The relationships between benthic macroinvertebrate and local water quality and physical habitat characteristics in the Rio Chama, New Mexico

by

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Abstract

Incorporating the process of adaptive management in rivers management can assist with mitigating impacts of altered streamflow and prevent loss of aquatic biodiversity. Streamflow regimes are important drivers of stream ecology and structuring adaptive management around benthic macroinvertebrates could be an efficient means to understand ecological responses to management of streamflow regime. Over the past decade, there has been interest in implementing adaptive management practices to managing stream flow in the Rio Chama below El Vado Dam in northern New Mexico. The goal of this research project is to improve understanding of environmental drivers shape the benthic macroinvertebrate communities in the Rio Chama below El Vado Dam, with the objectives of 1) assessing which water quality and physical habitat parameters may be driving the macroinvertebrate community structure in riffle habitats; 2) exploring differences between macroinvertebrate communities, water quality, and physical habitat parameters between sites below El Vado Dam and reference sites above the dam; and 3) examining how the water quality and physical habitat varies longitudinally downstream below El Vado Dam, and how that variability may impact macroinvertebrate community dynamics. Benthic macroinvertebrate, water quality, and physical habitat samples were collected from June 17- 23, 2018. Results showed that there was a dominance of slightly tolerant to tolerant taxa (name), as well as a dominance of collector-gatherer taxa (add name) at study and reference sites. the presence of these taxa indicated some impairment from turbidity and fine sediment is occurring in both study and reference reaches in the Rio Chama. These results provide insights about biological structure in the Rio Chama which may reduce some uncertainty in implementing adaptive management of the stream flow regime on the Rio Chama below El Vado Dam.

Introduction

Adaptive management in rivers with altered streamflow regime can benefit stream ecology (King 2009, Wyatt et al. 2011). Adaptive management is an iterative process that is structured around reducing uncertainty and continually modifying and adapting policies and management around lessons learned (Walters 1986). Streamflow reductions, as a result of climate change and dam operations, in aridland regions are putting streams at risk of alterations and declines of freshwater biodiversity (Ruhí et al. 2016). Adaptive management of streamflow can be incorporated by altering and adapting specific aspects of a streamflow regime (i.e. magnitude, frequency, timing, duration, rate of change), which can provide managers the tools to mitigate impacts and prevent loss of aquatic freshwater biodiversity (Poff 1997, Wyatt et al. 2011, Schülting et al. 2018). Adaptive management programs can be strategically designed around recovery of species and/or ecosystem restoration (Thom et al. 2016). Streamflow regime can impact stream ecology in terms of water quality, physical habitat, biotic interactions, and food-web dynamics (Poff et al. 1997). The complexity of how streamflow regimes interact with stream biology can make adaptively managing streamflow for aquatic biodiversity a challenge (Davies et al. 2014).

Adaptive management of streamflow regime can be designed to positively impact macroinvertebrate community parameters, including richness, abundance and diversity (Kail et al. 2015). Structuring adaptive management around benthic macroinvertebrates can be an efficient means to understand a number of ecological responses to modification of altered streamflow regime, including changes in water quality, physical habitat, biotic interactions, and food-web dynamics. Macroinvertebrates have various life-history requirements regarding water quality, with some taxa more or less tolerant to impairments of water quality; therefore, macroinvertebrate community dynamics can signal short-term and long-term water quality conditions occurring in streams (Lenat 1988, Xu et al. 2014, Damanik-Ambarita et al. 2016, Smith et al. 2019). Similarly, different macroinvertebrate taxa need specific habitat characteristics (e.g., coarse substrate, sediment, velocity, vegetation) to reproduce and acquire food resources (Voshell 2002, Larsen et al. 2011, and Zhou et al. 2019). Water quality levels and physical habitat availability can have cascading effects on biotic interactions (e.g. competition, predator-prey relationships) occurring among the macroinvertebrate community (Clements 1999, Colas et al. 2014). Water quality and physical habitat impacts on benthic macroinvertebrate communities can have consequences on food-web dynamics in stream ecosystems. Macroinvertebrates enable energy flows within aquatic food webs by helping break down and cycle organic matter and nutrients into secondary production. Different invertebrate taxa process different types of organic matter and/or nutrients (Covich et al. 1999, Voshell 2002, Huryn et al. 2008). Consequently, monitoring macroinvertebrates can provide considerable information about stream ecosystems and aid in the implementation and assessment of adaptive management of altered streamflow regime (Wyatt et al. 2011).

Adaptive management of streamflow regime could be implemented in the Rio Chama, a river that is impacted by an altered streamflow regime and subsequent sedimentation issues that are exacerbated in years with reduced annual streamflow. Over the past decade, there has been interest in incorporating adaptive management of streamflow as a mechanism to benefit the Rio Chama ecosystem in the reach between El Vado Dam and Abiquiu Reservoir, in northern New Mexico (Figure 1). Management of streamflow in the reach between El Vado Dam and Abiquiu Reservoir, is largely shaped by delivery demands for agricultural and municipal water, as well as compact deliveries, altering the natural streamflow regime. Further modifying the streamflow regime in this reach is the addition of 118 cubic hectometers per year (hm^3/year) of San Juan Chama Project (SJCP) water for additional agricultural and municipal water needs downstream The potential for adaptive management of Rio Chama streamflow was highlighted in 2009 when unusually high spring temperatures caused rapid snowmelt and precipitation in the forecast necessitated an emergency release of 159 cubic meters per second (m^3/s) from El Vado Reservoir, which had not occurred in over 30 years (Harm-Benson et al. 2013, Bean 2018). Mobilized sediment and altered channel geomorphology resulting from high flows led stakeholders to assess what type of ecological benefits could be achieved by adapting streamflow to have a greater magnitude of the spring runoff peak below El Vado Dam (Bean 2018). Four flow alternative recommendations were developed by stake holders in 2013, which included 1) a peak flow of 170 m^3/s every 10 years to reconnect the floodplain to the main channel , 2) a discharge of 127 m^3/s every three to five years to encourage riparian growth by overbanking flows, 3) a discharge of 71 m^3/s every two years to provide maximum geomorphic disturbance to flush sediments within the channel , and 4) a steady base flow of at least 3 m^3/s to reduce loss of brown trout habitat (Morrison and Stone 2015). In 2014, an experimental peak flow release of approximately 58 m^3/s was released to validate flow alternative recommendation #3 for geomorphic disturbance and fine sediment flushing (Gregory et al. 2018). The experimental flow release was shown to generate suitable conditions to provide adequate shear stresses to mobilize fine sediments (i.e. particles ≤ 5 millimeters [mm]) (Gregory et al. 2018); however, it remains unclear how stream biota and stream ecology were impacted from that peak flow event.

Macroinvertebrate monitoring has been implemented on the Rio Chama a number of times over the past 30 years, showing communities potentially impacted by sediment impairment. Continued monitoring and analysis of macroinvertebrate communities has the potential to assist water managers in assessing the outcomes of adaptive management of streamflow regime in the Rio Chama, below El Vado Dam. When choosing an adaptive management approach, decisions should be made based on the current level of understanding and anticipated consequences of management actions (Williams and Brown 2014). Two baseline studies of macroinvertebrate communities residing in the Rio Chama below El Vado Dam have been conducted to examine the macroinvertebrate community, with some consideration of environmental drivers. Jacobi and McGuire (1992) sampled four sites below El Vado Dam in 1991. The community was dominated by Chironomidae (midges) taxa and the species *Baetis tricaudatus* (mayfly). Based on their results of their macroinvertebrate community analyses, the authors hypothesized that the sites sampled were somewhat impaired to moderately impaired by localized sediment scour and/or sediment accumulation on substrates (Jacobi and McGuire 1992). The Bureau of Land Management (BLM) also implemented macroinvertebrate monitoring at five sites below El Vado Dam (2011-2013, 2015) to investigate the macroinvertebrate community and potential impairment due to the altered flow regime that is a result of water management and operation of El Vado Dam and Reservoir, with the objective of providing recommendations on dam operations. The BLM monitoring results were similar to the 1991 study results, with the macroinvertebrate community dominated by Chironomidae taxa. Flow varied somewhat among sampling events (approximate range: 1.4 m^3/s – 5.7 m^3/s) and there were significant differences in abundance among some sites and some years. However, not every site was sampled each year and the researchers did not assess how streamflow may have impacted the differences in invertebrate abundance (BLM 2018). Although there is baseline information about the macroinvertebrate community, the current level of understanding of how water quality and physical habitat drive the macroinvertebrate community needs to be improved prior to implementing adaptive management of streamflow in the Rio Chama to benefit the stream ecosystem.

The goal of this research project is to improve understanding of how streamflow, water quality, and physical habitat shape benthic macroinvertebrates communities in the Rio Chama, below El Vado Dam, in northern New Mexico, with the objectives of 1) assessing which water quality and physical habitat parameters may be driving the macroinvertebrate community in riffle habitats; 2) exploring differences between macroinvertebrate communities, water quality, and physical habitat parameters between sites below El Vado Dam and reference sites above the dam; and 3) examining how water quality and physical habitat varies longitudinally downstream below El Vado Dam, and how that variability may impact macroinvertebrate community dynamics. The following hypotheses were tested:

> (i) Fine sediment deposition at each site, will be the dominant parameter that is driving macroinvertebrate community dynamics based on the range of taxa that have life history requirements more or less tolerant of fine sediment.
>
> (ii) Sample sites below El Vado Dam will have macroinvertebrate taxa that are more indicative of stream impairment compared to reference sites, due to the altered flow regime below El Vado Dam.

(iii) Taxa richness of macroinvertebrate communities at each site closer to the outflow of El Vado Dam, will be lower than that of sites farther downstream of El Vado Dam, because water quality and physical habitat conditions directly downstream are more stable and reflective of conditions occurring in El Vado Reservoir versus the Rio Chama.

Materials and Methods

Study Area

The Rio Chama originates in southern Colorado, flows into northern New Mexico and eventually converges with the Rio Grande as the Rio Grande's largest tributary. The climate is semi-arid, with average air temperatures ranging from approximately 27.2 degrees Celsius (°C) in summer to approximately 3.9 °C in winter. The region experiences an average annual precipitation of approximately 60 centimeters (cm) per year (U.S. Climate Data 2020).

The 30-year average annual flow volume in the study reach below El Vado (Rio Chama Below El Vado U.S Geological Survey Gage; USGS gage #08285500) is approximately 388 hm^3/year, whereas the average annual flow volume above the study reach at the USGS Rio Chama Near La Puente Gage (gage #08284100) is approximately 280hm^3/year (estimated from downloaded USGS flow gage data). The greater volume of water in the study reach is a result of the addition of SJCP water. The study reach has a number of arroyo tributaries; during summer monsoon and precipitation events, additional stream flow from arroyo tributaries deliver sediment (Fogg et al. 1992, Swanson 2012).

The study reach experiences several sources of sediment that impact turbidity, channel geometry and substrate characteristics. El Vado Reservoir releases result in high turbidity conditions within the study reach (Fogg 1992). Within the reach below El Vado, there are a number of tributaries that alter channel geometry and sediment characteristics (Fogg et al. 1992, Swanson and Meyer 2014). The tributaries increase streamflow but also deliver large quantities of sediment from erodible Mancos Group Shale during summer monsoon and precipitation events (Swanson 2012, Swanson and Meyer 2014). To flush sediment, it was determined by a panel of experts that flows of minimum of 58 m^3/s were necessary for transporting sediment downstream, as determined in a Rio Chama flow workshop in 2013. Gregory et al. (2018) demonstrated that a flow volume of 56 m^3/s was sufficient to initiate insipient motion and flush fine sediment. Larger debris brought in by tributaries may require higher flow volumes to initiate incipient motion depending on location and substrate size (Gregory 2013).

Sampling occurred at 12 transects on the Rio Chama once during the time frame from June 17 to 23 2018. Two transects (#1 and #2) were sampled above of the outlet of Heron Reservoir where the additional SJCP water supply is conveyed into the Rio Chama (reference), and ten transects (#3 through #12) were sampled within the reach between El Vado and Abiquiu (study reach) (Figure 2). Transects were placed across instream riffle habitats, and each transect contained three sampling sites (Table 1). Transects were systematically located within the study reach, extending from the outflow of El Vado Dam to just above the inflow of the Rio Gallina tributary. The location of transects were designed to capture the longitudinal environmental gradient of riffle habitats in the Rio Chama below El Vado Dam. Several transects were placed above and below the Rio Nutrias, Arroyo del Puerto Chiquito, and the Rio Cebolla tributaries to assess how those tributaries may impact the longitudinal environmental gradient within the study reach (Figure 2).

Sampling occurred in an extremely dry year with low water in the Rio Chama and surrounding Rio Grande Basin, where there was no spring flood pulse in the study reach (Figure 3). The annual volume during 2018 for the study reach was similar to the 30-year average with a magnitude of 393 $hm^3/year$. In contrast, the annual volume in 2018 for reference sites, located above the study reach, was 110 $hm^3/year$, or approximately 39 percent of the average. Streamflow during the study period ranged from approximately 0.6 m^3/s to 1.7 m^3/s at the Rio Chama Near La Puente Gage (USGS gage #08284100), in comparison to a range of 15.5 m^3/s to 21.5 m^3/s at the Rio Chama Below El Vado Gage (USGS #0828550).

Water Quality

Temperature (°C), dissolved oxygen (DO; mg/L and %), pH. specific conductivity (µS/cm) and total dissolved solids (TDS; mg/L), were measured at each site, using a handheld YSI Model 556 multiparameter meter. A 125 mL sample of water was collected at each site to assess anion concentrations (Cl^-, NO_2^-, NO_3^-, Br^-, PO_4^{3-}, and SO_4^{2-}). Samples were filtered with a glass fiber filter (0.7 µm pore size). Anion concentrations (mg/L) were analyzed at the University of New Mexico (UNM) Analytical Chemistry lab using Dionex ion chromatography.

Physical Parameters

Velocity (m/s) and depth (cm) were measured at each site using a SonTeck Acoustic Doppler Velocimeter. Substrate conditions were analyzed at each transect. For coarse substrate, a pebble count at each transect was performed using the standard Wolman method, where 100 rocks are randomly selected from the riffle and measured across the intermediate axis (Wolman 1954). The particle size representing the median cumulative percentile value (D_{50}) was calculated in the field. Water turbidity (NTU) was measured in the field at each transect using a LaMotte 2020 EW turbidity meter. The amount of fine sediment in the bed of the river at each site was measured using the Quorer method for determining resuspended sediment (Quinn et al. 1997). To assess resuspended sediment, polyvinyl chloride (PVC) pipe that was 32 cm in height and had a diameter of 24 cm, was placed at each site on the bed of the river. The PVC pipe was pushed down into the substrate to create a seal, preventing water from moving in or out of the PVC thus creating a stilling well. The substrate within the PVC pipe was agitated for approximately one minute and an additional 125 mL sample of water post sediment resuspension was collected. Five water depth measurements within the PVC sampler were made before (background) and after sediment resuspension, enabling an estimate of the volume of fine sediment resuspended.

The samples were placed in a cooler and were dried and weighed at a UNM laboratory. Once the samples were dried and weighed, the amounts of resuspended fine sediment in the 125 mL background and resuspension samples were expanded to the volume of the cylinder, and the background amount of sediment in the stream was subtracted from the amount of fine sediment in the cylinder using the following equations (modified from Quinn et al. 1997):

Background:

$$\frac{w_{pre}}{125(cm^3)} = \frac{x_{pre}}{\pi r^2 \bar{d}_{pre}}$$

Resuspended (total):

$$\frac{w_{post}}{125(cm^3)} = \frac{x_{post}}{\pi r^2 \bar{d}_{post}}$$

Resuspended (corrected for background):

$$x_{post} - x_{pre}$$

Where w_{pre} and w_{post} are the weight of the background and resuspended sample (mg); *r* is the radius of the cylinder, $\bar{d}_{pre}$ and $\bar{d}_{post}$ are the average of the five depth measurements pre-and-post resuspension (cm), and x_{pre} and x_{post} are the weight per volume of resuspended sediment (mg/mL), solved for in both equations. Once samples were dried, the remaining sample was ashed to determine the amount of inorganic material in each sample. The remaining inorganic material was subtracted from the initial dry weight to calculate ash free dry weight (AFDW), which is then quantified as a percentage (Lamberti et al. 2006).

Macroinvertebrate Parameters

Macroinvertebrates were sampled using a Surber sampler, (mesh size 500 µm, sampling area 0.093 m^2). Once the Surber sampler was placed in the substrate with the open net facing upstream, the rocks within the delineated sample area were scrubbed for a total of 4 minutes and the remaining bed material was agitated for a total of 1 minute. Macroinvertebrate samples were preserved in 10% formalin in the field, and were subsequently rinsed and preserved in 70% ethanol once back in the lab. Macroinvertebrate samples were hand-picked in their entirety and taxa were identified to either order, family, or genus. These invertebrate taxa (individual/m^2) collected from each site were placed into the following metrics commonly used in benthic macroinvertebrate studies (Voshell 2002, Jacobi et al. 2006, Merritt et al. 2008):

- Taxonomic richness – counts of distinct taxa within selected taxonomic groups.
- Taxonomic evenness – measure of how evenly taxa are distributed within a sample.
- EPT richness – the richness of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), collectively referred to as EPT. These taxa are generally considered sensitive to impairment.
- Chironomidae richness – the richness of Chironomidae taxa, which are generally considered tolerant to impairment.
- Hilsenhoff Biotic Index (HBI) score – a metric used to identify the overall community tolerance to impairment within a sample. The HBI score ranges from 0 – 10, or excellent to very poor, and indicates the level of stream impairment likely occurring (Hilsenhoff 1988).
- Functional feeding group (FFG) – the classification of taxa by the mode of feeding that is based on morphology and the mechanism or locomotion adapted for acquiring food resources (Table 2).

Data Analysis

To characterize the relationship between macroinvertebrate community composition and the local water quality and physical habitat conditions, non-metric multidimensional scaling (NMDS) and negative binomial regression modelling was used. NMDS was done using the ‘metaMDS’ function, and the parameters sampled, which are continuous variables, were plotted over the ordination space as vectors using the ‘envfit’ function in the *vegan* (Oksanen et al. 2019) package in R statistical software (R Core Team 2020). Rare taxa were excluded from the analysis (~ 99% of taxa representation from all samples included in analysis). The continuous abiotic variable vectors fitted on top of the ordination represent environmental gradients, or the parameters sampled in this analysis. The direction of the arrows represents the direction of the gradient, or the direction in which the parameter is maximized. The length of the arrow represents the strength of the gradient, or the correlation between ordination and environmental variables.

Macroinvertebrate count data were often zero-inflated and had high variance compared to the mean; therefore, negative binomial regression modelling was used to model relationships for several macroinvertebrate metrics and environmental variables. Bayesian inference was used to estimate model parameters. A negative binomial regression model was fit using the ‘glm’ function in the *MASS* package (Ripley et al. 2020) in R statistical software (R Core Team 2020). The ‘dredge’ function was used to perform model selection, ranked by Akaike’s information criterion (AIC), and the ‘model.avg’ function to calculate model-averaged parameter estimates with standard errors and 95% confidence intervals. Both functions are within the *MuMin* (Bartoń 2020) package in R statistical software (R Core Team 2020). Because the parameters are measured in different units, each parameter was scaled in the model. In this analysis, a one-unit increase in the independent variable of parameter sampled, is expected to either increase or decrease the log count of the dependent variable (i.e., the metric). Parameters shown with points above the zero-estimate line cause the count of the dependent variable to increase; whereas those below, cause the count to decrease. If the parameter is plotted on the zero-estimate line, then it does not have a significant impact to the count either way. Similarly, if the 95% confidence-interval crosses the zero-estimate line, then the impact is uncertain and there is no statistical significance in the results.

Spatial trend analysis was used to explore how macroinvertebrate community composition, in addition to physical and chemical parameters, varied in the transects moving longitudinally from upstream to downstream. The spatial trend analysis was done solely within the study reach, and was done using R Core statistical software (R Core Team 2020; R software). A Kruskal-Wallis non-parametric test was used to explore the difference in ranks for the composition of EPT, Chironomidae, and FFGs, as well as water quality and physical habitat parameters between reference sites and study sites. The null-hypothesis of the Kruskal-Wallis test is that the mean ranks of two groups are the same, and the null hypothesis is rejected if the mean ranks of the two groups are not the same (p-value <0.5 is significant) (McDonald 2014). The Kruskal-Wallis analysis was done using the 'kruskal.test' function in the *PMCMRplus* package (Pohlert 2020) in R statistical software (R Core Team 2020).

Results

Water Quality

Temperature ranged from 14.1 °C to 19.3 °C, with a mean of 16.3°C. There was a significant difference in the mean rank temperature at reference sites compared to study sites (p-value < 0.05)(Table 3). Dissolved oxygen ranged from 8.0 mg/L to 9.1 mg/L and 80.7 percent to 98.3 percent saturation, with a mean of 8.7 mg/L and 88.2 percent saturation. The value of pH ranged from 7.67 to 8.69, with a mean of 8.04. There was a significant difference in the mean ranks for pH at reference sites compared to study sites (p-value $<< 0.05$)(Table 3). Specific conductivity ranged from 190 µS/cm to 261 µS/cm, with a mean of 208 µS/cm. There was a significant difference in the mean ranks for specific conductivity at reference sites compared to study sites (p-value $<< 0.05$) (Table 3). Total dissolved solids ranged from 123 mg/L to 169 mg/L, with a mean of 135 mg/L. There was a significant difference in the mean ranks for TDS at reference sites compared to study sites (p-value << 0.05)(Table 3). Of the cations assessed (Cl^-, NO_2^-, NO_3^-, Br^-, PO_4^{3-}, and SO_4^{2-}), Br^- and PO_4^{3-} were not detected at any sites, and NO_2^- was found at only four out of 36 sites. Full water quality results are available in Appendix A (Table 1.A).

Physical Habitat

Velocity measurements ranged from 0.02 m/s to 0.67 m/s, with a mean of 0.28 m/s. Depth at each site ranged from 8 cm to 30 cm (maximum depth constrained to height of the Surber sampler [0.32 cm]), with an average depth of 17 cm. The median (D_{50}) grain size from the pebble count sampled across each transect, ranged from 24.9 mm to 73 mm, with an average D_{50} of 51 mm. Turbidity at each transect ranged from 3.7 NTU to 65 NTU, with an average of 44 NTU. There was a significant difference in the mean ranks for turbidity between reference sites and study sites (p-value << 0.05)(Table 3). The mean turbidity for the reference transects was 5.7 NTU, compared to 52 NTU at study sites. Resuspended sediment at each site ranged from 2.3 mg/L to 274.9 mg/L, with a mean of 79.3 mg/L. There was a significant difference in the mean ranks for resuspended sediment between reference sites and study sites (p-value << 0.05)(Table 3). The mean amount of resuspended sediment at reference sites was 15.6 mg/L, compared to 92.0 mg/L at study sites. The percent of AFDW ranged from 50.1 percent to 59.6 percent, with a mean of 50.6 percent. There was a significant difference in the mean ranks for percent AFDW at study sites compared to reference sites (p-value < 0.05)(Table 3); however, the mean value for AFDW at reference sites was 54.2 percent at reference sites, compared to a mean of 50.9 percent at study sites. Full physical habitat data are available in Appendix A (Table A.2).

Macroinvertebrate Community

There was a total of 27,584 macroinvertebrate individuals counted from all 12 transects, which were subsequently identified to 21 taxa. The number of taxa inhabiting each site ranged from 8 to 21 taxa, with a mean number of taxa of 15. The dominant taxa for all sites combined was *Baetis* spp., from the Order Ephemeroptera (mayflies). The average HBI score was 4.46, which is rated as “Good,” and indicates some minor water quality or physical habitat impairment. Slightly tolerant to tolerant taxa dominated the taxa found, with a dominance of approximately 69 percent. Collector-gatherers were the most abundant functional feeding group at 80 percent of the total taxa count. Full benthic macroinvertebrate results are available in Appendix A (Table A.3).

Macroinvertebrate interactions with water quality and physical habitat

Displaying the macroinvertebrate taxa and sites as a dissimilarity matrix with 3 dimensions (k=3) in 2-dimensional space through NMDS ordination indicated some taxa with potentially similar life-history requirements and sites with similar environmental characteristics through clustering (Figure 4). Several water quality environmental variables overlaid on top of the ordination results were correlated to specific macroinvertebrate taxa based on arrow direction and length. The DO environmental vector was strongly correlated to *Ephemerella* (p-value <0.05), a mayfly genus associated with pristine water quality environments and classified as a collector-gatherer (Lenat 1993, Barbour et al. 1999). The water quality vector for TDS was strongly correlated with reference sites and *Paraleptophlebia* (p-value <0.05), a mayfly genus associated with pristine water quality environments and classified as a facultative shredder that is capable of acquiring food resources as a collector-gatherer (Lenat 1993, Merritt et al. 2008). The pH environmental variable was strongly correlated with Hydropsychidae (p-value <0.05), a mayfly family classified as slightly sensitive and capable of withstanding some water quality or physical habitat impairment, and classified as a collector-filterer (Voshell 2002, Merrit et al. 2008). Resuspended sediment was correlated with Nematoda, *Simulium.*, and *Tricorythodes* (p-value <0.05). Nematoda is the phylum of roundworms that represents a diverse group of organisms that are generally associated with stream impairment (Schmidt-Rhaesa 2014). *Simulium* is a genus of blackfly larvae that is associated with moderate levels of impairment, and classified as a filter-feeder (Voshell 2002). *Tricorythodes* is a genus of mayfly that is tolerant of sediment and is classified as a collector-gatherer (Jacobi and McGuire 1992, Merritt et al. 2008).

Negative binomial regression modeling results signaled several water quality and physical habitat variables that impact a number of metrics, including EPT richness, Chironomidae richness, and FFGs, found at each site or transect. The number of EPT taxa found at each site was positively associated with an increasing D_{50} (p-value < 0.05), but negatively associated with an increase in DO concentration levels (p-value < 0.05)(Figure 5a). No water quality or physical habitat parameters were shown to have a significant influence on the number of Chironomidae taxa found at each site (Figure 5b). The parameters that had a significantly negative impact on the number of collector-filters were resuspended fine sediment (p-value < 0.05) and turbidity (p-value = 0.05)(Figure 5c). There were no water quality or physical habitat parameters shown to have a significant impact on the number of collector-gatherers (Figure 5d). Increases in the magnitude of velocity ($p < 0.05$) and D_{50} ($p < 0.05$) had a significant positive impact the number of shredder taxa (Figure 5e). For scraper taxa, increases in the size of D_{50} (p-value < 0.05) had a significant negative impact on their numbers (Figure 5f).

Macroinvertebrate community at Reference sites compared to Study sites

The dominant taxon within the study reach was *Baetis* spp. (35%), followed by Chironomidae (21%), from the Order Diptera (true flies). In contrast, the dominant taxon at reference transects was Hydropsychidae (27%), from the Order Trichoptera (caddisflies), followed by Chironomidae (26%) (Figure 6). There was a significant difference in the mean ranks for taxa evenness between reference sites and study (p-value << 0.05)(Table 4). The average taxa evenness at reference sites was 0.69 (range: 0 – 1), compared to an average of 0.58 at study sites. Slightly tolerant to tolerant taxa were dominant at both reference sites and study sites. The average HBI score at both reference sites and study sites was approximately 4.5; however, the HBI score at reference sites ranged from 4.2 to 4.8, whereas the HBI score at study sites had a greater range, extending from 3.0 to 7.2.

Evenness of FFG composition as a whole, also differed between reference sites and study sites (Figure 7a – 7b). There was a significant difference in mean ranks between percent composition of collector-filterers at reference sites compared to study sites (p-value << 0.05)(Table 4). The average percent composition of collector-filterer taxa for reference sites was 29.6 percent, compared to 4.8 percent at study sites. There was significant difference in the mean ranks for the percent composition of collector-gatherer taxa at reference sites compared to study sites (p-value << 0.05)(Table 4). The average percent composition of collector-gather taxa at reference sites was 49.9 percent, compared to an average of 84.5 percent at study sites. There was a significant difference in the mean rank value for the percent composition of scraper taxa between reference sites and study sites (p-value = 0.05)(Table 4). The average percent composition of scraper taxa at reference sites was 10.7 percent, compared to an average percent composition of 5.8 percent at study sites. Finally, the Kruskal-Wallis test showed a significant difference in the means of the percent composition of predator taxa at reference sites compared to study sites (p-value < 0.05). The average percent composition of predator taxa was 8.4 percent at reference sites compared to an average of 3.2 percent at study sites.

The NMDS ordination results demonstrated that reference sites (#1 – #6) were more similar to one another compared to study sites (Figure 4). The taxa that were plotted in similar ordination space with reference sites were *Paraleptophlebia*, Hydropsychidae, *Glossosoma*, and Perlodidae. The genus *Glossosoma*, is a caddisfly associated with pristine water quality environments and is classified as a scraper (Lenat 1993, McNeely et al. 2006). Increasing concentration of TDS was strongly correlated with reference site samples. In contrast, turbidity is strongly correlated with study site samples.

Longitudinal trends of macroinvertebrate community dynamics in the Study Reach

Several of the macroinvertebrate metrics analyzed displayed increasing or decreasing longitudinal trends moving from upstream, near El Vado Dam, to downstream within the study reach. The metrics that had an increasing trend moving from upstream to downstream were taxa richness, taxa evenness, HBI score, and the percent composition of collector-gather taxa, predator taxa, and Chironomidae taxa. The metrics that displayed a decreasing trend moving from upstream to downstream were the percent composition of EPT taxa, collector-filterer taxa, and shredder taxa. The percent composition of scrapers did not demonstrate an increasing or decreasing trend moving from upstream to downstream within the study reach.

The NMDS ordination results yielded some insights about how site similarity changes moving longitudinally from upstream to downstream within the study reach. Sites within transect 3 (#7 - #9), located below El Vado Dam, demonstrated the greatest dissimilarity in ordination space (Figure 4). Transects 4 – 8 and transects 9 – 12, demonstrated a split at the 0.0 value on axis 1 (NMDS1), with transects 4 – 8 located to the right and transects 9 – 12 located to the left. Transects 9 – 12 were more similar in ordination space, demonstrated through tighter clustering.

Discussion

The macroinvertebrate community at study sites were dominated by *Baetis* spp., a slightly sensitive taxon, and Chironomidae, a tolerant taxon. Overall, the sites were dominated by slightly tolerant to tolerant taxa, indicating some impairment of turbidity and sediment in the reach below El Vado Dam. The dominance of slightly tolerant to tolerant taxa is consistent with the results of the 1991 macroinvertebrate survey (Jacobi and McGuire 1992). The HBI score results indicated that some impairment was probable at both reference sites and study sites. The results of the analysis of which water quality and physical habitat parameters are potentially impacting the macroinvertebrate community highlight several water quality and physical habitat parameters that are potentially causing impairment and impacting the macroinvertebrate community residing in instream riffle habitats in the Rio Chama, below El Vado, in northern New Mexico. Plotting sites and taxa through NMDS ordination provided some initial insights for which macroinvertebrate taxa may be suited to similar water quality and physical habitat conditions and those that are not, as well as sites that provide similar water quality and physical habitat conditions, or in contrast very dissimilar conditions. Water quality and physical habitat parameters placed on top of ordination space revealed DO, pH, TDS, NO_3^-, turbidity, resuspended sediment, and D_{50} size play a possible role in driving the macroinvertebrate community. While negative binomial regression modeling results indicated that DO concentration, velocity, D_{50} size, resuspended sediment, turbidity, and velocity were potentially impacting several macroinvertebrate community metrics.

Understanding general relationships between benthic macroinvertebrate communities and water quality parameters can become confounded temporally. For example, temperature, DO, and pH exhibited diurnal fluctuations. The diurnal variation in DO concentration may have caused negative binomial regression modeling to indicate that the number of EPT taxa was negatively associated with increasing DO concentrations rather than a trend. A requirement of EPT taxa is high levels of DO concentration to maintain gill respiration (Voshell 2002, Merritt et al. 2008), and EPT taxa are most often found in greater numbers in environments with higher DO concentrations (Hrovat et al. 2014). Although temperature fluctuated diurnally, potentially confounding the analysis, there was still a significant difference in mean ranks between reference sites and study sites. Sample results for TDS and pH also demonstrated significant differences of mean ranks between reference and study sites, but it is unclear from a limited temporal data set if these results are anomalous or representative of normal water quality trends for reference sites and study sites. Additionally, the sample result ranges detected for DO, pH, TDS and NO_3^- at both reference sites and study sites are not indicative of impairment (Langman and Nolan 2005). Additional or long-term monitoring results could help with determining if these parameters are playing a stronger role in the macroinvertebrate community.

Physical habitat sample results are more likely to represent more long-term conditions at a site, because extreme changes generally require a large disturbance. Turbidity in the Rio Chama, below El Vado Dam, is influenced by two sources: El Vado Reservoir releases and tributary inputs (Fogg et al. 1992, Swanson and Mayer 2014). Abrupt increases in flow from El Vado Reservoir can double the turbidity levels in comparison to background levels (Fogg et al. 1992). At the time of sampling, discharge at the Rio Chama Near La Puente Gage (USGS gage #08284100) was approximately 1.3 m^3/s, with an average turbidity of 5.7 NTU; whereas, the discharge at Rio Chama Below El Vado Gage (USGS #0828550) ranged from a minimum of 15.5 m^3/s to a maximum of 21.5 m^3/s, with an average turbidity of 52 NTU. There were no precipitation events directly leading up to or during the sample period that would have caused in sudden increase in turbidity below El Vado Dam; consequently, the source of turbidity at study sites, which was significantly higher than reference sites, would be from El Vado Reservoir. Based on macroinvertebrate community results, increased turbidity levels below El Vado Dam are likely causing impairment and impacting the macroinvertebrate community residing in instream riffle habitats. An indication that impairment is occurring, is the difference in the proportion of collector-filterers at reference sites compared to study sites. Results of the negative binomial regression modeling indicated that the number of collector-filter taxa are negatively impacted by increasing levels of turbidity. The average percent composition of collector-filterers at reference sites was 29.6 percent, compared to an average of 4.8 percent at study sites. Increased turbidity can cause the feeding apparatuses of collector-filtering taxa to become clogged with inorganic material, leading to decreased feeding efficiency and survival (Strand and Merritt 1997, Runde and Hellenthal 2000). Additionally, the differences in the abundance of scraper taxa and predator taxa may also be indicative of impairment occurring from turbidity. Although there was not sufficient information about how turbidity impacts scraper taxa or predator taxa from this analysis, there was a significant difference in the mean ranks for the percent composition of both scraper taxa and predatora between reference sites and study sites, with a higher percent composition of both scraper taxa and predator taxa at reference sites (Table 4). As a major food resource for scraper taxa, periphyton can be impacted by high levels of turbidity, because of reduced light levels for photosynthesizers (US EPA

2000, Fuller et al. 2011). Additionally, high turbidity can reduce feeding efficacy of predatory macroinvertebrates (Kefford et al. 2010). Higher levels of turbidity below El Vado Dam, is likely a dominant driver for the difference in FFG evenness between reference and study sites (Figure 7), potentially indirectly impacting both biotic interactions and food-web dynamics in the reach below El Vado Dam.

As noted above, a disturbance can alter physical habitat conditions; in contrast, a lack of disturbance can also have implications for physical habitat conditions. Sampling took place in a year where there was no spring flow peak above 71 m^3/s threshold, as recommended to flush sediment in the Rio Chama Flow Project recommendation #3 (Gregory et al. 2018). The lack of a flow peak above 71 m^3/s may have resulted in an increased level of fine sediment at study sites. In support of the sediment impairment hypothesis made by Jacobi and McGuire (1992), the results of this analysis demonstrated sediment is likely impacting the macroinvertebrate community in the Rio Chama below El Vado Dam. Based on the negative binomial regression modeling results, sediment may also have an impact on the number of collector-filterer taxa found at each site. As is the case with turbidity, specialized feeding apparatus become clogged with increased sediment deposition, decreasing feeding efficiency and survival (Voshell 2002, Merritt et al. 2008, Jones 2012). Although the negative binomial regression modeling results did not indicate an impact for the number of EPT taxa found at a site, EPT taxa may be affected by increasing sediment deposition. Sediment can cause abrasion and clogging of gill respiration for EPT taxa (Larsen et al. 2011, Jones et al. 2012, McKenzie et al. 2020). While there was no significant difference in the mean rank of EPT between reference sites and study sites, there was a decreasing trend of EPT taxa moving longitudinally from upstream to downstream below El Vado Dam, corresponding to an increasing trend in sediment deposition from upstream to downstream. In contrast, Chironomidae, known to occur in greater numbers in habitats characterized by fine substrate (Fornaroli et al. 2014, Zhou et al 2019), increased moving from upstream to downstream. The increasing fine sediment moving longitudinally downstream is a result of sediment inputs from tributaries (Fogg et al. 1992). Although there was no precipitation leading up sampling, sediment may have been introduced by tributaries during precipitation events in 2017. Coarse substrate habitat is also extremely important to macroinvertebrate community dynamics (Zhou et al. 2019); however, a more robust sampling design is needed to better understand how coarse substrate impacts the macroinvertebrate community. While there was evidence that D_{50} impacted a number of macroinvertebrate community metrics, the pebble count method used in this analysis was performed across a transect and may or may not have been representative of site specific conditions. Collecting information on the coarse substrate at the site scale is recommended for further interpretation of these results.

Revisiting Hypotheses

i. Fine sediment deposition at each site will be the dominant parameter that is driving macroinvertebrate community dynamics based on the range of taxa that have life history requirements more or less tolerant to fine sediment.

The results of this research have supported the hypothesis that sediment parameters are strong drivers of the invertebrate communities in the Rio Chama. Fine sediment deposition at each site, measured as resuspended sediment, was shown to be a statistically significant driver of the macroinvertebrate community residing in riffle habitats in the Rio Chama below El Vado Dam. In addition to fine sediment, turbidity was also a statistically significant driver of the macroinvertebrate community. Taxa sampled at each site with life-histories that are more tolerant of fine sediment, like Chironomidae and other Diptera taxa, increased in abundance as levels of fine sediment increased. In contrast, taxa with life-history characteristics that were less tolerant of fine sediment, like EPT taxa and collector-filterer taxa, decreased as levels of fine sediment increased. Another physical habitat parameter that was shown to be a dominant driver of the macroinvertebrate community residing in riffle habitats below El Vado Dam was turbidity.

ii. Sample sites below El Vado Dam will have macroinvertebrate taxa that are more indicative of stream impairment compared to reference sites, due to the novel flow regime below El Vado Dam.

The results of this research did not strongly support this hypothesis that the macroinvertebrate taxa were more indicative of stream impairment at study sites, compared to reference sites. The dominant macroinvertebrate taxon at reference sites was the caddisfly family Hydropsychidae, compared to a dominance of *Baetis* spp. at study sites; both are considered slightly tolerant to stream impairment (Voshell 2002). The second most dominant taxon at both reference sites and study sites was the family Chironomidae, also tolerant of impairment. Additionally, the average HBI score was similar for samples from the reference sites and study sites. Despite these results that tolerance values were similar between reference sites and study sites, a greater taxa evenness at reference sites compared to study sites may indicate an impairment from increased levels of turbidity and sediment at study sites. Taxa with life-histories more tolerant of fine sediment and turbidity, like collector-gatherer taxa, were found at greater abundances than were taxa with life-histories more intolerant to sediment and turbidity, including collector-filterer taxa.

iii. Taxa richness of macroinvertebrate communities at each site closer to the outflow of El Vado Dam, will be lower than that of sites farther downstream of El Vado Dam, because water quality and physical habitat conditions directly downstream are more stable and reflective of conditions occurring in El Vado Reservoir versus the Rio Chama.

The results from this research supported this hypothesis with data that supports longitudinal patterns along the reach below El Vado Dam. Taxa richness closer to the outfall of El Vado Dam was lower than that of sites sampled further downstream. It is possible that lower sediment deposition at sites closer to the outflow of El Vado Dam is less favorable to taxa with life-histories that are more tolerant to increased levels fine sediment, allowing for different taxa to also inhabit sites located longitudinally downstream.

Results from the NMDS ordination showed that sites closer to El Vado Dam, extending downstream to transect 7 (sites #3 - #21) were more dissimilar to one another compared to downstream sites. These comparative data could assist with designing future studies to test for differences in taxa evenness and richness between upstream sites and downstream sites in this reach.

Management implications

For managers, the results of this analysis which shows that water quality and physical habitat parameters are potentially impacting the macroinvertebrate community in the Rio Chama provides valuable insights about the relationships between the biology and the environmental drivers in the Rio Chama. Additionally, the results of this research may reduce some uncertainty in implementing adaptive management of the streamflow regime on the Rio Chama below El Vado Dam. The results of the HBI score and the dominance of slightly tolerant to tolerant taxa support the 1991 monitoring results that impairment of sediment within the Rio Chama below El Vado Dam (Jacobi and McGuire 1992). The water quality and physical habitat conditions may be causing an overall dominance of collector gatherer taxa. A lack of FFG diversification may have consequences on food-webs dynamics below El Vado Dam, including impacts to nutrient cycling, accumulation of fine and course detritus, and decline in food resources for fish species (Wallace and Hutchens 2000).

The results of this analysis are representative of a year without a flow volume great enough to initiate mobilization of fine sediment (Gregory et al. 2018); therefore, these results offer a baseline comparison for managers interested in testing how the 2013 Rio Chama flow workshop flow recommendations might impact stream ecology in the Rio Chama below El Vado Dam. Sampling the benthic macroinvertebrate community at each site following a spring run-off event that is above the 71 m^3/s threshold could be used to assess how flow recommendation #3 (summary of #3) impacts the macroinvertebrate community. Comparing the macroinvertebrate communities between a year without a sediment-mobilizing flow to one with sediment-mobilizing flow, will further reduce uncertainty of what the roles streamflow and sediment play in influencing the macroinvertebrate community structure in the Rio Chama. Additionally, the comparison of both results from both types of stream flow could assist with interpreting why invertebrate abundances were significantly different for some sites and years, as shown in the BLM monitoring results, and if the spring flood pulse or other aspects of the streamflow regime may have been a factor. Another consideration for water managers is the potential turbidity impairment that results from El Vado Reservoir releases. The magnitude of discharge measured at the El Vado gage during the sample period was largely sustained until October in the year of this study, with just a few increases and decreases in discharge. Therefore, it is likely that high turbidity levels were sustained into the fall months. Managers may want to consider ways to reduce turbidity from El Vado Reservoir to have a positive impact on the macroinvertebrate community and overall stream ecology of the Rio Chama. Implementing adaptive management to obtain optimized conditions for the benthic macroinvertebrate community residing in instream riffle habitats on the Rio Chama below El Vado Dam could have indirect positive effects on other aspects of the stream ecosystem (Thom et al. 2016).

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Figures

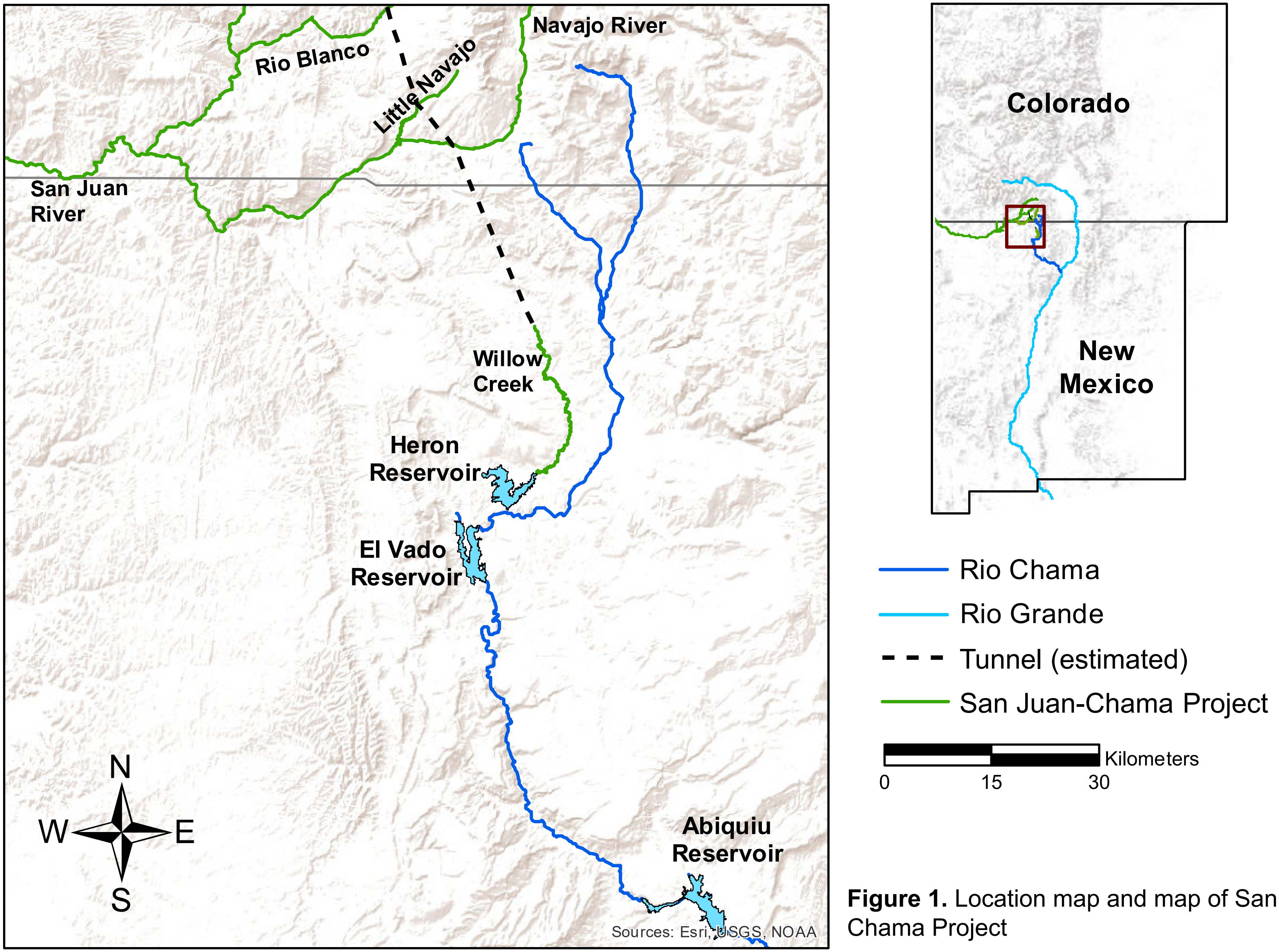


Figure 1. Location map and map of San Juan-Chama Project

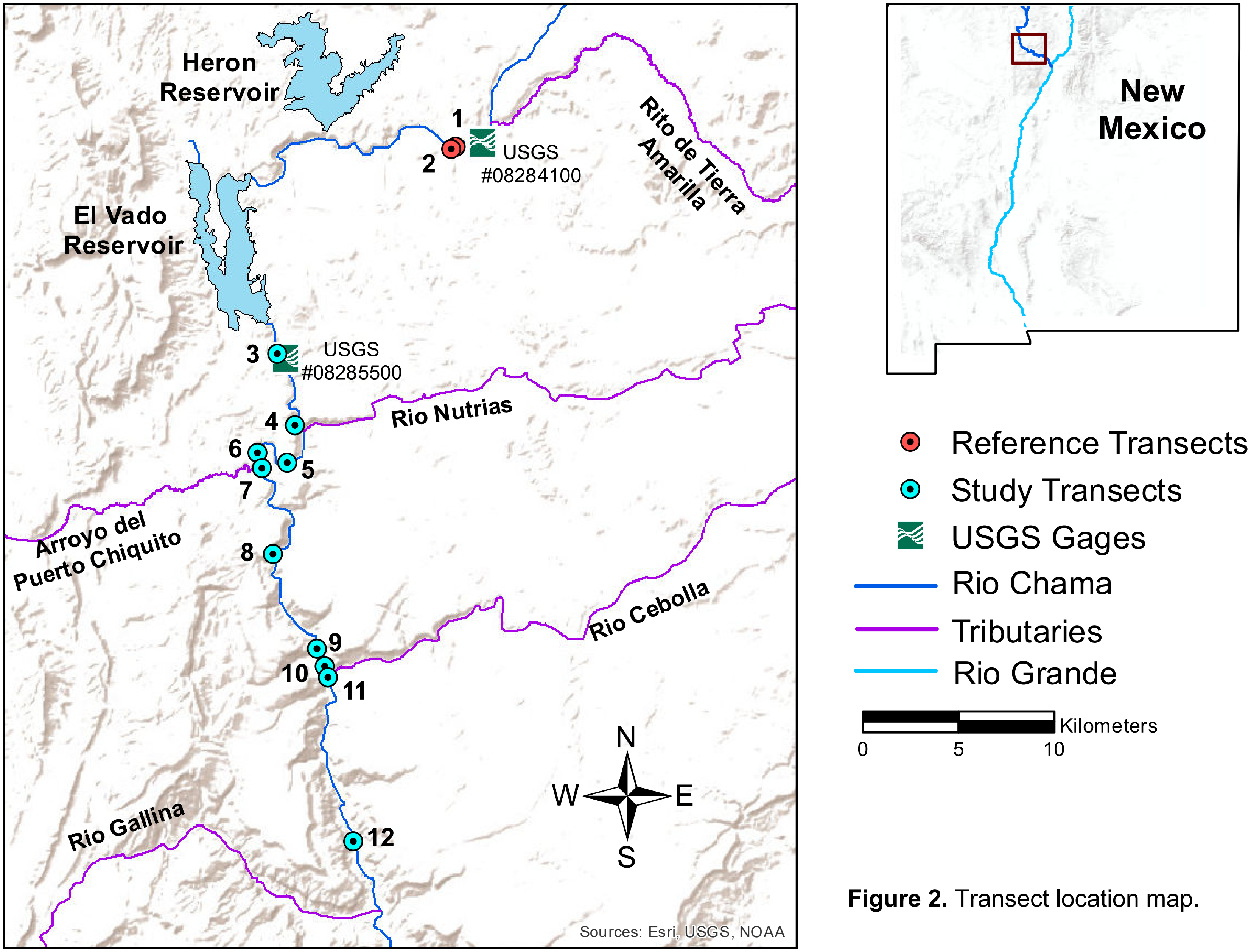


Figure 2. Transect location map.

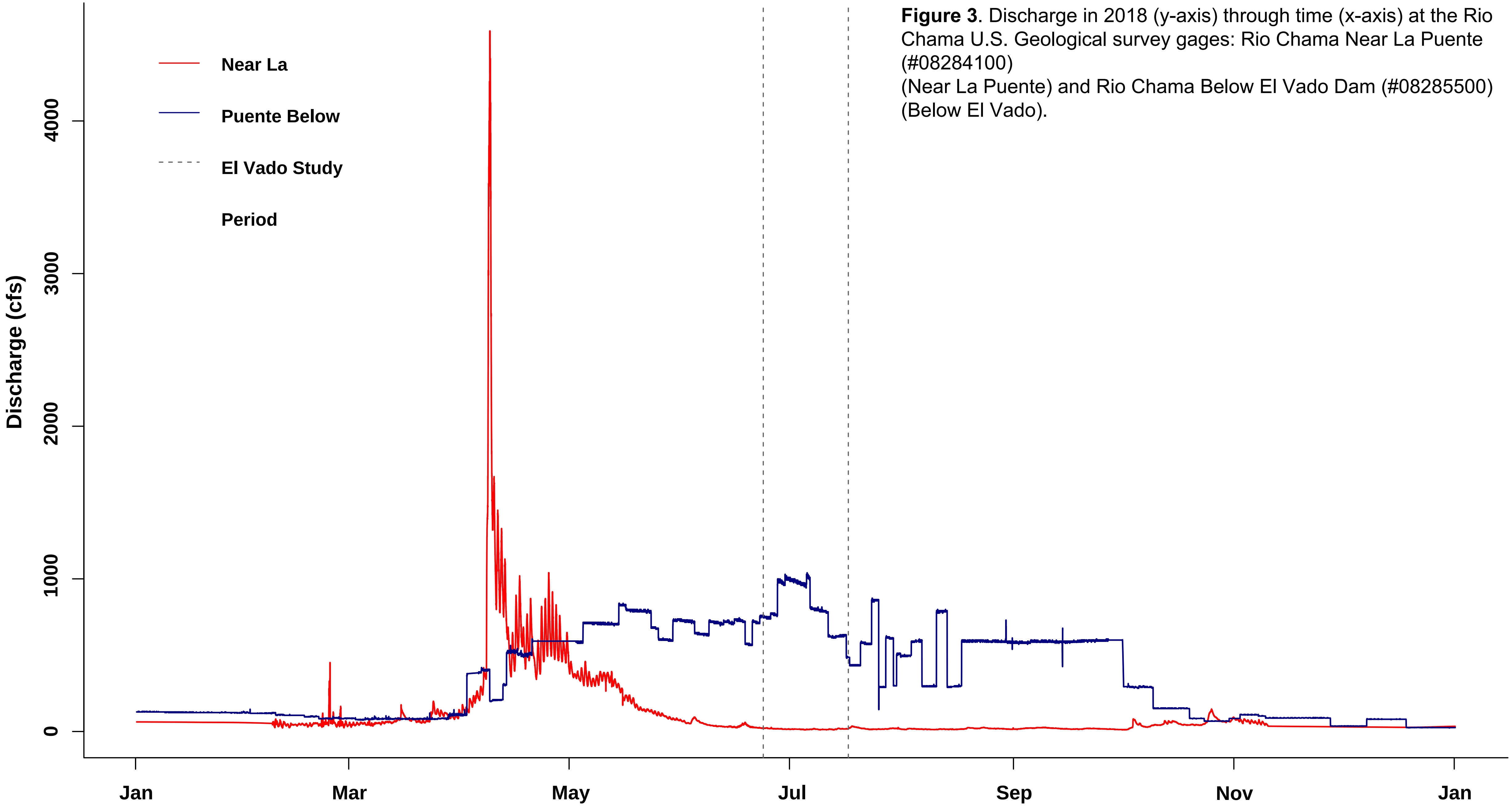


Figure 3. Discharge in 2018 (y-axis) through time (x-axis) at the Rio Chama U.S. Geological survey gages: Rio Chama Near La Puente (#08284100)
(Near La Puente) and Rio Chama Below El Vado Dam (#08285500) (Below El Vado).

Figure 4. NMDS ordination results. Taxa are in red, sites are in black, and arrows and text in blue represent environmental parameters overlaid on top of community data. Arrow direction represents the direction the parameter is maximized and arrow length represents correlation between the ordination and the parameter (stress = 0.11).

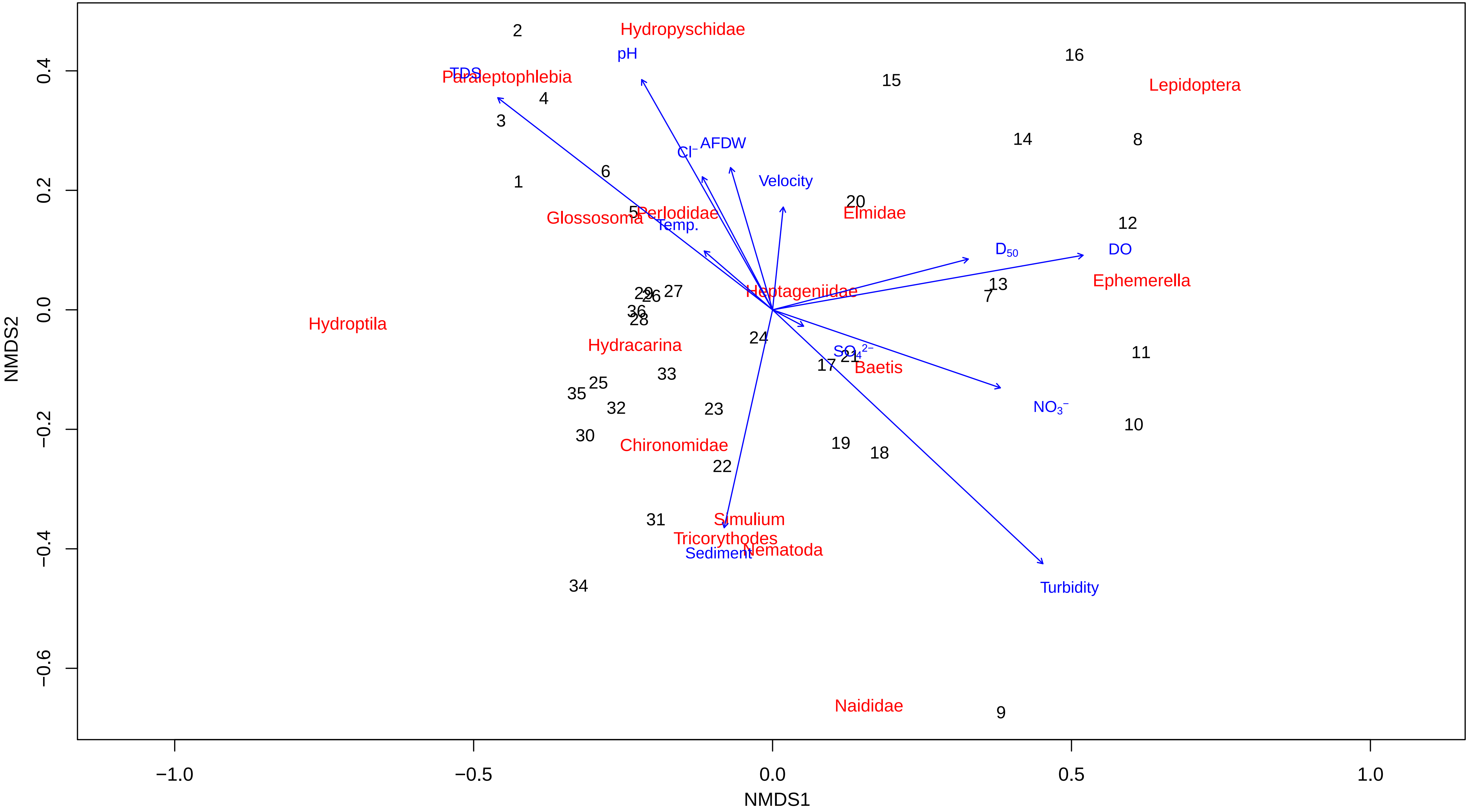


Figure 5a. Negative binomial regression modeling results for the numbers of EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa.

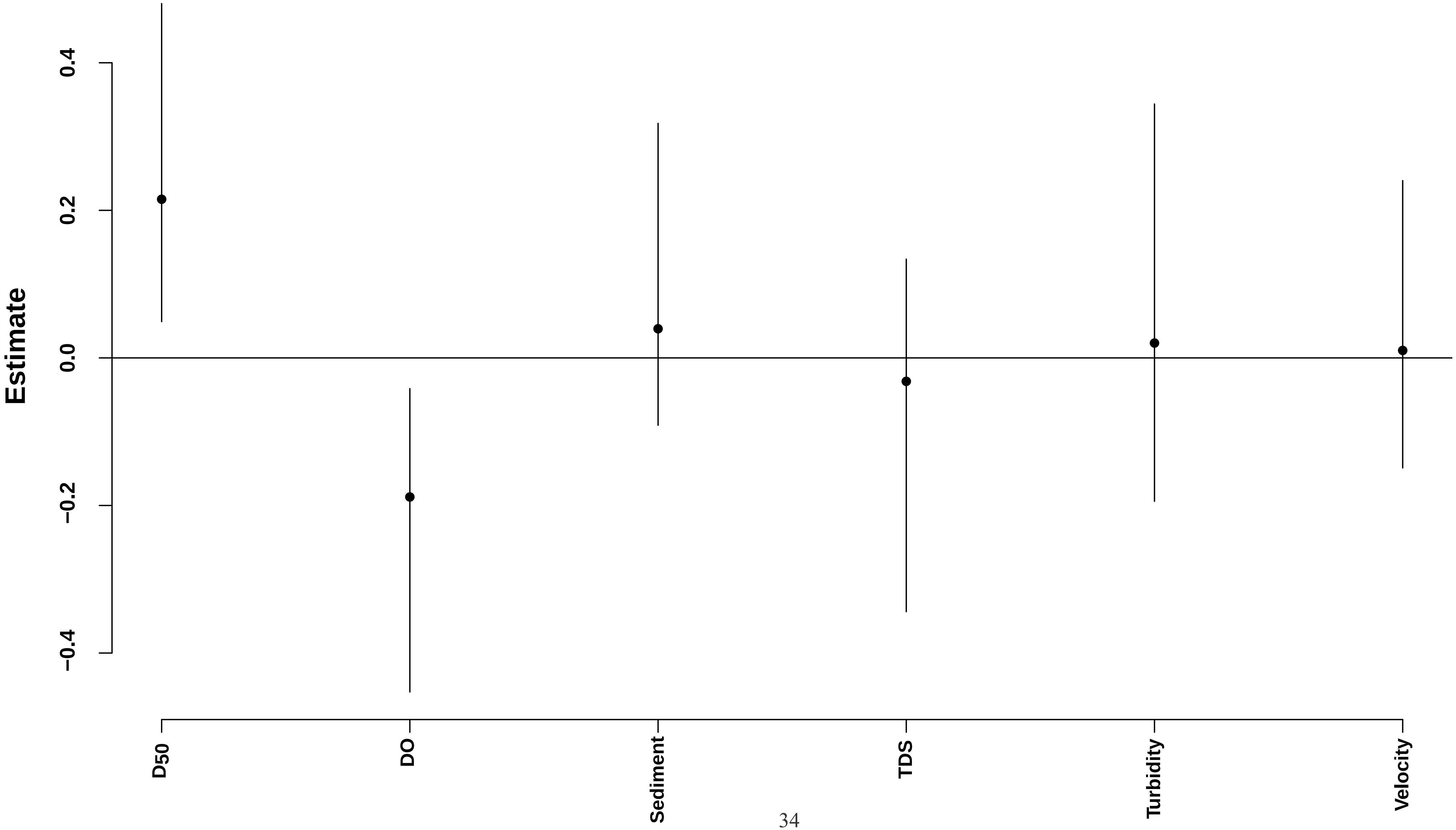


Figure 5b. Negative binomial regression modeling results for Chironomidae taxa.

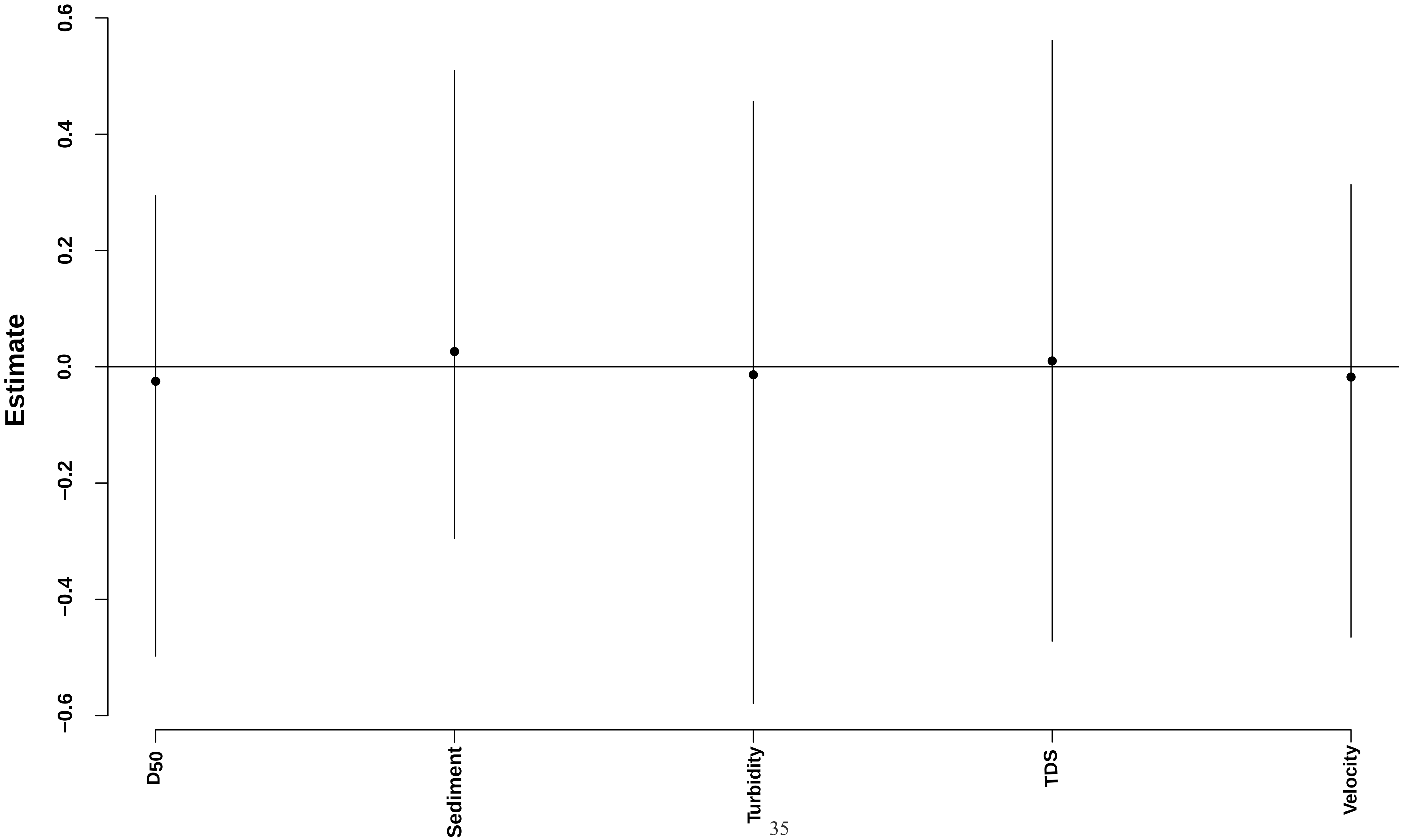


Figure 5c. Negative binomial regression modeling results for collector-filterer taxa.

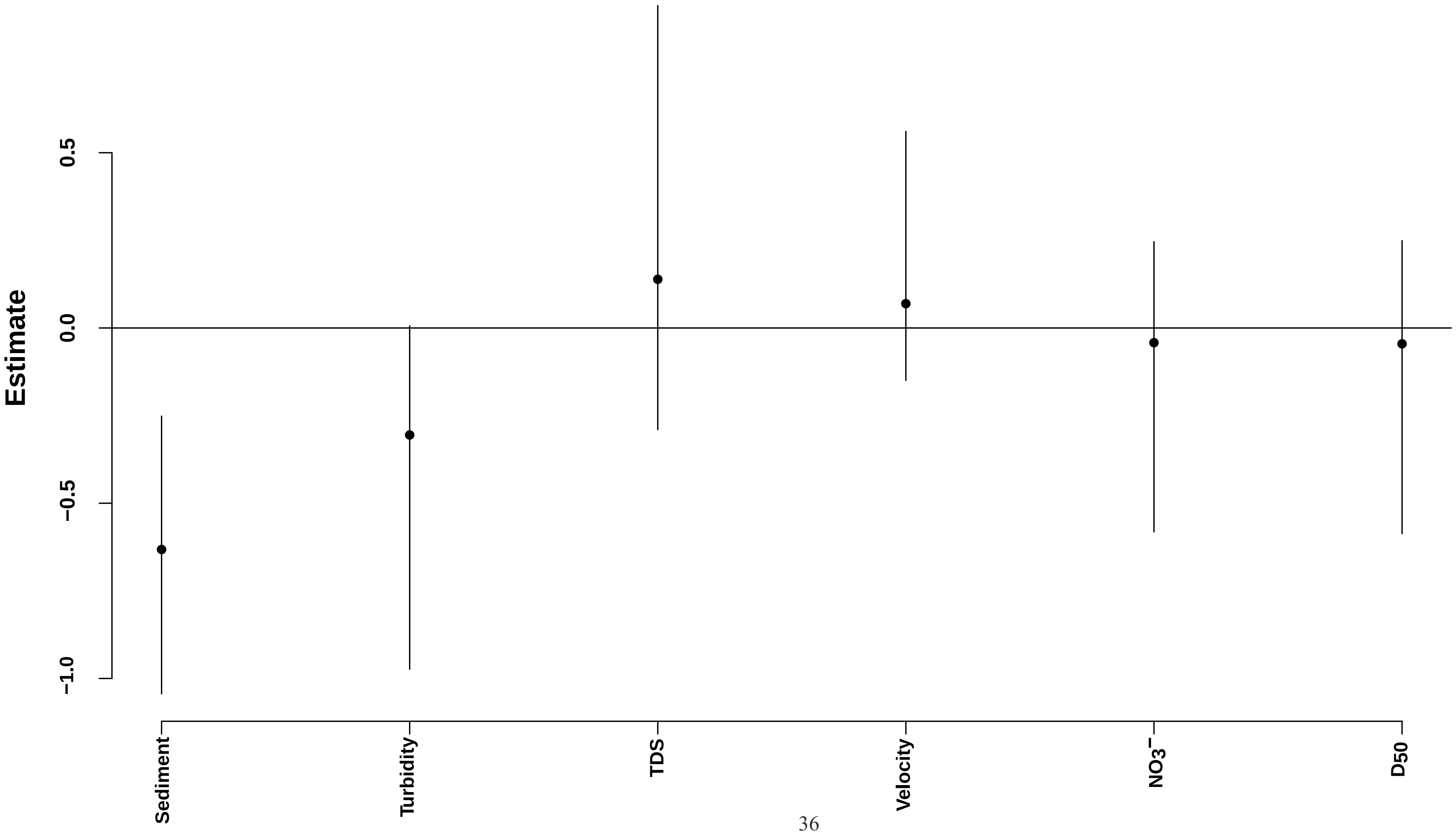


Figure 5d. Negative binomial regression modeling results for collector-gatherer taxa.

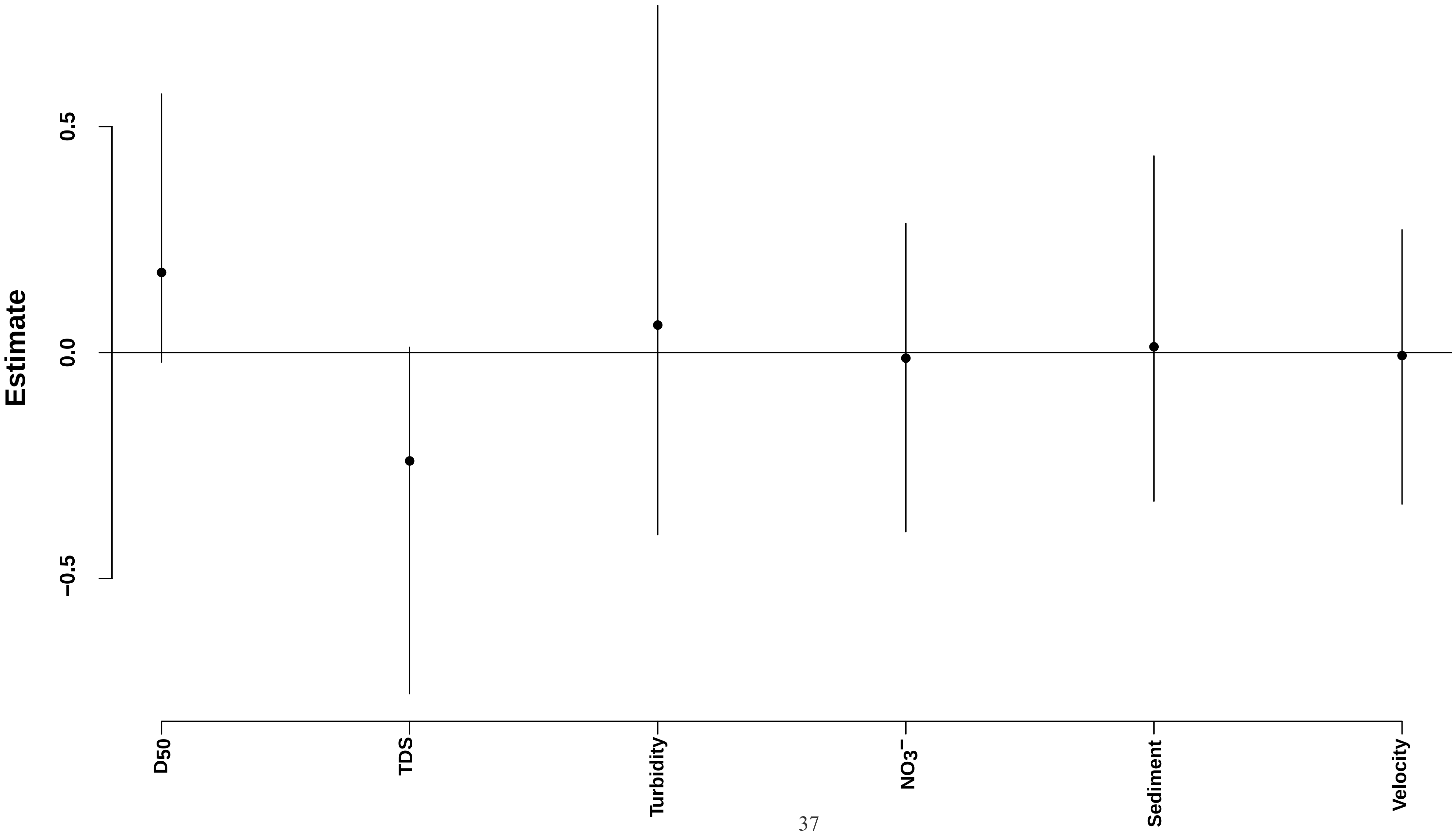


Figure 5e. Negative binomial regression modeling results for shredder taxa.

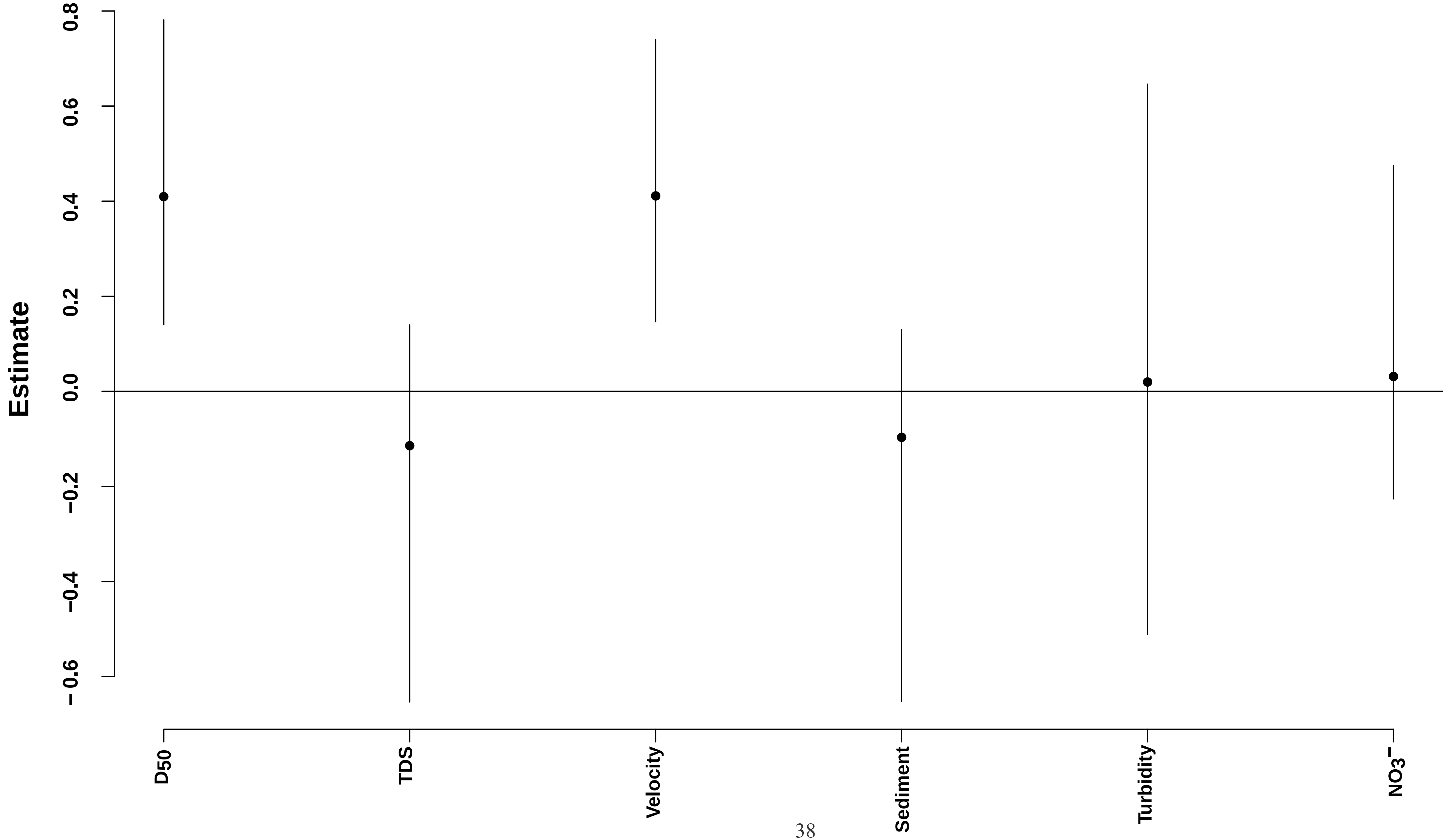
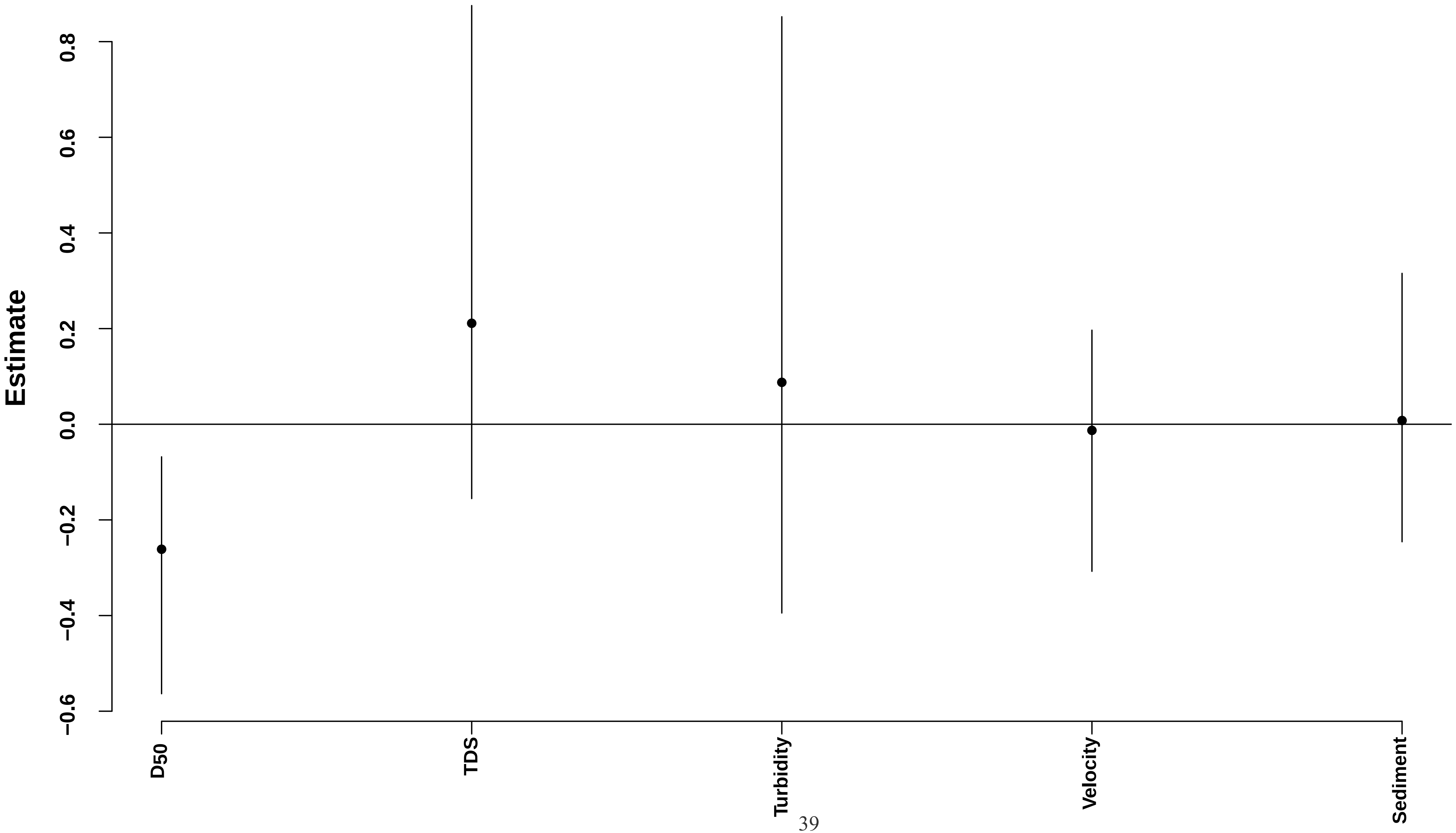


Figure 5f. Negative binomial regression modeling results for scraper taxa.



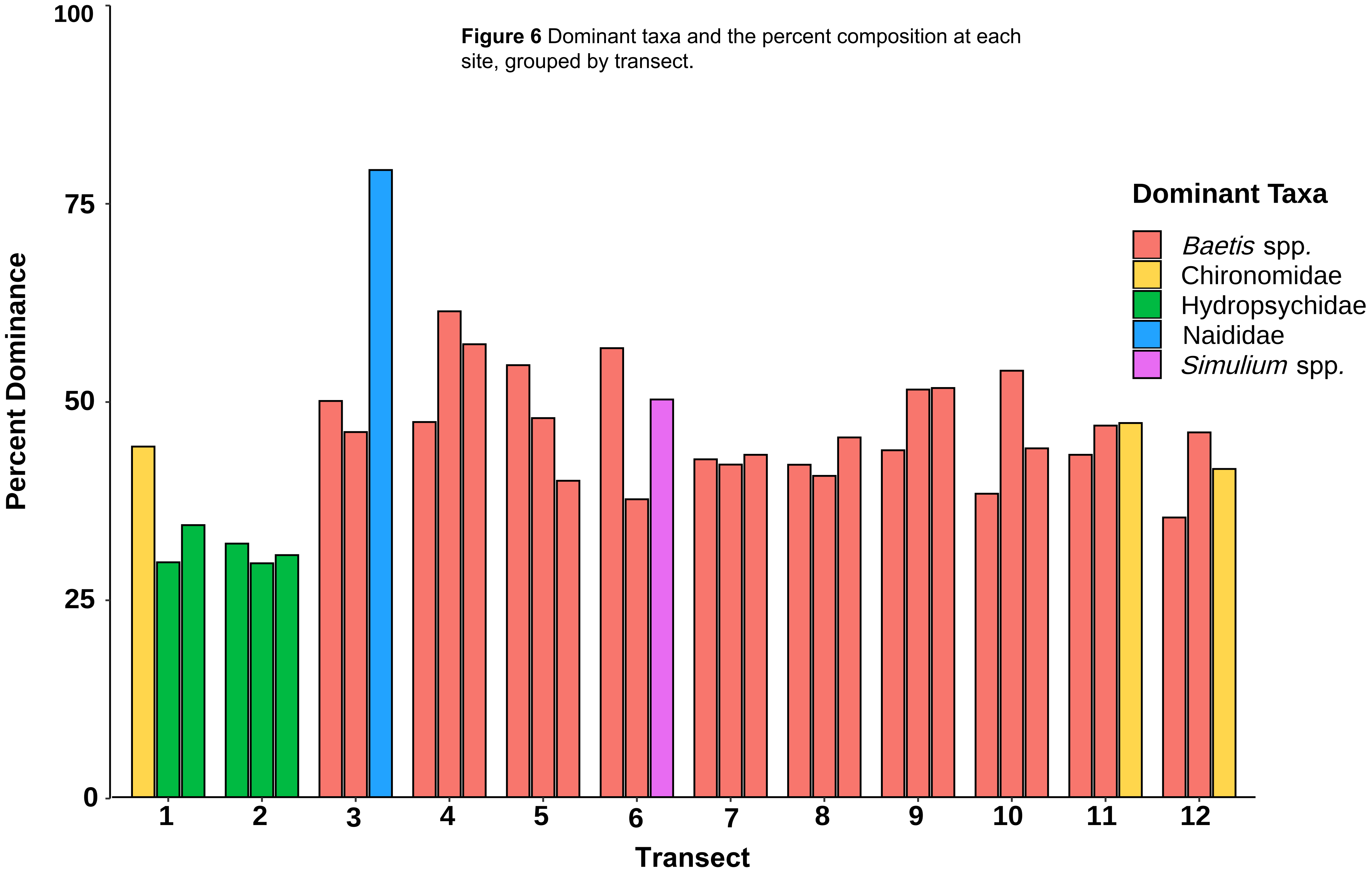


Figure 6 Dominant taxa and the percent composition at each site, grouped by transect.

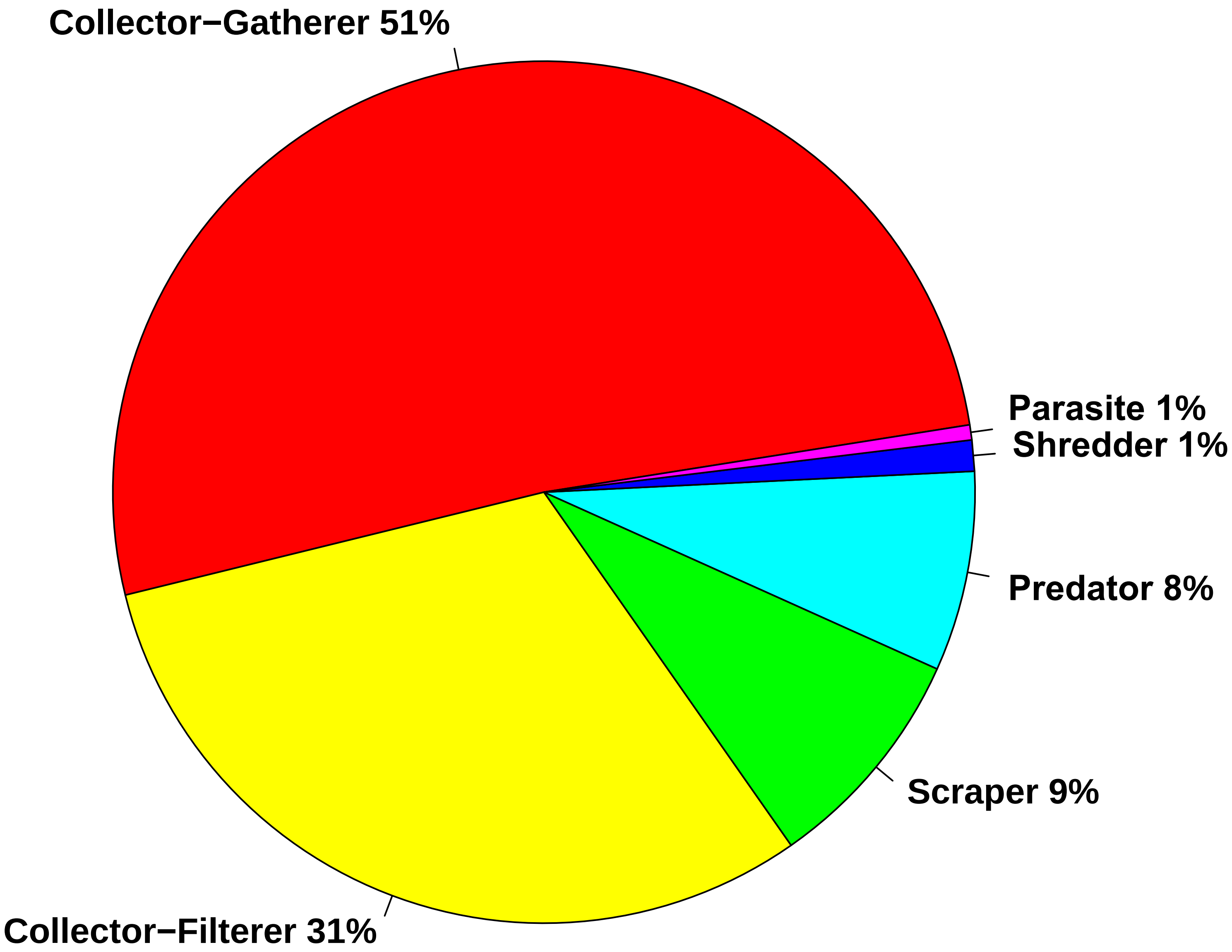


Figure 7a. Functional feeding group composition at reference sites.

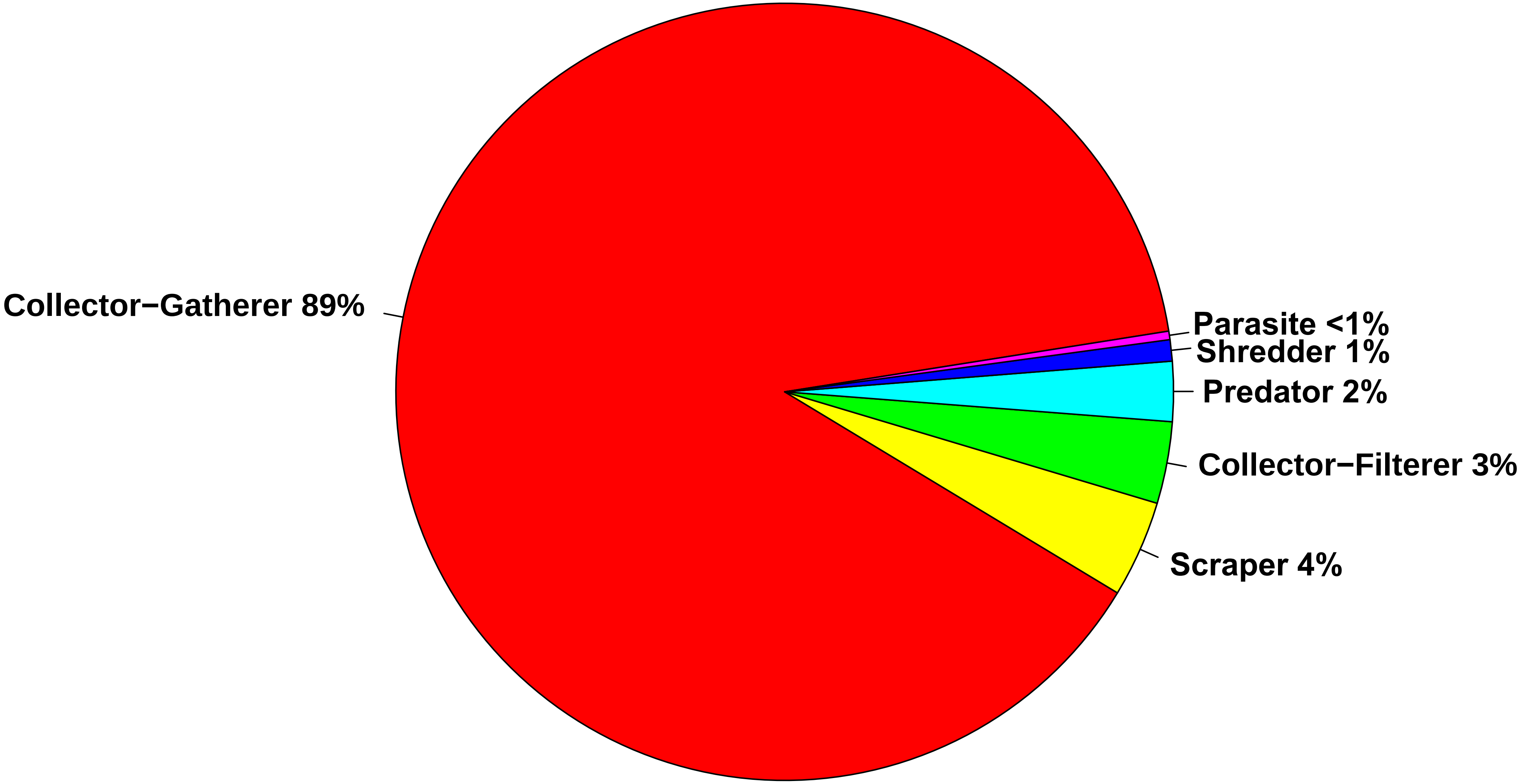


Figure 7b. Functional feeding group composition at study sites.

Tables

Table 1. Transect names, abbreviation, location, and site numbers within each transect.

Transect	Abbreviation	Transect Number	Latitude	Longitude	Site Numbers		
La Puente Up Stream	LAPU_U	1	36.660250	-106.6443611	1	2	3
La Puente Down Stream	LAPU_D	2	36.659250	-106.6465833	4	5	6
El Vado Cooper's Ranch	COOP	3	36.582028	-106.7283333	7	8	9
Above Rio Nutrias	NUTR_A	4	36.554861	-106.7199167	10	11	12
Below Rio Nutrias	NUTR_B	5	36.540500	-106.7235556	13	14	15
Above Archuleta	ARCH_U	6	36.544472	-106.7377222	16	17	18
Below Archuleta	ARCH_B	7	36.538639	-106.7358333	19	20	21
Above Aragon	ARAG_A	8	36.506139	-106.7305833	22	23	24
Dark Canyon	DARK	9	36.470111	-106.7098611	25	26	27
Above Rio Cebolla	CEBO_A	10	36.463389	-106.7061111	28	29	30
Below Rio Cebolla	CEBO_B	11	36.459194	-106.7044722	31	32	33
Benson's Bar	BENS	12	36.397111	-106.6924722	34	35	36

Table 2. Macroinvertebrate functional feeding group and description of food resources, modified from Cummins (2018).

Functional feeding group (FFG)	**Food and descriptions**
Collector-filterers	Fine particulate organic matter (FPOM) suspended in the current.
Gathering-collectors	Fine particulate organic matter (FPOM) entrained in depositional areas, characterized by bacteria or mineral particles.
Shredders	Coarse particulate organic matter (CPOM), or plant litter accumulations that may be colonized by fungi and bacteria.
Scrapers	single cell or colonies of non-filamentous algae attached to substrates, called periphyton, in stream riffles and runs.
Predators	Prey on live invertebrates and found in essentially any habitat where prey are found.

Table 3. Physical and chemical parameters sampled at each transect and/or site, with minimum (min.), mean ± standard error (SE), and maximum (max.) values for the study sites and reference sites. Right hand column includes results of Kruskal-Wallace test.

	Study Sites			**Reference Sites**			**Kruskal-Wallace test**	
Parameter	**min.**	**mean (SE)**	**max.**	**min.**	**mean (SE)**	**max.**	**chi-squared**	**p-value**
Temperature (C°)	16	17.6 ± 0.7	19.3	14.1	16.0 ± 0.3	18.8	4.69	**0.03**
DO (mg/L)	8	8.6 ± 0.2	9.1	8.3	8.7 ± 0.0	9.1	0.03	0.87
DO %	80.7	90.5 ± 3.1	98.3	82	87.8 ± 0.6	93.2	0.72	0.40
pH	8.3	8.5 ± 0.1	8.7	7.7	8.0 ± 0.0	8.4	13.97	**1.9x10^{-4}**
Conductivity (µS/m)	227	244 ± 7.5	261	190	200 ± 1.1	210	14.62	**1.3x10^{-4}**
TDS (mg/L)	148	158.5 ± 4.7	169	123	130.2 ± 0.7	136	14.73	**1.2x10^{-5}**
Velocity (m/s)	0.04	0.33 ± 0.09	0.56	0.02	0.27 ± 0.03	0.67	0.69	0.41
Depth (cm)	12.0	20.5 ± 3.0	30.0	8.0	16.5 ± 0.9	27.0	1.87	0.17
Turbidity (NTU)	3.7	5.7 ± 0.9	7.7	42.0	52.1 ± 1.4	65	14.74	**1.2x10^{-4}**
Chloride (mg/L)	1.9	2.8 ± 0.4	3.9	1.4	2.2 ± 0.1	2.7	2.47	0.12
Nitrate (mg/L)	0.0	0.2 ± 0.1	0.4	0.0	0.4 ± 0.0	0.7	1.87	0.17
Sulfate (mg/L)	12.7	20.3 ± 2.6	27.4	10.0	23.5 ± 1.1	32.9	1.51	0.22
d50 (mm)	35.6	53.5 ± 8.0	71.3	24.9	50.7 ± 2.8	73.0	0.59	0.44
Resuspended Sediment (mg/L)	2.28	15.6 ± 5.5	32.4	5.7	92.0 ± 11.7	269.2	10.40	**1.3x10^{-3}**
AFDW (%)	50.5	54.2 ± 1.7	59.6	50.1	50.9 ± 0.2	56.5	6.06	**0.01**

Bold indicates significant (p-value > 0.05)

Table 4. Macroinvertebrate community metric results assessed for each transect and/or site, with minimum (min.), mean ± standard error (SE), and maximum (max.) values for the study sites and reference sites. Right hand column includes results of Kruskal-Wallace test.

	Study Sites			**Reference Sites**			**Kruskal-Wallace ANOVA**	
Metric	**min.**	**mean (SE)**	**max.**	**min.**	**mean (SE)**	**max.**	**chi^2**	**p-value**
Number of Taxa	12	15 ± 1.0	19	8	15 ± 1.6	21	0.077	0.78
Taxa Evenness	0.65	0.69 ± 0.01	0.72	0.31	0.58 ± 0.01	0.71	10.96	**9.3×10^{-4}**
HBI	4.2	4.5 ± 0.1	4.8	3.0	4.5 ± 0.2	7.2	0.00018	0.97
EPT (%)	52.8	65.0 ± 3.6	75.6	13.0	64.63 ± 3.6	97.6	0.029	0.87
Chironomidae (%)	20.7	26.6 ± 3.2	42.2	0.0	20.3 ± 2.5	45.0	1.21	0.27
Collector-gatherer (%)	40.1	49.9 ± 3.7	64.4	43.3	84.5 ± 1.7	99.4	13.3	**2.6×10^{-4}**
Collector-Filterer (%)	15.0	29.6 ± 3.2	36.9	0.0	4.8 ± 1.6	48.3	12.41	**4.3×10^{-4}**
Shredder (%)	0.2	1.0 ± 0.3	1.9	0.0	1.3 ± 0.3	6.1	0.004	0.95
Scraper (%)	2.6	10.7 ± 2.5	16.7	0.0	5.8 ± 0.7	13.1	3.81	**0.05**
Predator (%)	2.9	8.4 ± 1.9	13.5	0.2	3.2 ± 0.3	8.2	6.71	**0.01**
Parasite (%)	0.0	0.5 ± 0.2	1.4	0.0	0.4 ± 0.1	2.6	0.38	0.85

Bold indicates significant (p-value > 0.05)

Appendix A

Table 1.A. Water quality parameter results.

	Parameter:	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	pH	Conductivity (µS/m)
Transect	**Date**					
La Puente Up Stream	6/18/2018	16.06	8.37	85.0	8.34	227
La Puente Up Stream	6/18/2018	16.02	8.47	85.9	8.42	228
La Puente Up Stream	6/18/2018	16.01	7.98	80.7	8.62	227
La Puente Down Stream	6/17/2018	19.27	9.07	98.3	8.69	260
La Puente Down Stream	6/17/2018	19.14	8.91	96.5	8.51	261
La Puente Down Stream	6/17/2018	19.18	8.91	96.4	8.45	261
Cooper's Ranch	6/18/2018	14.78	8.50	83.2	8.26	191
Cooper's El Vado Ranch	6/18/2018	14.8	9.12	90.2	7.80	190
Cooper's El Vado Ranch	6/18/2018	18.84	9.11	90.0	7.67	191
Above Rio Nutrias	6/19/2018	15.32	8.88	88.7	7.95	192
Above Rio Nutrias	6/19/2018	15.3	8.88	88.7	8.01	192
Above Rio Nutrias	6/19/2018	15.27	8.89	88.7	8.22	192
Below Rio Nutrias	6/19/2018	17.15	8.82	91.6	7.83	195
Below Rio Nutrias	6/19/2018	17.12	8.85	91.8	7.74	194
Below Rio Nutrias	6/19/2018	17.12	8.89	92.2	7.72	195
Above Archuleta	6/20/2018	14.68	8.90	87.7	8.27	202
Above Archuleta	6/20/2018	14.73	8.92	88.0	8.19	199
Above Archuleta	6/20/2018	14.83	9.08	89.7	8.14	200
Below Archuleta	6/20/2018	17.44	8.93	93.2	7.72	200
Below Archuleta	6/20/2018	17.39	8.88	92.6	7.70	199
Below Archuleta	6/20/2018	17.37	8.77	91.4	7.80	200
Above Aragon	6/21/2018	14.59	8.57	84.3	7.90	202
Above Aragon	6/21/2018	14.55	8.56	84.2	7.94	201
Above Aragon	6/21/2018	14.5	8.59	84.3	8.15	203
Dark Canyon	6/21/2018	18.2	8.52	90.4	7.72	204
Dark Canyon	6/21/2018	18.22	8.57	91.0	7.70	203
Dark Canyon	6/21/2018	18.26	8.57	91.1	7.71	201
Above Rio Cebolla	6/22/2018	14.69	8.50	83.9	8.44	204
Above Rio Cebolla	6/22/2018	14.72	8.55	84.3	8.27	203
Above Rio Cebolla	6/22/2018	14.76	8.49	83.8	8.20	203
Below Rio Cebolla	6/22/2018	17.71	8.31	87.3	7.72	209
Below Rio Cebolla	6/22/2018	17.67	8.32	87.3	7.69	206
Below Rio Cebolla	6/22/2018	17.61	8.34	87.4	7.75	209
Benson's Bar	6/23/2018	14.15	8.45	82.3	7.98	209
Benson's Bar	6/23/2018	14.08	8.43	82.0	8.05	210
Benson's Bar	6/23/2018	14.05	8.46	82.3	8.18	210

	Parameter:	**TDS (mg/L)**	**Cl$^-$ (mg/L)**	**NO$_2^-$ (mg/L)**	**NO$_3^-$ (mg/L)**	**SO$_4^{2-}$ (mg/L)**
Transect	**Date**					
La Puente Up Stream	6/18/2018	148	1.91	ND	ND	13.09
La Puente Up Stream	6/18/2018	148	2.44	ND	0.163	20.87
La Puente Up Stream	6/18/2018	148	2.21	ND	ND	12.71
La Puente Down Stream	6/17/2018	169	2.66	ND	0.411	20.76
La Puente Down Stream	6/17/2018	169	3.82	ND	0.244	27.11
La Puente Down Stream	6/17/2018	169	3.94	ND	0.188	27.35
Cooper's Ranch	6/18/2018	124	2.75	0.69	0.681	27.08
Cooper's El Vado Ranch	6/18/2018	123	1.44	ND	0.318	10.04
Cooper's El Vado Ranch	6/18/2018	124	1.52	ND	0.404	15.11
Above Rio Nutrias	6/19/2018	126	2.24	ND	0.716	23.56
Above Rio Nutrias	6/19/2018	126	2.38	ND	0.561	27.14
Above Rio Nutrias	6/19/2018	124	2.03	ND	0.345	19.21
Below Rio Nutrias	6/19/2018	127	2.59	ND	0.505	28.16
Below Rio Nutrias	6/19/2018	126	2.47	ND	0.509	25.63
Below Rio Nutrias	6/19/2018	127	2.25	ND	0.419	22.62
Above Archuleta	6/20/2018	131	1.97	ND	0.503	24.11
Above Archuleta	6/20/2018	130	1.66	ND	0.337	17.57
Above Archuleta	6/20/2018	129	2.74	ND	0.382	29.59
Below Archuleta	6/20/2018	130	2.57	ND	0.55	29.97
Below Archuleta	6/20/2018	130	2.60	ND	0.629	29.94
Below Archuleta	6/20/2018	130	2.07	ND	0.337	20.21
Above Aragon	6/21/2018	131	1.87	ND	0.327	16.80
Above Aragon	6/21/2018	131	2.69	ND	0.673	31.00
Above Aragon	6/21/2018	132	2.58	0.66	0.54	30.65
Dark Canyon	6/21/2018	133	1.85	ND	0.235	16.06
Dark Canyon	6/21/2018	131	2.50	0.63	0.437	27.86
Dark Canyon	6/21/2018	130	2.61	ND	0.414	29.43
Above Rio Cebolla	6/22/2018	133	2.03	ND	0.585	21.57
Above Rio Cebolla	6/22/2018	132	2.16	0.61	0.702	21.20
Above Rio Cebolla	6/22/2018	132	2.62	ND	0.474	29.37
Below Rio Cebolla	6/22/2018	136	2.39	ND	ND	24.24
Below Rio Cebolla	6/22/2018	134	1.89	ND	0.379	20.16
Below Rio Cebolla	6/22/2018	136	1.90	ND	0.163	18.10
Benson's Bar	6/23/2018	136	1.55	ND	0.427	13.86
Benson's Bar	6/23/2018	136	2.70	ND	0.245	32.88
Benson's Bar	6/23/2018	136	1.90	ND	ND	21.63

ND = not detected

Table 2.A. Physical habitat parameter results

	Parameter:	Depth (cm)	Velocity (m/s)	Turbidity (NTU)	D_{50} (mm)	Sediment (mg/L)	AFDW (%)
Transect	**Date**						
La Puente Up Stream	6/18/2018	30	0.35	7.7	35.6	2.3	59.6
La Puente Up Stream	6/18/2018	13	0.08	7.7	35.6	31.6	50.7
La Puente Up Stream	6/18/2018	12	0.04	7.7	35.6	15.6	50.5
La Puente Down Stream	6/17/2018	19	0.56	3.7	71.3	32.4	51.0
La Puente Down Stream	6/17/2018	22	0.40	3.7	71.3	4.0	58.5
La Puente Down Stream	6/17/2018	27	0.54	3.7	71.3	7.9	55.1
Cooper's Ranch	6/18/2018	12	0.57	51.9	73	5.7	56.5
Cooper's El Vado Ranch	6/18/2018	12	0.16	51.9	73	14.1	53.7
Cooper's El Vado Ranch	6/18/2018	20	0.23	51.9	73	57.4	50.6
Above Rio Nutrias	6/19/2018	18	0.32	65.0	69.7	45.9	50.7
Above Rio Nutrias	6/19/2018	22	0.49	65.0	69.7	67.0	50.8
Above Rio Nutrias	6/19/2018	22	0.31	65.0	69.7	99.9	50.5
Below Rio Nutrias	6/19/2018	20	0.40	59.6	62.1	75.4	50.4
Below Rio Nutrias	6/19/2018	22	0.37	59.6	62.1	57.3	50.5
Below Rio Nutrias	6/19/2018	14	0.35	59.6	62.1	42.8	51.0
Above Archuleta	6/20/2018	20	0.24	44.7	35.3	111.4	50.6
Above Archuleta	6/20/2018	14	0.05	44.7	35.3	63.5	50.7
Above Archuleta	6/20/2018	12	0.04	44.7	35.3	90.1	50.2
Below Archuleta	6/20/2018	12	0.05	59.8	47.8	46.4	50.4
Below Archuleta	6/20/2018	18	0.08	59.8	47.8	112.2	50.3
Below Archuleta	6/20/2018	24	0.14	59.8	47.8	77.0	50.6
Above Aragon	6/21/2018	11	0.03	49.7	24.9	196.2	50.2
Above Aragon	6/21/2018	16	0.24	49.7	24.9	166.5	50.2
Above Aragon	6/21/2018	27	0.34	49.7	24.9	117.8	50.6
Dark Canyon	6/21/2018	12	0.38	43.5	44.1	106.8	50.3
Dark Canyon	6/21/2018	18	0.48	43.5	44.1	20.1	52.4
Dark Canyon	6/21/2018	20	0.67	43.5	44.1	51.3	50.7
Above Rio Cebolla	6/22/2018	18	0.35	42.0	52.8	136.2	50.2
Above Rio Cebolla	6/22/2018	14	0.07	42.0	52.8	111.6	50.1
Above Rio Cebolla	6/22/2018	8	0.02	42.0	52.8	189.8	50.2
Below Rio Cebolla	6/22/2018	18	0.02	49.7	62.4	10.8	51.4
Below Rio Cebolla	6/22/2018	10	0.11	49.7	62.4	179.4	50.1
Below Rio Cebolla	6/22/2018	8	0.37	49.7	62.4	54.7	50.5
Benson's Bar	6/23/2018	12	0.27	55.2	34.8	274.9	50.1
Benson's Bar	6/23/2018	18	0.53	55.2	34.8	151.5	50.4
Benson's Bar	6/23/2018	24	0.33	55.2	34.8	27.4	52.6

Table 3.A. Macroinvertebrate sample results.

	Taxa:	**Ephemeroptera**				
Transect	**Date**	*Baetis* spp.	*Ephemerella infrequens*	Heptageniidae	*Paraleptophlebia* spp.	*Tricorythodes* spp.
La Puente Up Stream	6/18/2018	86.5	5	21	5	1
La Puente Up Stream	6/18/2018	45.5	1	40.5	14	0
La Puente Up Stream	6/18/2018	55.5	2	41.5	9	9
La Puente Down Stream	6/17/2018	30.5	1	47.5	8.5	0
La Puente Down Stream	6/17/2018	242	0	22.5	6	0
La Puente Down Stream	6/17/2018	90	0	23	8	0
Cooper's Ranch	6/18/2018	527	222	0	0	0
Cooper's El Vado Ranch	6/18/2018	237.5	159.5	0	0	0
Cooper's El Vado Ranch	6/18/2018	617.5	87	2	1	1
Above Rio Nutrias	6/19/2018	133.5	117.5	8.5	0	3
Above Rio Nutrias	6/19/2018	297.5	137	37.5	0	5
Above Rio Nutrias	6/19/2018	67	31	16	0	1
Below Rio Nutrias	6/19/2018	145.5	73.5	24	0	3
Below Rio Nutrias	6/19/2018	155	75	16	0.5	1.5
Below Rio Nutrias	6/19/2018	336	231	35	1	4
Above Archuleta	6/20/2018	26.5	9	2	0	0
Above Archuleta	6/20/2018	138.5	99	20	1	3.5
Above Archuleta	6/20/2018	43	36.5	11	0	3
Below Archuleta	6/20/2018	192.5	23	55	0	8
Below Archuleta	6/20/2018	107.5	37	35.5	3	5
Below Archuleta	6/20/2018	146.5	54	41.5	0	3
Above Aragon	6/21/2018	332	10	99	3	24.5
Above Aragon	6/21/2018	181.5	24	39	1	5
Above Aragon	6/21/2018	183	19	22	1	3
Dark Canyon	6/21/2018	461	13	26.5	0	0
Dark Canyon	6/21/2018	326	41.5	19.5	1.5	1
Dark Canyon	6/21/2018	402.5	34	38.5	3	3
Above Rio Cebolla	6/22/2018	326.5	9.5	34	3	8
Above Rio Cebolla	6/22/2018	597	23	43.5	1	18.5
Above Rio Cebolla	6/22/2018	443	8	18	1	33
Below Rio Cebolla	6/22/2018	147	3.5	22	0	24
Below Rio Cebolla	6/22/2018	631	16	32.5	0	23
Below Rio Cebolla	6/22/2018	450	27	26	2	15
Benson's Bar	6/23/2018	483.5	3	36.5	2	123.5
Benson's Bar	6/23/2018	159.5	10	18	0	8
Benson's Bar	6/23/2018	346.5		30.5	0	21

	Taxa:	**Plecoptera**		
Transect	**Date**	*Claassenia* spp.	*Hesperoperla* spp.	Perlodidae
La Puente Up Stream	6/18/2018	0	0	37
La Puente Up Stream	6/18/2018	0	0	33
La Puente Up Stream	6/18/2018	0	0	52.5
La Puente Down Stream	6/17/2018	0	0	8
La Puente Down Stream	6/17/2018	0	0	11.5
La Puente Down Stream	6/17/2018	0	1	4
Cooper's Ranch	6/18/2018	0	9.5	4
Cooper's El Vado Ranch	6/18/2018	0	3	0
Cooper's El Vado Ranch	6/18/2018	0	3	1
Above Rio Nutrias	6/19/2018	0	5	0
Above Rio Nutrias	6/19/2018	1	2	0
Above Rio Nutrias	6/19/2018	0	0	3
Below Rio Nutrias	6/19/2018	1	0	2
Below Rio Nutrias	6/19/2018	1	0	2
Below Rio Nutrias	6/19/2018	0	0	13
Above Archuleta	6/20/2018	0	0	4
Above Archuleta	6/20/2018	0	0	13
Above Archuleta	6/20/2018	0	0	7
Below Archuleta	6/20/2018	0	0	10
Below Archuleta	6/20/2018	0	0	5
Below Archuleta	6/20/2018	0	0	7
Above Aragon	6/21/2018	0	0	4
Above Aragon	6/21/2018	0	0	6
Above Aragon	6/21/2018	0	1	12
Dark Canyon	6/21/2018	2	0	16
Dark Canyon	6/21/2018	4	0	25
Dark Canyon	6/21/2018	5	0	18
Above Rio Cebolla	6/22/2018	4	1	19
Above Rio Cebolla	6/22/2018	2	0	47
Above Rio Cebolla	6/22/2018	1	1	18.5
Below Rio Cebolla	6/22/2018	0	0	3
Below Rio Cebolla	6/22/2018	0	0	19
Below Rio Cebolla	6/22/2018	0	0	5
Benson's Bar	6/23/2018	0	0	5
Benson's Bar	6/23/2018	2	0	18
Benson's Bar	6/23/2018	6	1	30

	Taxa:	**Trichoptera**				
Transect	**Date**	*Brachycentrus* spp.	*Glossosoma* spp.	Hydropyschidae	*Hydroptila* spp.	Phychomia
La Puente Up Stream	6/18/2018	0	2	68	11	2
La Puente Up Stream	6/18/2018	0	0	87	3	1
La Puente Up Stream	6/18/2018	0	5	142	11	0
La Puente Down Stream	6/17/2018	0	3	85.5	4	0
La Puente Down Stream	6/17/2018	0	2	281	2	6
La Puente Down Stream	6/17/2018	0	2	107.5	2	1
Cooper's Ranch	6/18/2018	0	3	22	0	0
Cooper's El Vado Ranch	6/18/2018	0	1	24	0	0
Cooper's El Vado Ranch	6/18/2018	0	0	0	0	0
Above Rio Nutrias	6/19/2018	0	0	0	0	0
Above Rio Nutrias	6/19/2018	0	0	1	0	0
Above Rio Nutrias	6/19/2018	0	0	2	0	0
Below Rio Nutrias	6/19/2018	0	0	5.5	0	0
Below Rio Nutrias	6/19/2018	0	0	22	0	0
Below Rio Nutrias	6/19/2018	0	13	159.5	0	0
Above Archuleta	6/20/2018	0	0	2	0	0
Above Archuleta	6/20/2018	0	0	7	0	0
Above Archuleta	6/20/2018	0	0	1	0	0
Below Archuleta	6/20/2018	0	0	7	0	0
Below Archuleta	6/20/2018	0	0	7	0	0
Below Archuleta	6/20/2018	2	2	3	0	0
Above Aragon	6/21/2018	0	2	5	0	0
Above Aragon	6/21/2018	1	1	1	1	0
Above Aragon	6/21/2018	0	4	13.5	0	0
Dark Canyon	6/21/2018	3	3	24	8	0
Dark Canyon	6/21/2018	5	5	25.5	3	0
Dark Canyon	6/21/2018	5	4	37.5	4	0
Above Rio Cebolla	6/22/2018	1	7	31	7	0
Above Rio Cebolla	6/22/2018	3.5	9	31	8	0
Above Rio Cebolla	6/22/2018	1	0	10	16	0
Below Rio Cebolla	6/22/2018	0	1	0	1	0
Below Rio Cebolla	6/22/2018	4	1	16.5	10	0
Below Rio Cebolla	6/22/2018	5	2	33	3	0
Benson's Bar	6/23/2018	0	0	2	16	0
Benson's Bar	6/23/2018	0	2	1	2	0
Benson's Bar	6/23/2018	0	13	30	9	0

	Taxa:	**Lepidoptera**	**Coleoptera**	
Transect	**Date**		Elmidae	Dryopidae
La Puente Up Stream	6/18/2018	2	1	0
La Puente Up Stream	6/18/2018	0	1	0
La Puente Up Stream	6/18/2018	0	1	0
La Puente Down Stream	6/17/2018	3	0	0
La Puente Down Stream	6/17/2018	12	6	0
La Puente Down Stream	6/17/2018	5	2	0
Cooper's Ranch	6/18/2018	33	9	0
Cooper's El Vado Ranch	6/18/2018	23.5	0	0
Cooper's El Vado Ranch	6/18/2018	3	0	0
Above Rio Nutrias	6/19/2018	1	7	0
Above Rio Nutrias	6/19/2018	10	2	0
Above Rio Nutrias	6/19/2018	1	0	0
Below Rio Nutrias	6/19/2018	2	1	0
Below Rio Nutrias	6/19/2018	13	0	0
Below Rio Nutrias	6/19/2018	8	16	0
Above Archuleta	6/20/2018	2	1	0
Above Archuleta	6/20/2018	0	0	1
Above Archuleta	6/20/2018	3	0	0
Below Archuleta	6/20/2018	1	0	0
Below Archuleta	6/20/2018	2	1	0
Below Archuleta	6/20/2018	1	0	0
Above Aragon	6/21/2018	0	4	0
Above Aragon	6/21/2018	0	1	0
Above Aragon	6/21/2018	0	7	0
Dark Canyon	6/21/2018	0	3	0
Dark Canyon	6/21/2018	0	4	0
Dark Canyon	6/21/2018	1	2	0
Above Rio Cebolla	6/22/2018	1	4	0
Above Rio Cebolla	6/22/2018	1	0	0
Above Rio Cebolla	6/22/2018	0	1	0
Below Rio Cebolla	6/22/2018	0	0	0
Below Rio Cebolla	6/22/2018	0	1	0
Below Rio Cebolla	6/22/2018	1	9	0
Benson's Bar	6/23/2018	0	0	0
Benson's Bar	6/23/2018	0	1	0
Benson's Bar	6/23/2018	2	3	0

	Taxa:	**Diptera**			
Transect	**Date**	Athercidae	Chironomidae	Ceratopoginidae	Empidiae
La Puente Up Stream	6/18/2018	0	190.5	0	0
La Puente Up Stream	6/18/2018	0	78	0	0
La Puente Up Stream	6/18/2018	0	90	0	0
La Puente Down Stream	6/17/2018	0	75	0	0
La Puente Down Stream	6/17/2018	0	229	0	0
La Puente Down Stream	6/17/2018	0	81	0	0
Cooper's Ranch	6/18/2018	0	56	0	16
Cooper's El Vado Ranch	6/18/2018	3	40.5	0	1
Cooper's El Vado Ranch	6/18/2018	0	599.5	0	4
Above Rio Nutrias	6/19/2018	0	6	0	0
Above Rio Nutrias	6/19/2018	0	3	0	0
Above Rio Nutrias	6/19/2018	0	0	0	0
Below Rio Nutrias	6/19/2018	0	4	0	0
Below Rio Nutrias	6/19/2018	0	38	0	0
Below Rio Nutrias	6/19/2018	0	31	1	0
Above Archuleta	6/20/2018	0	3	0	0
Above Archuleta	6/20/2018	0	94.5	0	0
Above Archuleta	6/20/2018	0	46.5	0	0
Below Archuleta	6/20/2018	0	158.5	0	0
Below Archuleta	6/20/2018	0	50	0	0
Below Archuleta	6/20/2018	0	65	0	0
Above Aragon	6/21/2018	0	426.5	0	0
Above Aragon	6/21/2018	0	129	3	0
Above Aragon	6/21/2018	0	82	6	0
Dark Canyon	6/21/2018	0	420.5	0	0
Dark Canyon	6/21/2018	0	163	0	1
Dark Canyon	6/21/2018	0	191	0	0
Above Rio Cebolla	6/22/2018	0	283	1	0
Above Rio Cebolla	6/22/2018	0	200	3	0
Above Rio Cebolla	6/22/2018	2	354.5	2	0
Below Rio Cebolla	6/22/2018	0	125.5	0	0
Below Rio Cebolla	6/22/2018	0	253.5	1	0
Below Rio Cebolla	6/22/2018	0	516.5	0	0
Benson's Bar	6/23/2018	0	451	0	0
Benson's Bar	6/23/2018	0	209.5	0	0
Benson's Bar	6/23/2018	0	209	0	0

	Taxa:	**Diptera**			
Transect	**Date**	*Hexatoma* spp.	Limoniidae	*Simulium* spp.	Tipulidae
La Puente Up Stream	6/18/2018	0	0	0	0
La Puente Up Stream	6/18/2018	0	0	0	0
La Puente Up Stream	6/18/2018	0	0	0	0
La Puente Down Stream	6/17/2018	0	0	0	0
La Puente Down Stream	6/17/2018	0	0	87	0
La Puente Down Stream	6/17/2018	0	0	19	0
Cooper's Ranch	6/18/2018	0	0	41	0
Cooper's El Vado Ranch	6/18/2018	0	0	2	0
Cooper's El Vado Ranch	6/18/2018	0	0	17	0
Above Rio Nutrias	6/19/2018	0	0	0	0
Above Rio Nutrias	6/19/2018	0	0	0	0
Above Rio Nutrias	6/19/2018	0	0	0	0
Below Rio Nutrias	6/19/2018	0	0	1	0
Below Rio Nutrias	6/19/2018	0	0	0	0
Below Rio Nutrias	6/19/2018	0	0	0	0
Above Archuleta	6/20/2018	0	0	0	0
Above Archuleta	6/20/2018	0	0	0	0
Above Archuleta	6/20/2018	0	0	143	0
Below Archuleta	6/20/2018	0	0	0	0
Below Archuleta	6/20/2018	0	0	0	0
Below Archuleta	6/20/2018	0	0	0	0
Above Aragon	6/21/2018	0	0	8	0
Above Aragon	6/21/2018	0	0	0	0
Above Aragon	6/21/2018	0	0	1	0
Dark Canyon	6/21/2018	0	0	9	0
Dark Canyon	6/21/2018	0	0	9	0
Dark Canyon	6/21/2018	1	0	9	0
Above Rio Cebolla	6/22/2018	2	0	7	0
Above Rio Cebolla	6/22/2018	0	0	6	0
Above Rio Cebolla	6/22/2018	0	0	0	0
Below Rio Cebolla	6/22/2018	0	0	3	0
Below Rio Cebolla	6/22/2018	0	1	5.5	0
Below Rio Cebolla	6/22/2018	0	0	7	0
Benson's Bar	6/23/2018	0	0	5	1
Benson's Bar	6/23/2018	0	0	24	0
Benson's Bar	6/23/2018	0	0	19	0

	Taxa:	**Decapoda**	**Hemiptera**	**Haplotaxida**	
Transect	**Date**		Veliidae	Lumbricidae	Naididae
La Puente Up Stream	6/18/2018	0	0	0	1
La Puente Up Stream	6/18/2018	0	0	1	0
La Puente Up Stream	6/18/2018	1	1	0	7
La Puente Down Stream	6/17/2018	1	0	0	2
La Puente Down Stream	6/17/2018	0	0	0	58
La Puente Down Stream	6/17/2018	0	0	2	12
Cooper's Ranch	6/18/2018	0	0	0	143
Cooper's El Vado Ranch	6/18/2018	0	0	0	40
Cooper's El Vado Ranch	6/18/2018	0	0	3	4125
Above Rio Nutrias	6/19/2018	0	0	1	9
Above Rio Nutrias	6/19/2018	0	0	3	5
Above Rio Nutrias	6/19/2018	0	0	0	2
Below Rio Nutrias	6/19/2018	0	0	5	9
Below Rio Nutrias	6/19/2018	0	0	3	12
Below Rio Nutrias	6/19/2018	0	0	4	16
Above Archuleta	6/20/2018	0	0	0	0
Above Archuleta	6/20/2018	0	0	0	1
Above Archuleta	6/20/2018	0	0	0	0
Below Archuleta	6/20/2018	0	0	2	8
Below Archuleta	6/20/2018	0	0	1	14
Below Archuleta	6/20/2018	0	0	0	26
Above Aragon	6/21/2018	0	0	0	125
Above Aragon	6/21/2018	0	0	0	58
Above Aragon	6/21/2018	0	0	0	46
Dark Canyon	6/21/2018	0	0	0	91
Dark Canyon	6/21/2018	0	0	0	15
Dark Canyon	6/21/2018	0	0	2	45
Above Rio Cebolla	6/22/2018	0	0	0	132
Above Rio Cebolla	6/22/2018	0	0	0	159
Above Rio Cebolla	6/22/2018	0	0	0	141
Below Rio Cebolla	6/22/2018	0	0	1	18
Below Rio Cebolla	6/22/2018	0	0	10	358
Below Rio Cebolla	6/22/2018	0	0	0	23
Benson's Bar	6/23/2018	0	0	0	303
Benson's Bar	6/23/2018	0	0	0	66
Benson's Bar	6/23/2018	0	0	0	37

	Taxa:	Trombidiformes	Nematoda	Tubellaria	Mollusca
Transect	**Date**	Hydracarina			
La Puente Up Stream	6/18/2018	19	0	0	0
La Puente Up Stream	6/18/2018	2	0	0	0
La Puente Up Stream	6/18/2018	5	0	0	0
La Puente Down Stream	6/17/2018	10	1	0	0
La Puente Down Stream	6/17/2018	23	10	0	0
La Puente Down Stream	6/17/2018	5	5	1	0
Cooper's Ranch	6/18/2018	5	7	5	3
Cooper's El Vado Ranch	6/18/2018	1	0	4	0
Cooper's El Vado Ranch	6/18/2018	0	4	0	0
Above Rio Nutrias	6/19/2018	1	3	0	0
Above Rio Nutrias	6/19/2018	1	3	0	1
Above Rio Nutrias	6/19/2018	0	0	0	0
Below Rio Nutrias	6/19/2018	3	0	0	0
Below Rio Nutrias	6/19/2018	0	0	0	0
Below Rio Nutrias	6/19/2018	1	0	8	5
Above Archuleta	6/20/2018	0	0	0	0
Above Archuleta	6/20/2018	6	2	0	0
Above Archuleta	6/20/2018	3	1	0	0
Below Archuleta	6/20/2018	6	3	0	0
Below Archuleta	6/20/2018	1	0	0	0
Below Archuleta	6/20/2018	4	1	0	0
Above Aragon	6/21/2018	6	18	0	0
Above Aragon	6/21/2018	8	7	0	4
Above Aragon	6/21/2018	2	11	0	9
Dark Canyon	6/21/2018	21	3	0	0
Dark Canyon	6/21/2018	12	2	0	0
Dark Canyon	6/21/2018	11	1	0	0
Above Rio Cebolla	6/22/2018	8	6	0	0
Above Rio Cebolla	6/22/2018	10	0	0	0
Above Rio Cebolla	6/22/2018	3	1	0	0
Below Rio Cebolla	6/22/2018	4	3	0	0
Below Rio Cebolla	6/22/2018	25	1	0	1
Below Rio Cebolla	6/22/2018	22	2	0	0
Benson's Bar	6/23/2018	2	4	0	0
Benson's Bar	6/23/2018	10	0	0	0
Benson's Bar	6/23/2018	3	4	0	0