6	0.1
Physidae	0.1	0.3	0.1	0.0	0.4	0.1	0.1	nc

1/ Upstream sites include bdc0.5, 1.0, and 1.5C; downstream sites include bdc2.0, 3.0, and 5.0.

2/ nc indicates species not collected.

TABLE 8

SUMMARY OF KEY COMMUNITY PARAMETERS AND INDICES
BIG DRY CREEK SITES, FALL 2016 VS. 2010-2014

			Metric				
Site	Total Taxa	EPT Taxa	Species Diversity	ICI	HBI	% Chironomidae	RBP 1.5C
Fall 2010							
Upstream Sites							
bdc0.5	36	6	3.37	36	5.49	9.4	
bdc1.0	36	9	3.50	42	5.99	41.1	
bdc1.5C	26	7	3.42	30	6.21	56.0	100.0
Mean	**33**	**7**	**3.43**	**36.0**	**5.90**	**35.5**	
Downstream Sites							
bdc2.0	22	5	2.27	20	6.17	70.3	65.0
bdc3.0	33	7	2.37	28	6.16	75.5	78.0
bdc5.0	46	5	2.55	24	8.31	22.5	70.0
Mean	**34**	**6**	**2.40**	**24.0**	**6.88**	**56.1**	**71.0**
Fall 2012							
Upstream Sites							
bdc0.5	41	5	4.18	38	6.04	23.2	
bdc1.0	34	8	3.82	32	6.52	37.9	
bdc1.5C	31	7	2.99	26	6.84	63.2	100.0
Mean	**35**	**7**	**3.66**	**32.0**	**6.47**	**41.4**	
Downstream Sites							
bdc2.0	25	5	2.84	16	7.16	48.3	62.0
bdc3.0	41	8	3.54	32	8.22	27.6	90.0
bdc5.0	33	5	3.76	26	6.60	31.0	90.0
Mean	**33**	**6**	**3.38**	**24.7**	**7.33**	**35.6**	**80.7**
Fall 2014							
Upstream Sites							
bdc0.5	35	5	3.58	32	5.75	21.9	
bdc1.0	36	6	3.69	34	6.20	31.1	
bdc1.5C	34	6	3.83	24	6.90	63.3	100.0
Mean	**35**	**6**	**3.70**	**30.0**	**6.28**	**38.8**	
Downstream Sites							
bdc2.0	35	6	3.75	26	6.47	34.7	87.0
bdc3.0	42	7	4.11	28	7.25	38.2	91.0
bdc5.0	27	8	3.30	36	5.73	31.8	83.0
Mean	**35**	**7**	**3.72**	**30.0**	**6.48**	**34.9**	**87.0**
Fall 2016							
Upstream Sites							
bdc0.5	46	6	3.76	42	6.21	40.2	
bdc1.0	33	7	4.11	34	6.17	43.4	
bdc1.5C	30	6	3.71	26	6.75	53.6	100.0
Mean	**36**	**6**	**3.86**	**34.0**	**6.38**	**45.7**	
Downstream Sites							
bdc2.0	29	6	3.62	26	6.74	37.5	87.0
bdc3.0	36	6	3.13	24	8.10	17.2	78.0
bdc5.0	24	4	2.27	12	8.47	19.2	52.0
Mean	**30**	**5**	**3.01**	**20.7**	**7.77**	**24.6**	**72.3**

FIGURE 7
PERCENT RELATIVE ABUNDANCE OF MACROINVERTEBRATE TAXONOMIC GROUPS
COLLECTED IN KICK SAMPLES FROM BIG DRY CREEK, FALL 2010- 2016

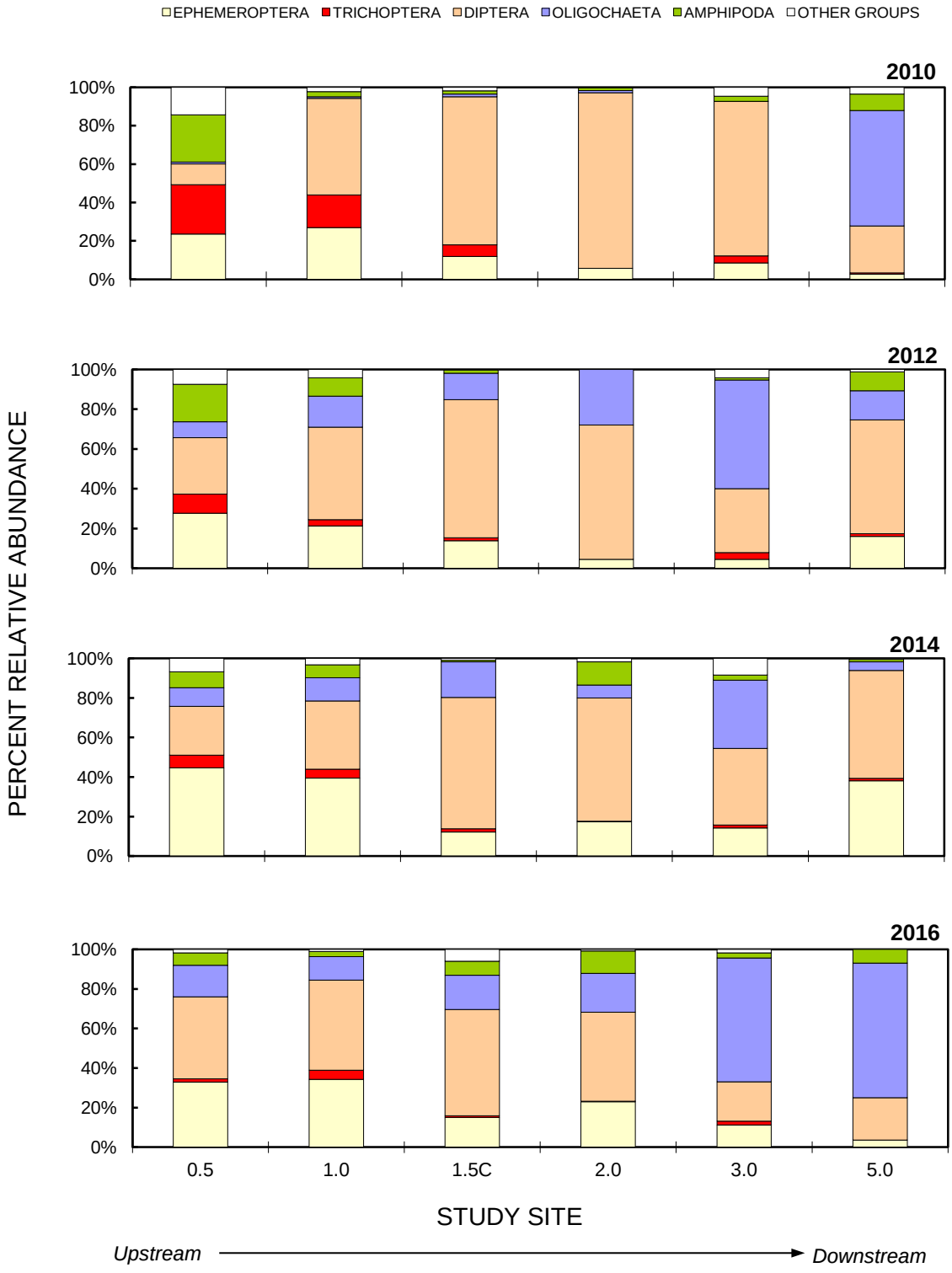


FIGURE 8

MACROINVERTEBRATE DENSITY AND TOTAL NUMBER OF TAXA COLLECTED IN KICK SAMPLES FROM BIG DRY CREEK, FALL 2010- 2016

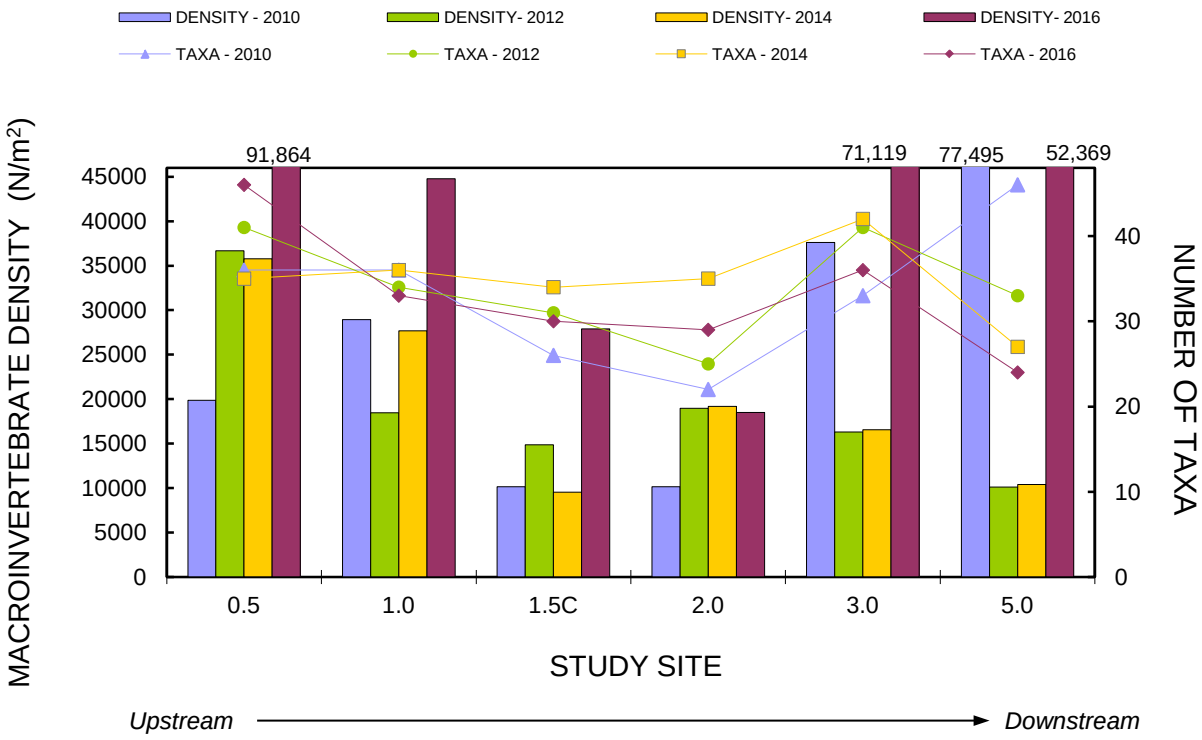


FIGURE 9

COMPARISON OF INVERTEBRATE COMMUNITY INDEX (ICI) SCORES
FOR BIG DRY CREEK SITES IN FALL,
1997-2010 MEAN VS. 2012, 2014 AND 2016

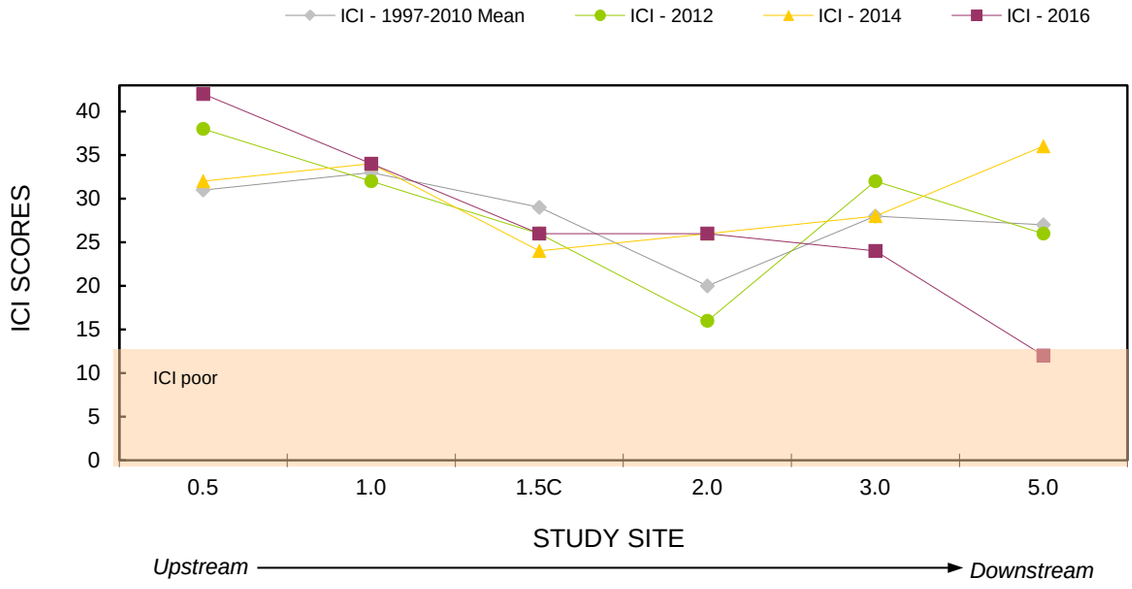


FIGURE 10

PERCENT RAPID BIOASSESSMENT PROTOCOL III (RBP) VALUES AS COMPARED TO
REFERENCE SITES AND INVERTEBRATE COMMUNITY INDEX (ICI) SCORES FOR
KICK SAMPLES FROM BIG DRY CREEK SITES, FALL 2016

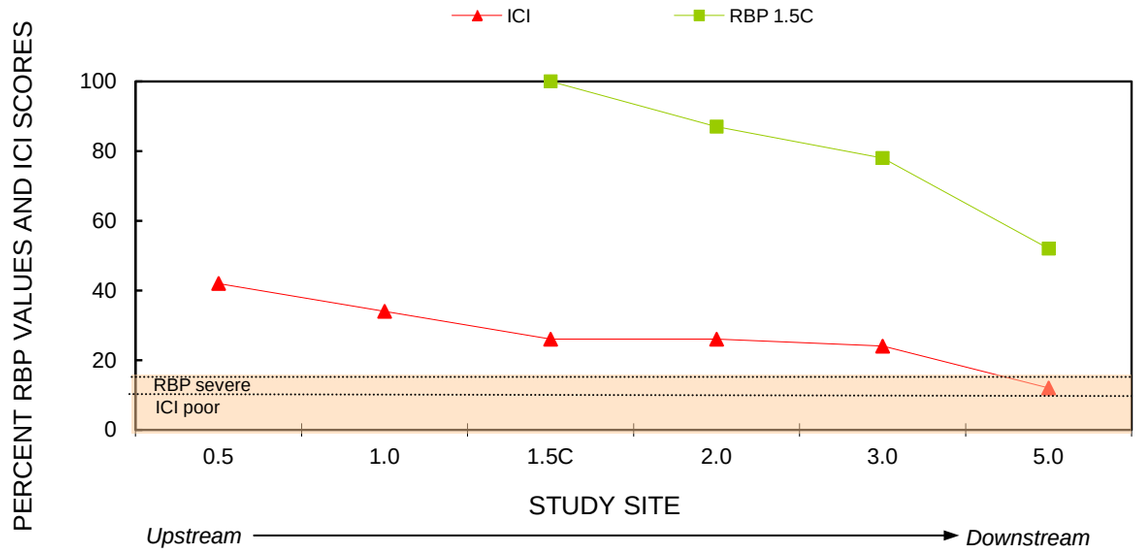


TABLE 9

MMI SCORES FOR BIG DRY CREEK SITES, FALL 2010, 2012, 2014 AND 2016

			MMI Sores				
Site	**Location**	**Biotype**	**2010**	**2012**	**2014**	**2016**	**4-yr mean**
BDC 0.5	d/s from Old Wadsworth Ave., at Church Ranch Open Space	3	**64.1**	**64.7**	**49.9**	**60.8**	59.9
BDC 1.0	u/s from 112th Ave.	3	**48.8**	**50.8**	**49.2**	**55.2**	51.0
BDC 1.5C	d/s from 120th Ave., immediately u/s Broomfield WWTP	3	**49.0**	**46.4**	**63.1**	**45.8**	51.1
BDC 2.0	u/s from 128th Ave., d/s from Broomfield WWTP	3	29.6	42.2	**56.4**	**50.2**	44.6
BDC 3.0	at I-25, d/s from Westminster WWTP	3	28.3	**53.2**	**50.7**	**44.5**	44.2
BDC 5.0	d/s from Weld County Rd. 4	3	40.8	**66.7**	39.2	24.8	42.9
		Annual Mean	43.4	54.0	54.0	46.9	

Bold indicates High Scoring Water (MMI ≥44 for Biotype 3). lowest annual score

MMI Impairment threshold for Class 2 streams is ≤22.

Comments for 2016

All 2016 MMI values met use attainment (MMIs ≥ 37 threshold for Class 2 streams).

Allsites except bdc5.0 were High Scoring Waters.

Lowest score in 2016 was at bdc5.0.

Score decrease (17.3 points) at bdc1.5C in 2016 vs. 2014, although 2016 score was similar to 2010 and 2012.

4.0 RECOMMENDATIONS

The following are AAI's proposed recommendations for the Big Dry Creek biological monitoring program for 2018.

- Keep future monitoring program intact (continue the reduced program that began in 2008 with six sites, fish and macroinvertebrates in the fall season only, and continue doing MMI analyses) with monitoring in even the years. Next event would be in 2018.

- As done in the past, program costs can be reduced if Cities provide assistance (2-4 people) for the 3-day fish sampling event.

- If program funding were to be reduced, the best options, while still keeping the program objectives intact, would be: 1) elimination of site bdc0.5 (atypical vs. other sites), and 2) for the habitat survey task, eliminate the RBP habitat analysis and rather only document habitat conditions through qualitative observations concurrent with the fall biological surveys. These changes would save ~$3,500-4,000.

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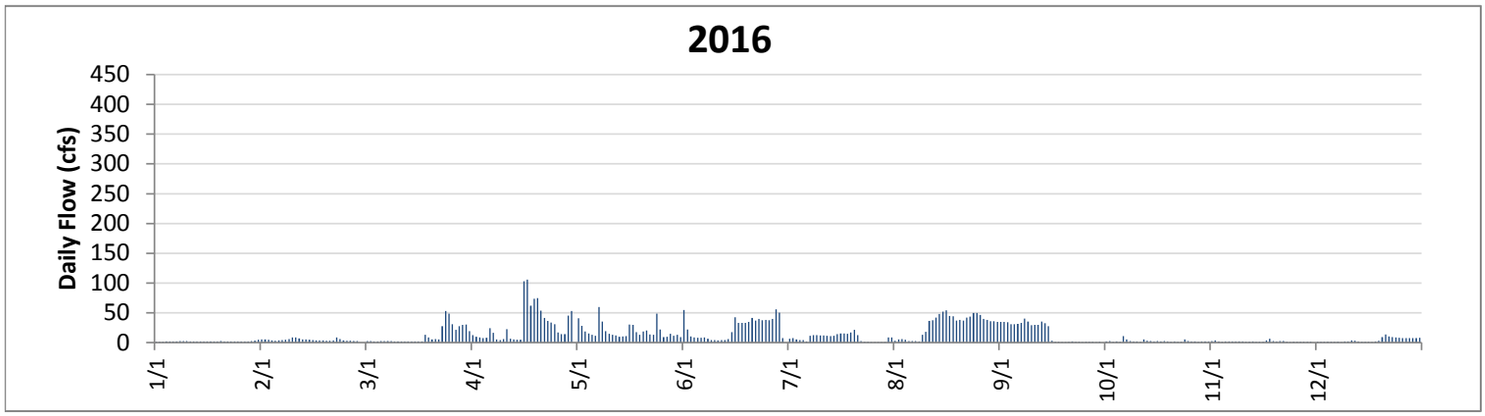
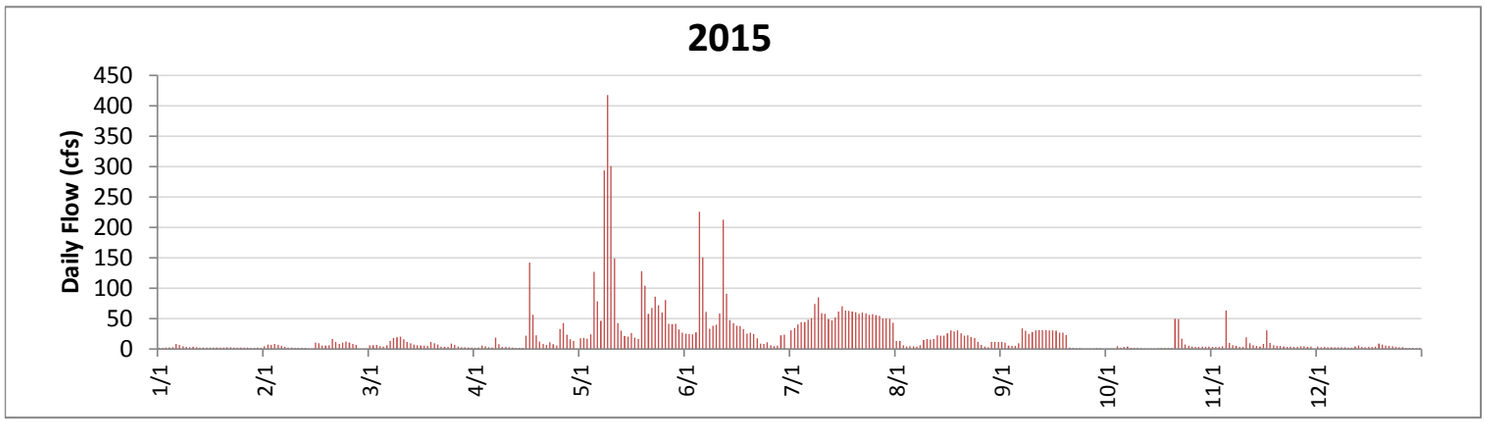
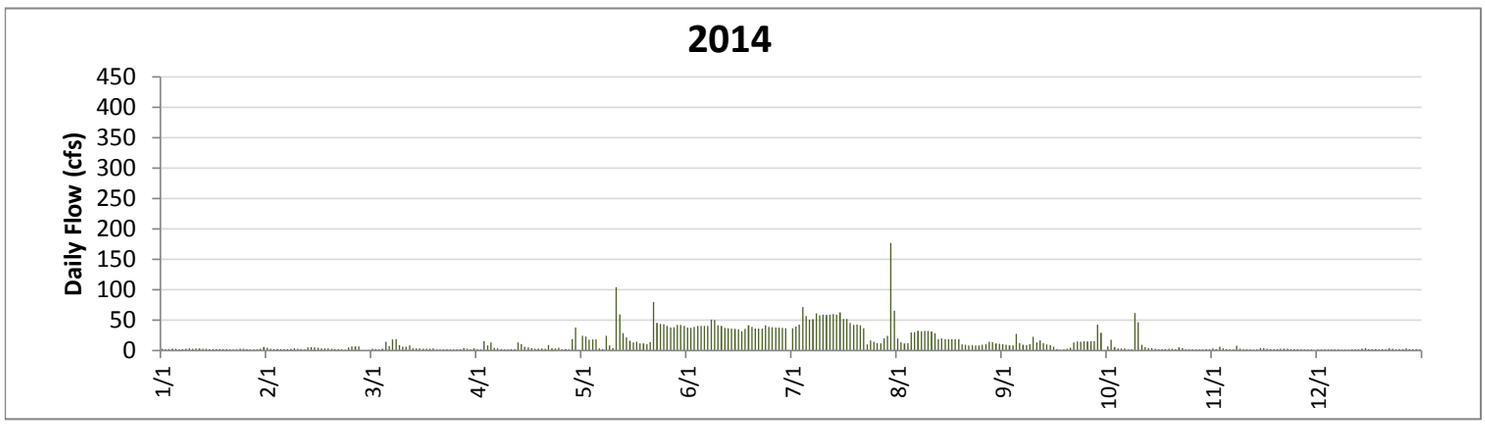
APPENDIX A

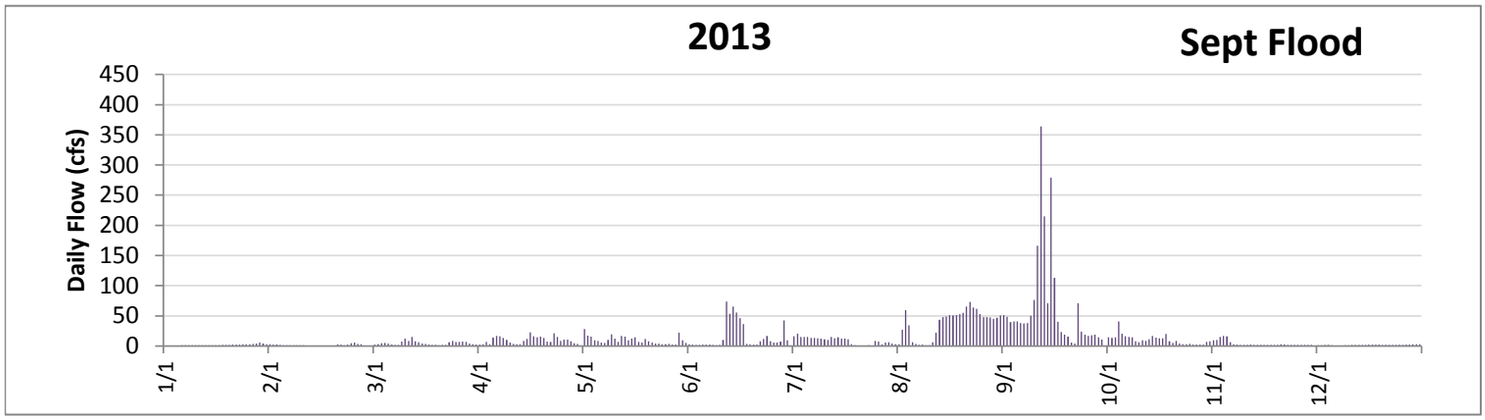
STREAMFLOW DATA AND PHOTOGRAPHIC DOCUMENTATION

Big Dry Creek Streamflow Data, 2013-2016









Source: USGS Streamflow data for gage 06720820 Big Dry Creek at Westminster, CO 2012-2014. U.S. Dept. of Interior, U.S. Geological Survey.

BDC 0.5


Low flow and dense algae and
aquatic weed growth in Oct 2016


Some bank erosion
Shallow run habitat

BDC 1.0

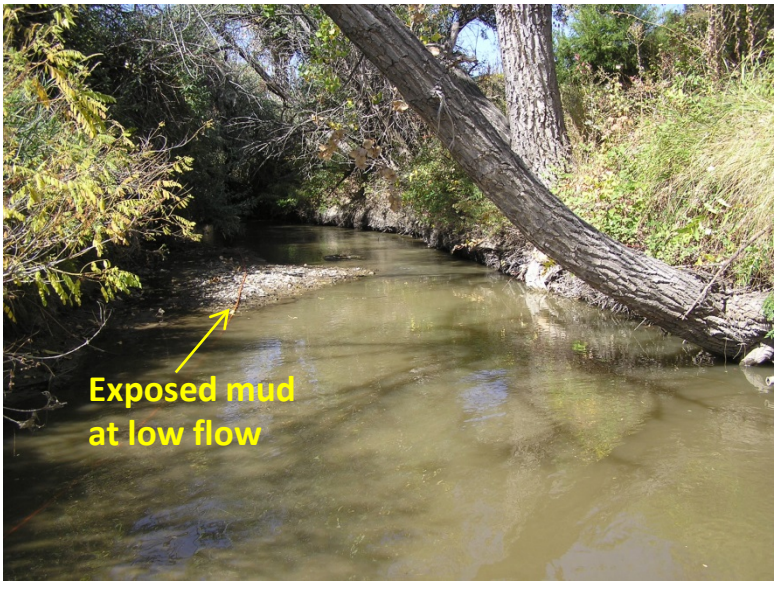

Eroded bank


Riparian vegetation
providing fish cover
and shade


Overhanging
vegetation
Abundant cobble
substrate

BDC 1.5C


Abundant trees shade
most of the stream reach


Exposed mud
at low flow


Overhanging
grasses
Only few areas with small
cobble substrate in Oct 2016

BDC 2.0


Large woody debris provides
good instream cover for fish


Banks covered by grasses
and riparian vegetation
Sand and silt substrates
are predominant with
isolated areas of gravel
Collapsed stream bank

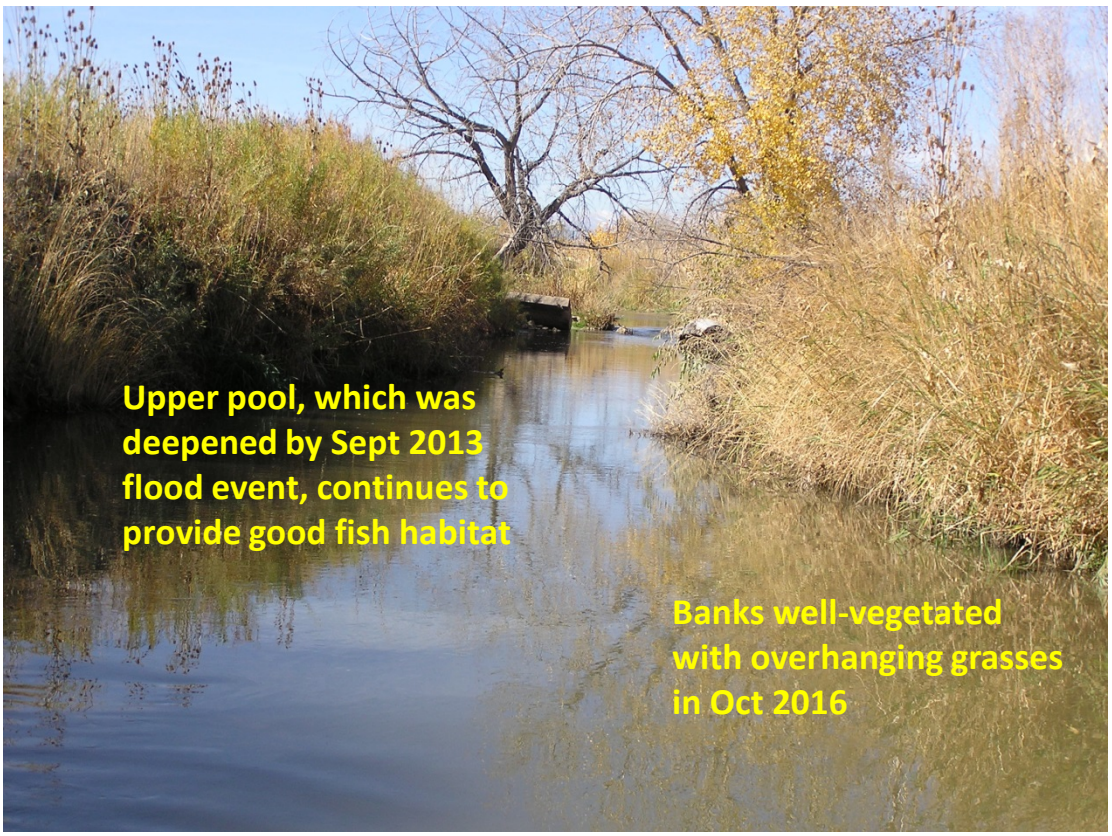
BDC 3.0


Overhanging grasses provide good cover for fish
Deep channelized reach upstream from I-25


Shifting sand and silt substrates are predominant with cobble in riffles near the I-25 overpass
Banks well-vegetated with grasses

BDC 5.0


Good flow conditions for fish and macroinvertebrate sampling in the stream reach in Oct 2016


Upper pool, which was deepened by Sept 2013 flood event, continues to provide good fish habitat
Banks well-vegetated with overhanging grasses in Oct 2016

BDC Sampling

Macroinvertebrates sampling with kick net at site bdc0.5 in Oct 2016

Undercut banks where most fish were collected at bdc1.5C in Oct 2016

BDC Fish Sampling

BDC Important Native Fish Species

APPENDIX B

FISH POPULATION DATA

FISH POPULATION DATA SUMMARY FALL 2016
BIG DRY CREEK

RELATIVE ABUNDANCE

	0.5	1.0	1.5C	2.0	3.0	5.0
Longnose Dace	16.7	48.4	6.3	0.3	29.3	0.9
Creek Chub	27.2	15.0	26.7	28.4	0.9	19.2
Fathead Minnow	41.5	9.2	25.7	30.7	20.0	20.9
Sand Shiner	-	11.5	0.3	-	7.6	14.9
White Sucker	11.6	14.5	37.6	39.3	28.0	22.8
Longnose Sucker	3.1	-	-	-	-	-
Johnny Darter	-	1.2	1.3	0.1	-	0.6
Green Sunfish	-	-	2.2	1.1	5.3	0.5
Mosquitofish	-	-	-	-	-	8.2
Largemouth Bass	-	-	-	-	-	1.3
Common Carp	-	0.1	-	0.1	7.6	10.3
Black Crappie	-	-	-	-	0.4	0.1
Bluegill	-	0.1	-	-	-	0.1
Black Bullhead	-	-	-	-	0.9	0.3

NUMBER COLLECTED

							overall- all sites	
	0.5	1.0	1.5C	2.0	3.0	5.0	N	%
Longnose Dace	108	365	20	2	66	16	577	13.0
Creek Chub	176	113	85	203	2	340	919	20.7
Fathead Minnow	269	69	82	220	45	371	1056	23.8
Sand Shiner	-	87	1	-	17	264	369	8.3
White Sucker	75	109	120	281	63	404	1052	23.7
Longnose Sucker	20	-	-	-	-	-		
Johnny Darter	-	9	4	1	-	11		
Green Sunfish	-	-	7	8	12	8		
Mosquitofish	-	-	-	-	-	145		
Largemouth Bass	-	-	-	-	-	23		
Common Carp	-	1	-	1	17	182		
Black Crappie	-	-	-	-	1	1		
Bluegill	-	1	-	-	-	1		
Black Bullhead	-	-	-	-	2	6		
Total Collected	648	754	319	716	225	1772	4434	
Total Species Collected	5	8	7	7	9	13	14	
Native Species	5	6	7	6	7	8	9	

Bold indicates native to South Platte River.

FISH SUMMARY DATA
BIG DRY CREEK 1999-2016
Comparison of Fish Numbers

	Numbers of Fish Collected							
Years	0.5	1.0	1.5	1.5C	2.0	3.0	5.0	6.0
1999	1892	144	226	ns	967	940	1464	329
2000	1212	360	1141	1149	230	990	1125	156
2001	780	351	290	496	222	152	794	266
2002	854	883	382	172	**59**	**88**	2612	206
2003	856	831	226	196	**9**	**68**	1762	156
2004	226	531	198	72	**38**	**67**	674	148
2006	841	2171	164	398	336	762	2660	223
2008	999	1012	ns	206	66	255	611	ns
2010	688	374	ns	176	129	416	3833	ns
2012	470	797	ns	403	1394	1118	2849	ns
2014	1474	541	ns	289	629	691	419	ns
2016	648	754	ns	319	716	225	1772	ns

ns indicates not sampled.

Bold indicates low fish numbers due to elevated ammonia and/or above normal flows.

JOHNNY DARTER COLLECTIONS
BIG DRY CREEK 1997-2016

	Numbers Collected							
Dates Sampled *	0.5	1.0	1.5	1.5C	2.0	3.0	5.0	6.0
1997 spring	10	5	0	ns	2	0	0	0
1997 fall	28	13	0	ns	0	0	0	0
1998	20	6	0	ns	4	0	0	0
1999	27	0	1	ns	0	0	0	0
2000	11	2	0	0	2	0	0	0
2001	15	0	0	0	1	0	0	0
2002	0	1	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0
2008	5	1	ns	0	0	0	0	ns
2010	40	2	ns	0	0	0	0	ns
2012	3	1	ns	0	0	0	0	ns
2014	2	0	ns	1	0	0	0	ns
2016	0	9	ns	4	1	0	11	ns
No. of Years Collected 1997-2016	9	8	1	2	5	nc	1	nc
Total Individuals (when collected)	3-40	1-13	1	1-4	1-4		11	

* Fish sampling includes only Fall collections for 1998-2016 period.
ns = not sampled
nc = not collected

FISH IBI SCORES
BIG DRY CREEK 2006-2016

IBI Score	0.5	1.0	1.5C	2.0	3.0	5.0
2006	33	37	31	27	35	41
2008	33	39	21	19	31	33
2010	35	33	27	25	33	33
2012	31	35	33	29	31	37
2014	33	31	31	27	37	37
2016	29	**39**	29	31	29	35
	min	max	min		min	
6-yr Mean IBI 2006-2016	32.3	35.7	28.7	**26.3**	32.7	**36.0**
mean up/down	32.2	upstream sites		31.7	downstream sites	

Condition Category	Score Range
Excellent	53 - 55
Good	44 - 52
Fair	37 - 43
Poor	29 - 36
Very Poor	11 - 28

FISH IBI SCORES
BIG DRY CREEK 1999-2016

IBI Score	0.5	1.0	1.5	1.5C	2.0	3.0	5.0	6.0
1999	41	31	29		35	41	41	35
2000	41	37	35	35	31	33	39	31
2001	39	35	27	29	21	29	39	33
2002	33	37	29	27	25	25	39	27
2003	37	37	31	33	21	29	35	33
2004	29	33	33	27	17	31	33	31
2006	33	37	29	31	27	35	41	29
2008	33	39		21	19	31	33	
2010	35	33		27	25	33	33	
2012	31	35		33	29	31	37	
2014	33	31		31	27	37	37	
2016	29	39		29	31	29	35	
12-yr Mean IBI 1999-2016	34.5	35.3	30.4	29.4	25.7	32.0	36.8	31.3
mean up/down	32.4	upstream sites			31.4	downstream sites		

Condition Category	Score Range
Excellent	53 - 55
Good	44 - 52
Fair	37 - 43
Poor	29 - 36
Very Poor	11 - 28

BDC Snail Population 1999-2016

		Numbers Collected					
year	season	0.5	1.0	1.5C	2.0	3.0	5.0
1999	spring	**2**	0	ns	0	0	0
2000	spring	**36**	0	0	0	0	0
	fall	**73**	0	0	0	0	0
2001	spring	**254**	0	0	0	**73**	0
	fall	**98**	**73**	0	0	**254**	**36**
2002	spring	**83**	**28**	**28**	0	0	0
	fall	**4774**	**388**	**413**	**167**	**358**	**248**
2003	spring	**559**	0	0	0	0	0
	fall	**551**	**413**	**55**	0	**110**	**55**
2004	spring	**78**	**78**	**39**	0	0	0
	fall	**496**	**55**	**110**	0	**96**	0
2006	spring	0	**138**	**28**	0	**28**	0
	fall	**78**	**248**	**83**	0	**55**	**18**
2008	fall	0	0	0	0	**2**	0
2010	fall	**83**	**469**	**165**	0	**55**	**717**
2012	fall	**165**	**276**	0	0	**28**	**28**
2014	fall	**386**	**33**	0	**110**	**55**	0
2016	fall	**331**	0	**1323**	**55**	0	0

APPENDIX C

MACROINVERTEBRATE COMMUNITY SUMMARIES AND METRICS

MACROINVERTEBRATE DATA SUMMARY - METRICS COMPARISONS
BIG DRY CREEK FALL 2010-2016

FALL 2010

	upstream sites				downstream sites			
metric	0.5	1	1.5C	**Means**	2	3	5	**Means**
diversity	3.37	3.50	3.42	**3.43**	2.27	2.37	2.55	**2.40**
HBI	5.49	5.99	6.21	**5.90**	6.17	6.16	8.31	**6.88**
ICI	36	42	30	**36.0**	20	28	24	**24.0**
ICI/HBI ratio	6.56	7.01	4.83	**6.13**	3.24	4.55	2.89	**3.56**
RBP 1.5C					65	78	70	**71.0**
EPT taxa	6	9	7	**7**	5	7	5	**6**
total taxa	36	36	26	**33**	22	33	46	**34**
density	19882	28926	10143	**19650**	10149	37608	77495	**41751**

FALL 2012

	upstream sites				downstream sites			
metric	0.5	1	1.5C	**Means**	2	3	5	**Means**
diversity	4.18	3.82	2.99	**3.66**	2.84	3.54	3.76	**3.38**
HBI	6.04	6.52	6.84	**6.47**	7.16	8.22	6.60	**7.33**
ICI	38	32	26	**32.0**	16	32	26	**24.7**
ICI/HBI ratio	6.29	4.91	3.80	**5.00**	2.23	3.89	3.94	**3.36**
RBP 1.5C					62	90	90	**80.7**
EPT taxa	5	8	7	**7**	5	8	5	**6**
total taxa	41	34	31	**35**	25	41	33	**33**
density	36658	18467	14862	**23329**	18963	16291	10126	**15127**

FALL 2014

	upstream sites				downstream sites			
metric	0.5	1	1.5C	**Means**	2	3	5	**Means**
diversity	3.58	3.69	3.83	**3.70**	3.75	4.11	3.30	**3.72**
HBI	5.75	6.20	6.90	**6.28**	6.47	7.25	5.73	**6.48**
ICI	32	34	24	**30.0**	26	28	36	**30.0**
ICI/HBI ratio	5.57	5.48	3.48	**4.84**	4.02	3.86	6.28	**4.72**
RBP 1.5C					87	91	83	**87.0**
EPT taxa	5	6	6	**6**	6	7	8	**7**
total taxa	35	36	34	**35**	35	42	27	**35**
density	35765	27673	9537	**24325**	19190	16574	10401	**15389**

FALL 2016

	upstream sites				downstream sites			
metric	0.5	1	1.5C	**Means**	2	3	5	**Means**
diversity	3.76	4.11	3.71	**3.86**	3.62	3.13	2.27	**3.01**
HBI	6.21	6.17	6.75	**6.38**	6.74	8.10	8.47	**7.77**
ICI	42	34	26	**34.0**	26	24	12	**20.7**
ICI/HBI ratio	6.76	5.51	3.85	**5.38**	3.86	2.96	1.42	**2.75**
RBP 1.5C					87	78	52	**72.3**
EPT taxa	6	7	6	**6**	6	6	4	**5**
total taxa	46	33	30	**36**	29	36	24	**30**
density	91864	44762	27893	**54840**	18511	71119	52369	**47333**

MACROINVERTEBRATE DATA SUMMARY - DENSITY & TAXA
BIG DRY CREEK FALL 2010-2016

	STUDY SITE						Annual
	0.5	1.0	1.5C	2.0	3.0	5.0	**Mean**
DENSITY (N/m^2)							
2010	19,882	28,926	10,143	10,149	37,608	77,495	30,701
2012	36,658	18,467	14,862	18,963	16,291	10,126	19,228
2014	35,765	27,673	9,537	19,190	16,574	10,401	19,857
2016	91,864	44,762	27,893	18,511	71,119	52,369	51,086
4-yr Mean 2010-2016	46,042	29,957	15,609	16,703	35,398	37,598	30,218
TAXA							
2010	36	36	26	22	33	46	33
2012	41	34	31	25	41	33	34
2014	35	36	34	35	42	27	35
2016	46	33	30	29	36	24	33
4-yr Mean 2010-2016	40	35	30	28	38	33	34

BIG DRY CREEK

MACROINVERTEBRATE DATA SUMMARY - ICI AND RBP METRICS COMPARISONS
FALL 2000-2016 Kick Samples

ICI Comparison		downstream sites				
	1.5C	2	3	5	6	mean (all sites)
2000	30	30	36	14	6	23.2
2001	38	14	32	32	8	24.8
2002	28	16	22	28	16	22.0
2003	34	14	22	22	12	20.8
2004	28	20	30	36	8	24.4
2006	28	10	30	28	26	24.4
2008	16	20	22	32	ns	22.5
2010	30	20	28	24	ns	25.5
2012	26	16	32	26	ns	25.0
2014	24	26	28	36	ns	28.5
2016	26	26	24	12	ns	22.0
11-yr mean ICI (for each site)						ICI overall mean (all sites)
2000-2016	28.0	19.3	27.8	26.4	12.7	22.8

RBP Comparison - 1.5C as Reference Site

	1.5C	2	3	5	6	mean (downstream sites)
2000	100	100	100	61	43	76.0
2001	100	61	91	87	43	70.5
2002	100	62	90	95	86	83.3
2003	100	59	55	55	41	52.5
2004	100	54	88	71	50	65.8
2006	100	74	70	87	83	78.5
2008	100	86	86	86	ns	86.0
2010	100	65	78	70	ns	71.0
2012	100	62	90	90	ns	80.7
2014	100	87	91	83	ns	87.0
2016	100	87	78	52	ns	72.3
11-yr mean RBP (for each site)						RBP overall mean (downstream sites)
2000-2016	100	72.5	83.4	76.1	57.7	72.4

BIG DRY CREEK

MACROINVERTEBRATE DATA SUMMARY - ICI AND RBP METRICS COMPARISONS
FALL 2010-2016 Kick Samples

ICI Comparison		downstream sites			
	1.5C	2	3	5	mean (all sites)
2010	30	20	28	24	25.5
2012	26	16	32	26	25.0
2014	24	26	28	36	28.5
2016	26	26	24	12	22.0
4-yr mean ICI (for each site)					ICI overall mean (all sites)
2010-2016	26.5	22.0	28.0	24.5	25.3

RBP Comparison - 1.5C as Reference Site

	1.5C	2	3	5	mean (downstream sites)
2010	100	65	78	70	71.0
2012	100	62	90	90	80.7
2014	100	87	91	83	87.0
2016	100	87	78	52	72.3
4-yr mean RBP (for each site)					RBP overall mean (downstream sites)
2010-2016	100	75.3	84.3	73.8	77.8

MACROINVERTEBRATE DATA SUMMARY
BIG DRY CREEK
2010-2016 Summary of Invertebrate Community Index (ICI) Results

	Study Site					
	BDC-0.5	**BDC-1.0**	**BDC-1.5C**	**BDC-2.0**	**BDC-3.0**	**BDC-5.0**
Fall 2010						
Kick Samples						
Total Score	36	42	30	20	28	24
Biological Condition Category	good	good	fair	fair	fair	fair
Fall 2012						
Kick Samples						
Total Score	38	32	26	16	32	26
Biological Condition Category	good	fair	fair	fair	fair	fair
Fall 2014						
Kick Samples						
Total Score	32	34	24	26	28	36
Biological Condition Category	fair	fair	fair	fair	fair	good
Fall 2016						
Kick Samples						
Total Score	42	34	26	26	24	12
Biological Condition Category	good	fair	fair	fair	fair	poor

MACROINVERTEBRATE DATA SUMMARY
BIG DRY CREEK
2010-2016 Summary of Rapid Bioassessment Protocol III Results

	Study Site				
	BDC-1.0	**BDC-1.5C**	**BDC-2.0**	**BDC-3.0**	**BDC-5.0**
Fall 2010- Kick Samples					
BDC-1.5C to downstream sites					
Total Score		46	30	36	32
Percent of Reference Score		100	65	78	70
Biological Condition Category		ref. site	slight	slight	slight
Fall 2012- Kick Samples					
BDC-1.5C to downstream sites					
Total Score		42	26	38	38
Percent of Reference Score		100	62	90	90
Biological Condition Category		ref. site	slight	nonimpaired	nonimpaired
Fall 2014- Kick Samples					
BDC-1.5C to downstream sites					
Total Score		46	40	42	38
Percent of Reference Score		100	87	91	83
Biological Condition Category		ref. site	nonimpaired	nonimpaired	nonimpaired
Fall 2016- Kick Samples					
BDC-1.5C to downstream sites					
Total Score		46	40	36	24
Percent of Reference Score		100	87	78	52
Biological Condition Category		ref. site	nonimpaired	slight	slight-mod

MACROINVERTEBRATE DATA SUMMARY
FALL 2016

DENSITY
KICK SAMPLES

Density by Order	BDC-0.5	BDC-1.0	BDC-1.5C	BDC-2.0	BDC-3.0	BDC-5.0
TURBELLARIA	331	0	0	0	1103	0
NEMATODA	221	331	331	0	0	0
OLIGOCHAETA	14678	5292	4851	3638	44541	35611
HIRUDINEA	4	110	0	0	4	0
ISOPODA	0	0	0	0	0	0
AMPHIPODA	5843	1213	1985	2095	1874	3638
DECAPODA	0	0	0	22	0	0
ACARI	0	0	0	0	0	0
COLLEMBOLA	0	0	0	0	0	0
EPHEMEROPTERA	30209	15325	4190	4245	7938	1874
ODONATA	0	0	0	0	4	0
HEMIPTERA	331	0	0	55	0	0
TRICHOPTERA	1544	2095	221	55	1433	0
COLEOPTERA	331	0	0	0	0	0
DIPTERA	38044	20396	14994	8324	14112	11246
GASTROPODA	331	0	1323	55	0	0
BIVALVIA	0	0	0	22	110	0
Total	91864	44762	27893	18511	71119	52369

RELATIVE ABUNDANCE
KICK SAMPLES

Relative Abundance by Order	BDC-0.5	BDC-1.0	BDC-1.5C	BDC-2.0	BDC-3.0	BDC-5.0
TURBELLARIA	0.36	0.00	0.00	0.00	1.55	0.00
NEMATODA	0.24	0.74	1.19	0.00	0.00	0.00
OLIGOCHAETA	15.98	11.82	17.39	19.65	62.63	68.00
HIRUDINEA	0.00	0.25	0.00	0.00	0.01	0.00
ISOPODA	0	0	0	0	0	0
AMPHIPODA	6.36	2.71	7.11	11.32	2.64	6.95
DECAPODA	0.00	0.00	0.00	0.12	0.00	0.00
ACARI	0	0	0	0	0	0
COLLEMBOLA	0	0	0	0	0	0
EPHEMEROPTERA	32.88	34.24	15.02	22.93	11.16	3.58
ODONATA	0.00	0.00	0.00	0.00	0.01	0.00
HEMIPTERA	0.36	0.00	0.00	0.30	0.00	0.00
TRICHOPTERA	1.68	4.68	0.79	0.30	2.02	0.00
COLEOPTERA	0.36	0.00	0.00	0.00	0.00	0.00
DIPTERA	41.41	45.57	53.75	44.97	19.84	21.47
GASTROPODA	0.36	0.00	4.74	0.30	0.00	0.00
BIVALVIA	0.00	0.00	0.00	0.12	0.16	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

*Isopoda, Acari or Collembola not collected in 2016.

MACROINVERTEBRATE SUMMARY DATA
COMMUNITY PARAMETERS - FALL 2010-2016

FALL 2010
KICK SAMPLES

Community Parameters	BDC-0.5	BDC-1.0	BDC-1.5C	BDC-2.0	BDC-3.0	BDC-5.0
Taxa Richness	36	36	26	22	33	46
Total Density (N/m^2)	19882	28926	10143	10149	37608	77495
Diversity (d)	3.37	3.50	3.42	2.27	2.37	2.55
% Dominant Taxon	24.95	23.35	27.45	50.52	58.85	58.26
EPT Index	6	9	7	5	7	5
EPT abundance	9784.69	12706.31	1819.13	578.81	4575.38	2590.88
Chironomid abundance	1874.25	11879.44	5677.88	7138.69	28389.38	17447.06
Ratio of EPT to Chironomids	5.22	1.07	0.32	0.08	0.16	0.15
Scraper abundance	192.94	716.63	413.44	82.69	110.25	771.75
Filterer abundance	5209.31	6587.44	2673.56	2094.75	3252.38	1212.75
Ratio of Scrapers to Filterers	0.04	0.11	0.15	0.04	0.03	0.64
Shredder abundance	1130.06	6725.25	1488.38	1571.06	3500.44	7056.00
Ratio of Shredders to Total	0.06	0.23	0.15	0.15	0.09	0.09
HBI	5.49	5.99	6.21	6.17	6.16	8.31
ICI	36	42	30	20	28	24
ICI/HBI ratio	6.56	7.01	4.83	3.24	4.55	2.89

FALL 2012
KICK SAMPLES

Community Parameters	BDC-0.5	BDC-1.0	BDC-1.5C	BDC-2.0	BDC-3.0	BDC-5.0
Taxa Richness	41	34	31	25	41	33
Total Density (N/m^2)	36658	18467	14862	18963	16291	10126
Diversity (d)	4.18	3.82	2.99	2.84	3.54	3.76
% Dominant Taxon	17.59	27.31	42.28	40.99	27.75	19.87
EPT Index	5	8	7	5	8	5
EPT abundance	13671.00	4520.25	2287.69	854.44	1295.44	1764.00
Chironomid abundance	8875.13	8351.44	10143.00	11052.56	5154.19	5347.13
Ratio of EPT to Chironomids	1.54	0.54	0.23	0.08	0.25	0.33
Scraper abundance	1598.63	441.00	2563.31	826.88	468.56	137.81
Filterer abundance	2866.50	716.63	248.06	1708.88	248.06	248.06
Ratio of Scrapers to Filterers	0.56	0.62	10.33	0.48	1.89	0.56
Shredder abundance	330.75	1378.13	744.19	1571.06	551.25	2094.75
Ratio of Shredders to Total	0.01	0.07	0.05	0.08	0.03	0.21
HBI	6.04	6.52	6.84	7.16	8.22	6.60
ICI	38	32	26	16	32	26
ICI/HBI ratio	6.29	4.91	3.80	2.23	3.89	3.94

MACROINVERTEBRATE SUMMARY DATA
COMMUNITY PARAMETERS - FALL 2010-2016

FALL 2014
KICK SAMPLES

Community Parameters	BDC-0.5	BDC-1.0	BDC-1.5C	BDC-2.0	BDC-3.0	BDC-5.0
Taxa Richness	35	36	34	35	42	27
Total Density (N/m^2)	35765	27673	9537	22888	20948	22712
Diversity (d)	3.58	3.69	3.83	3.75	4.11	3.30
% Dominant Taxon	27.28	29.88	23.70	27.70	21.05	22.82
EPT Index	5	6	6	6	7	8
EPT abundance	18246.38	12182.63	1323.00	4024.13	3307.50	8930.25
Chironomid abundance	7827.75	8599.50	6036.19	7938.00	7993.13	7221.38
Ratio of EPT to Chironomids	2.33	1.42	0.22	0.51	0.41	1.24
Scraper abundance	716.63	1047.38	1378.13	1543.50	385.88	385.88
Filterer abundance	3197.25	2149.88	413.44	6394.50	551.25	5292.00
Ratio of Scrapers to Filterers	0.22	0.49	3.33	0.24	0.70	0.07
Shredder abundance	606.38	2425.50	1350.56	2039.63	3748.50	5181.75
Ratio of Shredders to Total	0.02	0.09	0.14	0.09	0.18	0.23
HBI	5.75	6.20	6.90	6.47	7.25	5.73
ICI	32	34	24	26	28	36
ICI/HBI ratio	5.57	5.48	3.48	4.02	3.86	6.28

FALL 2016
KICK SAMPLES

Community Parameters	BDC-0.5	BDC-1.0	BDC-1.5C	BDC-2.0	BDC-3.0	BDC-5.0
Taxa Richness	46	33	30	29	36	24
Total Density (N/m^2)	91864	44762	27893	18511	71119	52369
Diversity (d)	3.76	4.11	3.71	3.62	3.13	2.27
% Dominant Taxon	23.64	14.29	20.95	22.04	30.23	64.00
EPT Index	6	7	6	6	6	4
EPT abundance	31752.00	17419.50	4410.00	4299.75	9371.25	1874.25
Chironomid abundance	36933.75	19404.00	14938.88	6945.75	12237.75	10032.75
Ratio of EPT to Chironomids	0.86	0.90	0.30	0.62	0.77	0.19
Scraper abundance	1543.50	882.00	1874.25	275.63	441.00	992.25
Filterer abundance	22711.50	3307.50	275.63	1400.18	3087.00	110.25
Ratio of Scrapers to Filterers	0.07	0.27	6.80	0.20	0.14	9.00
Shredder abundance	2212.35	7166.25	6118.88	4354.88	6174.00	3087.00
Ratio of Shredders to Total	0.02	0.16	0.22	0.24	0.09	0.06
HBI	6.21	6.17	6.75	6.74	8.10	8.47
ICI	42	34	26	26	24	12
ICI/HBI ratio	6.76	5.51	3.85	3.86	2.96	1.42

MACROINVERTEBRATE DATA SUMMARY
FALL 2010-2016
Rapid Bioassessment Protocol III Results

BDC-1.5C as Reference Site

FALL 2010
KICK SAMPLES

Community Parameters	BDC-1.5C	BDC-2.0	BDC-3.0	BDC-5.0
Taxa Richness	26	22	33	46
Total Density (N/m2)	10143	10149	37608	77495
Diversity (d)	3.42	2.27	2.37	2.55
% Dominant Taxon	27.45	50.52	58.85	58.26
EPT Index	7	5	7	5
EPT abundance	1819.13	578.81	4575.38	2590.88
Chironomid abundance	5677.88	7138.69	28389.38	17447.06
Ratio of EPT to Chironomids	0.32	0.08	0.16	0.15
Scraper abundance	413.44	82.69	110.25	771.75
Filterer abundance	2673.56	2094.75	3252.38	1212.75
Ratio of Scrapers to Filterers	0.15	0.04	0.03	0.64
Shredder abundance	1488.38	1571.06	3500.44	7056.00
Ratio of Shredders to Total	0.15	0.15	0.09	0.09
Modified HBI	6.21	6.17	6.16	8.31
Community Loss Index	n/a	0.45	0.33	0.22
Total Score	46	30	36	32
Percent of Reference Score	100	65	78	70
Biological Condition Category	ref. site	slight	slight	slight

FALL 2012
KICK SAMPLES

Community Parameters	BDC-1.5C	BDC-2.0	BDC-3.0	BDC-5.0
Taxa Richness	31	25	41	33
Total Density (N/m2)	14862	18963	16291	10126
Diversity (d)	2.99	2.84	3.54	3.76
% Dominant Taxon	42.28	40.99	27.75	19.87
EPT Index	7	5	8	5
EPT abundance	2287.69	854.44	1295.44	1764.00
Chironomid abundance	10143.00	11052.56	5154.19	5347.13
Ratio of EPT to Chironomids	0.23	0.08	0.25	0.33
Scraper abundance	2563.31	826.88	468.56	137.81
Filterer abundance	248.06	1708.88	248.06	248.06
Ratio of Scrapers to Filterers	10.33	0.48	1.89	0.56
Shredder abundance	744.19	1571.06	551.25	2094.75
Ratio of Shredders to Total	0.05	0.08	0.03	0.21
Modified HBI	6.84	7.16	8.22	6.60
Community Loss Index	n/a	0.52	0.22	0.36
Total Score	42	26	38	38
Percent of Reference Score	100	62	90	90
Biological Condition Category	ref. site	slight	nonimpaired	nonimpaired

MACROINVERTEBRATE DATA SUMMARY
FALL 2010-2016
Rapid Bioassessment Protocol III Results

BDC-1.5C as Reference Site

FALL 2014
KICK SAMPLES

Community Parameters	BDC-1.5C	BDC-2.0	BDC-3.0	BDC-5.0
Taxa Richness	34	35	42	27
Total Density (N/m^2)	9537	22888	20948	22712
Diversity (d)	3.83	3.75	4.11	3.30
% Dominant Taxon	23.70	27.70	21.05	22.82
EPT Index	6	6	7	8
EPT abundance	1323.00	4024.13	3307.50	8930.25
Chironomid abundance	6036.19	7938.00	7993.13	7221.38
Ratio of EPT to Chironomids	0.22	0.51	0.41	1.24
Scraper abundance	1378.13	1543.50	385.88	385.88
Filterer abundance	413.44	6394.50	551.25	5292.00
Ratio of Scrapers to Filterers	3.33	0.24	0.70	0.07
Shredder abundance	1350.56	2039.63	3748.50	5181.75
Ratio of Shredders to Total	0.14	0.09	0.18	0.23
Modified HBI	6.90	6.47	7.25	5.73
Community Loss Index	n/a	0.29	0.17	0.48
Total Score	46	40	42	38
Percent of Reference Score	100	87	91	83
Biological Condition Category	ref. site	nonimpaired	nonimpaired	nonimpaired

FALL 2016
KICK SAMPLES

Community Parameters	BDC-1.5C	BDC-2.0	BDC-3.0	BDC-5.0
Taxa Richness	30	29	36	24
Total Density (N/m^2)	27893	18511	71119	52369
Diversity (d)	3.71	3.62	3.13	2.27
% Dominant Taxon	20.95	22.04	30.23	64.00
EPT Index	6	6	6	4
EPT abundance	4410.00	4299.75	9371.25	1874.25
Chironomid abundance	14938.88	6945.75	12237.75	10032.75
Ratio of EPT to Chironomids	0.30	0.62	0.77	0.19
Scraper abundance	1874.25	275.63	441.00	992.25
Filterer abundance	275.63	1400.18	3087.00	110.25
Ratio of Scrapers to Filterers	6.80	0.20	0.14	9.00
Shredder abundance	6118.88	4354.88	6174.00	3087.00
Ratio of Shredders to Total	0.22	0.24	0.09	0.06
Modified HBI	6.75	6.74	8.10	8.47
Community Loss Index	n/a	0.34	0.25	0.54
Total Score	46	40	36	24
Percent of Reference Score	100	87	78	52
Biological Condition Category	ref. site	nonimpaired	slight	slight-mod

APPENDIX D

MACROINVERTEBRATE DATA

BDC-0.5

Sample Date: 26 October 2016

Taxon	Kick Sample n	Kick Sample N/m^2	Relative Abundance (%)
TURBELLARIA			
Dugesia sp.	90	330.75	0.36
NEMATODA	60	220.50	0.24
OLIGOCHAETA			
Enchytraeidae	60	220.50	0.24
Lumbricidae	4	14.70	0.02
Nais spp.	210	771.75	0.84
Ophidonais serpentina	30	110.25	0.12
Pristina leidyi			
Pristinella jenkinae	180	661.50	0.72
Tubificidae with hair chaetae	630	2315.25	2.52
Tubificidae w/o hair chaetae	2880	10584.00	11.52
HIRUDINEA			
Erpobdella punctata			
Mooreobdella microstoma	1	3.68	0.004
AMPHIPODA			
Crangonyx sp.	930	3417.75	3.72
Hyalella azteca	660	2425.50	2.64
DECAPODA			
Orconectes sp.			
EPHEMEROPTERA			
Acentrella insignificans			
Baetis tricaudatus	1650	6063.75	6.60
Callibaetis sp.			
Fallceon quilleri	660	2425.50	2.64
Heptagenia elegantula			
Paracloeodes minutus			
Tricorythodes explicatus	5910	21719.25	23.64
ODONATA			
Ophiogomphus severus			
HEMIPTERA			
Microvelia sp.			
Sigara grossolineata	30	110.25	0.12
Trichocorixa borealis	30	110.25	0.12
Trichocorixa calva	30	110.25	0.12
TRICHOPTERA			
Cheumatopsyche sp.	270	992.25	1.08
Hydropsyche sp.			
Hydroptila sp.	120	441.00	0.48
Oecetis sp.	30	110.25	0.12
COLEOPTERA			
Agabus sp.	90	330.75	0.36

BDC-0.5 (Continued)

Taxon	Kick Sample n	N/m^2	Relative Abundance (%)
DIPTERA			
Brillia sp.	90	330.75	0.36
Caloparyphus sp.	30	110.25	0.12
Ceratopogonidae			
Chironomus sp.	240	882.00	0.96
Cladotanytarsus sp.			
Cricotopus sp.	330	1212.75	1.32
Cryptochironomus sp.	540	1984.50	2.16
Dasyhelea sp.			
Dicrotendipes sp.	150	551.25	0.60
Eukiefferiella sp.	30	110.25	0.12
Hemerodromia sp.			
Hydrobaenus sp.	30	110.25	0.12
Limnophyes sp.	120	441.00	0.48
Micropsectra sp.	180	661.50	0.72
Microtendipes sp.	30	110.25	0.12
Nanocladius sp.			
Odontomesa sp.			
Ormosia sp.			
Parakiefferiella sp.			
Parametriocnemus sp.	90	330.75	0.36
Paraphaenocladius sp.			
Paratanytarsus sp.	780	2866.50	3.12
Phaenopsectra sp.	180	661.50	0.72
Polypedilum sp.	180	661.50	0.72
Procladius sp.	180	661.50	0.72
Pseudosmittia sp.			
Rheocricotopus sp.			
Rheotanytarsus sp.	5610	20616.75	22.44
Saetheria tylus	60	220.50	0.24
Simulium vittatum complex	270	992.25	1.08
Stictochironomus sp.	690	2535.75	2.76
Thienemanniella sp.			
Thienemannimyia group	540	1984.50	2.16
Tipula sp.	2	7.35	0.01
Tvetenia sp.			
GASTROPODA			
Ferrissia sp.	30	110.25	0.12
Physidae	60	220.50	0.24
BIVALVIA			
Corbicula sp.			
Pisidium sp.			
Totals:	24997	91863.98	100.00

Total Density (N/m^2)	91864
Total Number of Taxa	46
Diversity (d)	3.76

BDC-0.5

Community Parameters	Kick Sample	
Total Density (N/m^2)	91864	
Diversity (d)	3.76	
Total Number of Taxa	46	
% Dominant Taxon	23.64	
EPT Richness 3/0/3	6	
EPT (abundance)	31752.00	
Chiron (abundance)	36933.75	
EPT/Chironomid ratio	0.86	
Scraper (abundance)	1543.50	
Filterer (abundance)	22711.50	
SC/F ratio	0.07	
Shredder (abundance)	2212.35	
SH/Total ratio	0.02	
HBI	6.21	
ICI	42	good

Relative Abundance by Order	
TURBELLARIA	0.36
NEMATODA	0.24
OLIGOCHAETA	15.98
HIRUDINEA	0.00
ISOPODA	0
AMPHIPODA	6.36
DECAPODA	0.00
ACARI	0
COLLEMBOLA	0
EPHEMEROPTERA	32.88
ODONATA	0.00
HEMIPTERA	0.36
TRICHOPTERA	1.68
COLEOPTERA	0.36
DIPTERA	41.41
GASTROPODA	0.36
BIVALVIA	0.00
Totals:	100.00

Density by Order	
TURBELLARIA	331
NEMATODA	221
OLIGOCHAETA	14678
HIRUDINEA	4
ISOPODA	0
AMPHIPODA	5843
DECAPODA	0
ACARI	0
COLLEMBOLA	0
EPHEMEROPTERA	30209
ODONATA	0
HEMIPTERA	331
TRICHOPTERA	1544
COLEOPTERA	331
DIPTERA	38044
GASTROPODA	331
BIVALVIA	0
Totals:	91864

BDC-1.0

Sample Date: 26 October 2016

Taxon	Kick Sample n	N/m^2	Relative Abundance (%)
TURBELLARIA			
Dugesia sp.			
NEMATODA	90	330.75	0.74
OLIGOCHAETA			
Enchytraeidae	30	110.25	0.25
Lumbricidae			
Nais spp.	570	2094.75	4.68
Ophidonais serpentina			
Pristina leidyi			
Pristinella jenkinae	30	110.25	0.25
Tubificidae with hair chaetae	210	771.75	1.72
Tubificidae w/o hair chaetae	600	2205.00	4.93
HIRUDINEA			
Erpobdella punctata			
Mooreobdella microstoma	30	110.25	0.25
AMPHIPODA			
Crangonyx sp.	330	1212.75	2.71
Hyalella azteca			
DECAPODA			
Orconectes sp.			
EPHEMEROPTERA			
Acentrella insignificans			
Baetis tricaudatus	1740	6394.50	14.29
Callibaetis sp.			
Fallceon quilleri	1620	5953.50	13.30
Heptagenia elegantula	60	220.50	0.49
Paracloeodes minutus			
Tricorythodes explicatus	750	2756.25	6.16
ODONATA			
Ophiogomphus severus			
HEMIPTERA			
Microvelia sp.			
Sigara grossolineata			
Trichocorixa borealis			
Trichocorixa calva			
TRICHOPTERA			
Cheumatopsyche sp.	300	1102.50	2.46
Hydropsyche sp.	210	771.75	1.72
Hydroptila sp.	60	220.50	0.49
Oecetis sp.			
COLEOPTERA			
Agabus sp.			

BDC-1.0 (Continued)

Taxon	Kick Sample n	N/m^2	Relative Abundance (%)
DIPTERA			
Brillia sp.			
Caloparyphus sp.			
Ceratopogonidae			
Chironomus sp.	390	1433.25	3.20
Cladotanytarsus sp.	30	110.25	0.25
Cricotopus sp.	1740	6394.50	14.29
Cryptochironomus sp.	300	1102.50	2.46
Dasyhelea sp.			
Dicrotendipes sp.			
Eukiefferiella sp.	30	110.25	0.25
Hemerodromia sp.	30	110.25	0.25
Hydrobaenus sp.	60	220.50	0.49
Limnophyes sp.			
Micropsectra sp.	210	771.75	1.72
Microtendipes sp.	150	551.25	1.23
Nanocladius sp.			
Odontomesa sp.	30	110.25	0.25
Ormosia sp.			
Parakiefferiella sp.	360	1323.00	2.96
Parametriocnemus sp.			
Paraphaenocladius sp.			
Paratanytarsus sp.	300	1102.50	2.46
Phaenopsectra sp.	60	220.50	0.49
Polypedilum sp.	210	771.75	1.72
Procladius sp.			
Pseudosmittia sp.			
Rheocricotopus sp.			
Rheotanytarsus sp.			
Saetheria tylus	300	1102.50	2.46
Simulium vittatum complex	240	882.00	1.97
Stictochironomus sp.	1080	3969.00	8.87
Thienemanniella sp.			
Thienemannimyia group	30	110.25	0.25
Tipula sp.			
Tvetenia sp.			
GASTROPODA			
Ferrissia sp.			
Physidae			
BIVALVIA			
Corbicula sp.			
Pisidium sp.			
Totals:	12180	44761.50	100.00
Total Density (N/m^2)		44762	
Total Number of Taxa		33	
Diversity (d)		4.11	

BDC-1.0

Community Parameters	Kick Sample	
Total Density (N/m^2)	44762	
Diversity (d)	4.11	
Total Number of Taxa	33	
% Dominant Taxon	14.29	
EPT Richness 4/0/3	7	
EPT (abundance)	17419.50	
Chiron (abundance)	19404.00	
EPT/Chironomid ratio	0.90	
Scraper (abundance)	882.00	
Filterer (abundance)	3307.50	
SC/F ratio	0.27	
Shredder (abundance)	7166.25	
SH/Total ratio	0.16	
HBI	6.17	
ICI	34	fair

Relative Abundance by Order	
TURBELLARIA	0.00
NEMATODA	0.74
OLIGOCHAETA	11.82
HIRUDINEA	0.25
ISOPODA	0
AMPHIPODA	2.71
DECAPODA	0.00
ACARI	0
COLLEMBOLA	0
EPHEMEROPTERA	34.24
ODONATA	0.00
HEMIPTERA	0.00
TRICHOPTERA	4.68
COLEOPTERA	0.00
DIPTERA	45.57
GASTROPODA	0.00
BIVALVIA	0.00
Totals:	100.00

Density by Order	
TURBELLARIA	0
NEMATODA	331
OLIGOCHAETA	5292
HIRUDINEA	110
ISOPODA	0
AMPHIPODA	1213
DECAPODA	0
ACARI	0
COLLEMBOLA	0
EPHEMEROPTERA	15325
ODONATA	0
HEMIPTERA	0
TRICHOPTERA	2095
COLEOPTERA	0
DIPTERA	20396
GASTROPODA	0
BIVALVIA	0
Totals:	44762

BDC-1.5C

Sample Date: 26 October 2016

Taxon	Kick Sample n	N/m^2	Relative Abundance (%)
TURBELLARIA			
Dugesia sp.			
NEMATODA	90	330.75	1.19
OLIGOCHAETA			
Enchytraeidae			
Lumbricidae			
Nais spp.	720	2646.00	9.49
Ophidonais serpentina			
Pristina leidyi			
Pristinella jenkinae	15	55.13	0.20
Tubificidae with hair chaetae	90	330.75	1.19
Tubificidae w/o hair chaetae	495	1819.13	6.52
HIRUDINEA			
Erpobdella punctata			
Mooreobdella microstoma			
AMPHIPODA			
Crangonyx sp.	465	1708.88	6.13
Hyalella azteca	75	275.63	0.99
DECAPODA			
Orconectes sp.			
EPHEMEROPTERA			
Acentrella insignificans			
Baetis tricaudatus	15	55.13	0.20
Callibaetis sp.	15	55.13	0.20
Fallceon quilleri	555	2039.63	7.31
Heptagenia elegantula	45	165.38	0.59
Paracloeodes minutus			
Tricorythodes explicatus	510	1874.25	6.72
ODONATA			
Ophiogomphus severus			
HEMIPTERA			
Microvelia sp.			
Sigara grossolineata			
Trichocorixa borealis			
Trichocorixa calva			
TRICHOPTERA			
Cheumatopsyche sp.	60	220.50	0.79
Hydropsyche sp.			
Hydroptila sp.			
Oecetis sp.			
COLEOPTERA			
Agabus sp.			

BDC-1.5C (Continued)

Taxon	Kick Sample n	N/m^2	Relative Abundance (%)
DIPTERA			
Brillia sp.			
Caloparyphus sp.			
Ceratopogonidae			
Chironomus sp.	180	661.50	2.37
Cladotanytarsus sp.	15	55.13	0.20
Cricotopus sp.	1590	5843.25	20.95
Cryptochironomus sp.	300	1102.50	3.95
Dasyhelea sp.			
Dicrotendipes sp.	15	55.13	0.20
Eukiefferiella sp.			
Hemerodromia sp.			
Hydrobaenus sp.	90	330.75	1.19
Limnophyes sp.			
Micropsectra sp.	210	771.75	2.77
Microtendipes sp.			
Nanocladius sp.			
Odontomesa sp.			
Ormosia sp.			
Parakiefferiella sp.	45	165.38	0.59
Parametriocnemus sp.			
Paraphaenocladius sp.			
Paratanytarsus sp.	45	165.38	0.59
Phaenopsectra sp.	15	55.13	0.20
Polypedilum sp.	75	275.63	0.99
Procladius sp.			
Pseudosmittia sp.			
Rheocricotopus sp.			
Rheotanytarsus sp.			
Saetheria tylus	30	110.25	0.40
Simulium vittatum complex	15	55.13	0.20
Stictochironomus sp.	1395	5126.63	18.38
Thienemanniella sp.			
Thienemannimyia group	45	165.38	0.59
Tipula sp.			
Tvetenia sp.	15	55.13	0.20
GASTROPODA			
Ferrissia sp.	360	1323.00	4.74
Physidae			
BIVALVIA			
Corbicula sp.			
Pisidium sp.			
Totals:	7590	27893.25	100.00
Total Density (N/m^2)		27893	
Total Number of Taxa		30	
Diversity (d)		3.71	

BDC-1.5C

Community Parameters	Kick Sample	
Total Density (N/m^2)	27893	
Diversity (d)	3.71	
Total Number of Taxa	30	
% Dominant Taxon	20.95	
EPT Richness 5/0/1	6	
EPT (abundance)	4410.00	
Chiron (abundance)	14938.88	
EPT/Chironomid ratio	0.30	
Scraper (abundance)	1874.25	
Filterer (abundance)	275.63	
SC/F ratio	6.80	
Shredder (abundance)	6118.88	
SH/Total ratio	0.22	
HBI	6.75	
ICI	26	fair

Relative Abundance by Order	
TURBELLARIA	0.00
NEMATODA	1.19
OLIGOCHAETA	17.39
HIRUDINEA	0.00
ISOPODA	0
AMPHIPODA	7.11
DECAPODA	0.00
ACARI	0
COLLEMBOLA	0
EPHEMEROPTERA	15.02
ODONATA	0.00
HEMIPTERA	0.00
TRICHOPTERA	0.79
COLEOPTERA	0.00
DIPTERA	53.75
GASTROPODA	4.74
BIVALVIA	0.00
Totals:	100.00

Density by Order	
TURBELLARIA	0
NEMATODA	331
OLIGOCHAETA	4851
HIRUDINEA	0
ISOPODA	0
AMPHIPODA	1985
DECAPODA	0
ACARI	0
COLLEMBOLA	0
EPHEMEROPTERA	4190
ODONATA	0
HEMIPTERA	0
TRICHOPTERA	221
COLEOPTERA	0
DIPTERA	14994
GASTROPODA	1323
BIVALVIA	0
Totals:	27893

BDC-2.0

Sample Date: 26 October 2016

Taxon	Kick Sample n	N/m^2	Relative Abundance (%)
TURBELLARIA			
Dugesia sp.			
NEMATODA			
OLIGOCHAETA			
Enchytraeidae			
Lumbricidae			
Nais spp.	75	275.63	1.49
Ophidonais serpentina			
Pristina leidyi			
Pristinella jenkinae			
Tubificidae with hair chaetae	60	220.50	1.19
Tubificidae w/o hair chaetae	855	3142.13	16.97
HIRUDINEA			
Erpobdella punctata			
Mooreobdella microstoma			
AMPHIPODA			
Crangonyx sp.	510	1874.25	10.13
Hyalella azteca	60	220.50	1.19
DECAPODA			
Orconectes sp.	6	22.05	0.12
EPHEMEROPTERA			
Acentrella insignificans	30	110.25	0.60
Baetis tricaudatus	60	220.50	1.19
Callibaetis sp.			
Fallceon quilleri	375	1378.13	7.44
Heptagenia elegantula	45	165.38	0.89
Paracloeodes minutus			
Tricorythodes explicatus	645	2370.38	12.81
ODONATA			
Ophiogomphus severus			
HEMIPTERA			
Microvelia sp.	15	55.13	0.30
Sigara grossolineata			
Trichocorixa borealis			
Trichocorixa calva			
TRICHOPTERA			
Cheumatopsyche sp.			
Hydropsyche sp.			
Hydroptila sp.	15	55.13	0.30
Oecetis sp.			
COLEOPTERA			
Agabus sp.			

BDC-2.0 (Continued)

Taxon	Kick Sample n	N/m^2	Relative Abundance (%)
DIPTERA			
Brillia sp.	75	275.63	1.49
Caloparyphus sp.			
Ceratopogonidae			
Chironomus sp.	165	606.38	3.28
Cladotanytarsus sp.	105	385.88	2.08
Cricotopus sp.	1110	4079.25	22.04
Cryptochironomus sp.	15	55.13	0.30
Dasyhelea sp.			
Dicrotendipes sp.			
Eukiefferiella sp.	15	55.13	0.30
Hemerodromia sp.			
Hydrobaenus sp.			
Limnophyes sp.			
Micropsectra sp.	120	441.00	2.38
Microtendipes sp.			
Nanocladius sp.			
Odontomesa sp.			
Ormosia sp.			
Parakiefferiella sp.	45	165.38	0.89
Parametriocnemus sp.			
Paraphaenocladius sp.			
Paratanytarsus sp.			
Phaenopsectra sp.			
Polypedilum sp.			
Procladius sp.			
Pseudosmittia sp.	15	55.13	0.30
Rheocricotopus sp.			
Rheotanytarsus sp.			
Saetheria tylus	30	110.25	0.60
Simulium vittatum complex	375	1378.13	7.44
Stictochironomus sp.	120	441.00	2.38
Thienemanniella sp.	45	165.38	0.89
Thienemannimyia group	30	110.25	0.60
Tipula sp.			
Tvetenia sp.			
GASTROPODA			
Ferrissia sp.	15	55.13	0.30
Physidae			
BIVALVIA			
Corbicula sp.	6	22.05	0.12
Pisidium sp.			
Totals:	5037	18510.98	100.00
Total Density (N/m^2)		18511	
Total Number of Taxa		29	
Diversity (d)		3.62	

BDC-2.0

Community Parameters	Kick Sample	
Total Density (N/m^2)	18511	
Diversity (d)	3.62	
Total Number of Taxa	29	
% Dominant Taxon	22.04	
EPT Richness 5/0/1	6	
EPT (abundance)	4299.75	
Chiron (abundance)	6945.75	
EPT/Chironomid ratio	0.62	
Scraper (abundance)	275.63	
Filterer (abundance)	1400.18	
SC/F ratio	0.20	
Shredder (abundance)	4354.88	
SH/Total ratio	0.24	
HBI	6.74	
ICI	26	fair

Relative Abundance by Order	
TURBELLARIA	0.00
NEMATODA	0.00
OLIGOCHAETA	19.65
HIRUDINEA	0.00
ISOPODA	0
AMPHIPODA	11.32
DECAPODA	0.12
ACARI	0
COLLEMBOLA	0
EPHEMEROPTERA	22.93
ODONATA	0.00
HEMIPTERA	0.30
TRICHOPTERA	0.30
COLEOPTERA	0.00
DIPTERA	44.97
GASTROPODA	0.30
BIVALVIA	0.12
Totals:	100.00

Density by Order	
TURBELLARIA	0
NEMATODA	0
OLIGOCHAETA	3638
HIRUDINEA	0
ISOPODA	0
AMPHIPODA	2095
DECAPODA	22
ACARI	0
COLLEMBOLA	0
EPHEMEROPTERA	4245
ODONATA	0
HEMIPTERA	55
TRICHOPTERA	55
COLEOPTERA	0
DIPTERA	8324
GASTROPODA	55
BIVALVIA	22
Totals:	18511

BDC-3.0

Sample Date: 26 October 2016

Taxon	Kick Sample n	N/m^2	Relative Abundance (%)
TURBELLARIA			
Dugesia sp.	300	1102.50	1.55
NEMATODA			
OLIGOCHAETA			
Enchytraeidae			
Lumbricidae			
Nais spp.	5640	20727.00	29.14
Ophidonais serpentina	30	110.25	0.16
Pristina leidyi	30	110.25	0.16
Pristinella jenkinae			
Tubificidae with hair chaetae	570	2094.75	2.95
Tubificidae w/o hair chaetae	5850	21498.75	30.23
HIRUDINEA			
Erpobdella punctata	1	3.68	0.01
Mooreobdella microstoma			
AMPHIPODA			
Crangonyx sp.	390	1433.25	2.02
Hyalella azteca	120	441.00	0.62
DECAPODA			
Orconectes sp.			
EPHEMEROPTERA			
Acentrella insignificans			
Baetis tricaudatus	90	330.75	0.47
Callibaetis sp.			
Fallceon quilleri	480	1764.00	2.48
Heptagenia elegantula			
Paracloeodes minutus			
Tricorythodes explicatus	1590	5843.25	8.22
ODONATA			
Ophiogomphus severus	1	3.68	0.01
HEMIPTERA			
Microvelia sp.			
Sigara grossolineata			
Trichocorixa borealis			
Trichocorixa calva			
TRICHOPTERA			
Cheumatopsyche sp.	210	771.75	1.09
Hydropsyche sp.	90	330.75	0.47
Hydroptila sp.	90	330.75	0.47
Oecetis sp.			
COLEOPTERA			
Agabus sp.			

BDC-3.0 (Continued)

Taxon	Kick Sample n	N/m^2	Relative Abundance (%)
DIPTERA			
Brillia sp.			
Caloparyphus sp.			
Ceratopogonidae	30	110.25	0.16
Chironomus sp.	60	220.50	0.31
Cladotanytarsus sp.	120	441.00	0.62
Cricotopus sp.	1530	5622.75	7.91
Cryptochironomus sp.	210	771.75	1.09
Dasyhelea sp.			
Dicrotendipes sp.			
Eukiefferiella sp.	30	110.25	0.16
Hemerodromia sp.			
Hydrobaenus sp.	30	110.25	0.16
Limnophyes sp.			
Micropsectra sp.	750	2756.25	3.88
Microtendipes sp.			
Nanocladius sp.	30	110.25	0.16
Odontomesa sp.			
Ormosia sp.			
Parakiefferiella sp.	30	110.25	0.16
Parametriocnemus sp.			
Paraphaenocladius sp.	60	220.50	0.31
Paratanytarsus sp.	30	110.25	0.16
Phaenopsectra sp.			
Polypedilum sp.	150	551.25	0.78
Procladius sp.			
Pseudosmittia sp.			
Rheocricotopus sp.	30	110.25	0.16
Rheotanytarsus sp.	30	110.25	0.16
Saetheria tylus			
Simulium vittatum complex	480	1764.00	2.48
Stictochironomus sp.	120	441.00	0.62
Thienemanniella sp.	90	330.75	0.47
Thienemannimyia group			
Tipula sp.			
Tvetenia sp.	30	110.25	0.16
GASTROPODA			
Ferrissia sp.			
Physidae			
BIVALVIA			
Corbicula sp.			
Pisidium sp.	30	110.25	0.16
Totals:	19352	71118.60	100.00

Total Density (N/m^2)	71119
Total Number of Taxa	36
Diversity (d)	3.13

BDC-3.0

Community Parameters	Kick Sample	
Total Density (N/m^2)	71119	
Diversity (d)	3.13	
Total Number of Taxa	36	
% Dominant Taxon	30.23	
EPT Richness 3/0/3	6	
EPT (abundance)	9371.25	
Chiron (abundance)	12237.75	
EPT/Chironomid ratio	0.77	
Scraper (abundance)	441.00	
Filterer (abundance)	3087.00	
SC/F ratio	0.14	
Shredder (abundance)	6174.00	
SH/Total ratio	0.09	
HBI	8.10	
ICI	24	fair

Relative Abundance by Order	
TURBELLARIA	1.55
NEMATODA	0.00
OLIGOCHAETA	62.63
HIRUDINEA	0.01
ISOPODA	0
AMPHIPODA	2.64
DECAPODA	0.00
ACARI	0
COLLEMBOLA	0
EPHEMEROPTERA	11.16
ODONATA	0.01
HEMIPTERA	0.00
TRICHOPTERA	2.02
COLEOPTERA	0.00
DIPTERA	19.84
GASTROPODA	0.00
BIVALVIA	0.16
Totals:	100.00

Density by Order	
TURBELLARIA	1103
NEMATODA	0
OLIGOCHAETA	44541
HIRUDINEA	4
ISOPODA	0
AMPHIPODA	1874
DECAPODA	0
ACARI	0
COLLEMBOLA	0
EPHEMEROPTERA	7938
ODONATA	4
HEMIPTERA	0
TRICHOPTERA	1433
COLEOPTERA	0
DIPTERA	14112
GASTROPODA	0
BIVALVIA	110
Totals:	71119

BDC-5.0

Sample Date: 26 October 2016

Taxon	Kick Sample n	Kick Sample N/m^2	Relative Abundance (%)
TURBELLARIA			
Dugesia sp.			
NEMATODA			
OLIGOCHAETA			
Enchytraeidae	90	330.75	0.63
Lumbricidae			
Nais spp.	9120	33516.00	64.00
Ophidonais serpentina			
Pristina leidyi			
Pristinella jenkinae			
Tubificidae with hair chaetae	90	330.75	0.63
Tubificidae w/o hair chaetae	390	1433.25	2.74
HIRUDINEA			
Erpobdella punctata			
Mooreobdella microstoma			
AMPHIPODA			
Crangonyx sp.	150	551.25	1.05
Hyalella azteca	840	3087.00	5.89
DECAPODA			
Orconectes sp.			
EPHEMEROPTERA			
Acentrella insignificans			
Baetis tricaudatus			
Callibaetis sp.			
Fallceon quilleri	30	110.25	0.21
Heptagenia elegantula	30	110.25	0.21
Paracloeodes minutus	240	882.00	1.68
Tricorythodes explicatus	210	771.75	1.47
ODONATA			
Ophiogomphus severus			
HEMIPTERA			
Microvelia sp.			
Sigara grossolineata			
Trichocorixa borealis			
Trichocorixa calva			
TRICHOPTERA			
Cheumatopsyche sp.			
Hydropsyche sp.			
Hydroptila sp.			
Oecetis sp.			
COLEOPTERA			
Agabus sp.			

BDC-5.0 (Continued)

Taxon	Kick Sample n	N/m^2	Relative Abundance (%)
DIPTERA			
Brillia sp.			
Caloparyphus sp.			
Ceratopogonidae	30	110.25	0.21
Chironomus sp.	750	2756.25	5.26
Cladotanytarsus sp.	150	551.25	1.05
Cricotopus sp.	810	2976.75	5.68
Cryptochironomus sp.	30	110.25	0.21
Dasyhelea sp.	30	110.25	0.21
Dicrotendipes sp.			
Eukiefferiella sp.			
Hemerodromia sp.			
Hydrobaenus sp.			
Limnophyes sp.	30	110.25	0.21
Micropsectra sp.	450	1653.75	3.16
Microtendipes sp.			
Nanocladius sp.			
Odontomesa sp.			
Ormosia sp.	240	882.00	1.68
Parakiefferiella sp.			
Parametriocnemus sp.			
Paraphaenocladius sp.			
Paratanytarsus sp.	30	110.25	0.21
Phaenopsectra sp.			
Polypedilum sp.	30	110.25	0.21
Procladius sp.			
Pseudosmittia sp.			
Rheocricotopus sp.			
Rheotanytarsus sp.			
Saetheria tylus			
Simulium vittatum complex	30	110.25	0.21
Stictochironomus sp.	420	1543.50	2.95
Thienemanniella sp.	30	110.25	0.21
Thienemannimyia group			
Tipula sp.			
Tvetenia sp.			
GASTROPODA			
Ferrissia sp.			
Physidae			
BIVALVIA			
Corbicula sp.			
Pisidium sp.			
Totals:	14250	52368.75	100.00

Total Density (N/m^2)	52369
Total Number of Taxa	24
Diversity (d)	2.27

BDC-5.0

Community Parameters	Kick Sample	
Total Density (N/m^2)	52369	
Diversity (d)	2.27	
Total Number of Taxa	24	
% Dominant Taxon	64.00	
EPT Richness 4/0/0	4	
EPT (abundance)	1874.25	
Chiron (abundance)	10032.75	
EPT/Chironomid ratio	0.19	
Scraper (abundance)	992.25	
Filterer (abundance)	110.25	
SC/F ratio	9.00	
Shredder (abundance)	3087.00	
SH/Total ratio	0.06	
HBI	8.47	
ICI	12	poor

Relative Abundance by Order	
TURBELLARIA	0.00
NEMATODA	0.00
OLIGOCHAETA	68.00
HIRUDINEA	0.00
ISOPODA	0
AMPHIPODA	6.95
DECAPODA	0.00
ACARI	0
COLLEMBOLA	0
EPHEMEROPTERA	3.58
ODONATA	0.00
HEMIPTERA	0.00
TRICHOPTERA	0.00
COLEOPTERA	0.00
DIPTERA	21.47
GASTROPODA	0.00
BIVALVIA	0.00
Totals:	100.00

Density by Order	
TURBELLARIA	0
NEMATODA	0
OLIGOCHAETA	35611
HIRUDINEA	0
ISOPODA	0
AMPHIPODA	3638
DECAPODA	0
ACARI	0
COLLEMBOLA	0
EPHEMEROPTERA	1874
ODONATA	0
HEMIPTERA	0
TRICHOPTERA	0
COLEOPTERA	0
DIPTERA	11246
GASTROPODA	0
BIVALVIA	0
Totals:	52369