Effects of a Catastrophic Flood on Macroinvertebrate Populations and Guadalupe Bass Recruitment in Two Central Texas Rivers

Archis R. Grubh

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Cover photo: Blanco River, Blanco County, Texas taken in spring 2016

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EXECUTIVE SUMMARY

The Blanco and Colorado River basins in Texas experienced major flooding in May and October of 2015. Extreme drought and flood events cause change in hydrological conditions in a river and play a critical role in structuring aquatic communities. Macroinvertebrate communities either persist through a flood event by burrowing in the streambed or recolonize following the disturbance. Recovery in abundance and diversity of macroinvertebrates ranges from a few months to a few years and can affect all the trophic levels in a riverine ecosystem (Death 2008). Because macroinvertebrates play an important role in the riverine food-chain system, this disturbance could have direct implications on recruitment of fish species that use them as food source. Adult Guadalupe Bass are piscivorous; however, their diet during the juvenile stage (< 8.27 in.) total length consists largely of aquatic macroinvertebrates such as mayflies and midges. Effects following the second catastrophic flood event (October 2015) on macroinvertebrate communities and Guadalupe Bass recruitment were documented in this study. The main objectives of this study conducted in the two waterbodies, Blanco and Colorado Rivers, were to:

1. Assess the response and recovery time of macroinvertebrate communities to a catastrophic flood.
2. Assess the relationship between macroinvertebrate taxa and hydrologic parameters; and
3. Assess the effects of a catastrophic flood on Guadalupe Bass recruitment in the Colorado River.

Key findings of this study were:

- Macroinvertebrate communities from smaller river systems responded strongly to fine-scale flow conditions, measured as spot current velocity. In contrast, the communities from a larger river system responded strongly to broader-scale flow conditions, measured as discharge.
- The flow-sensitive macroinvertebrate taxa from the Colorado River showed greater impact compared to the taxa from the Blanco River, following the second catastrophic flood.
- The average recovery period of macroinvertebrate communities was about 82 days after the discharge levels had subsided, suggesting a longer than two-week recovery period after high pulse events.
- The recovery period of macroinvertebrate communities was much longer at downstream sites in both river basins.
- Several hydrological flow parameters affected macroinvertebrate taxa (e.g., number of days of base flow, duration of peak discharge during small flood pulse event, duration of recession, magnitude of rise, rate of median recession, and number of flow reversals) and were significantly correlated to the hydrologic disturbance gradient.
- Guadalupe Bass length frequency distributions showed bimodal distribution across the sampled reach in the Colorado River.
- Guadalupe Bass recruitment in the Colorado River was greatly affected by the flood events as seen in the weak year-class strength in the following year.

INTRODUCTION

Environmental factors such as climate, geomorphology, soils, and riparian vegetation, in conjunction with anthropogenic factors such as impoundments and diversions, influence flow regimes in a river. Flow conditions vary on a seasonal and longitudinal scale and affect aquatic communities in different ways depending on local environmental conditions (Poff et al. 1997). The natural flow regime, encompassing subsistence flow, base flow, high flow pulse, and overbanking flow components (TIFP 2008), are vital for the physiological and adaptive aspects of aquatic organisms (Richter et al. 1996; Poff and Zimmerman 2010). Flow pulses in rivers, which vary in magnitude, frequency, and duration, have a significant influence on productivity and interactions within a river system (Junk et al. 1989; Bayley 1995; Poff et al. 1997; Junk 2005). The effects of these flow pulses extend to the physical, chemical, and biological conditions of rivers, which makes vital contributions to the aquatic biodiversity. The relationship between flow pulses and aquatic biodiversity are directly correlated, and are instrumental in successful macroinvertebrate and fish recruitment, and biomass increase (Tockner et al. 2000; King et al. 2003). However, hydrologists, natural resource managers, and policy makers should take the potential for extreme flood events into account when making decisions pertaining to the management and preservation of river systems.

Seasonal variations in stream hydrology can significantly impact the structure and function of instream communities. The dynamics of aquatic macroinvertebrate assemblages are influenced by changes in streamflow over time by development of specific adaptation traits that enable them to exploit different aspects of flow patterns (Poff et al. 1997, 2006; Biggs et al. 2005). Certain species are highly sensitive to changes in hydrologic conditions due to their dependance on specific flow regimes for reproductive triggers and critical life stages. This sensitivity may be due to their dependence on particular flow conditions (Grossman 1982; Poff and Ward 1989), or their narrow tolerances for temperature and chemical conditions which can be affected by flow regimes and can have far-reaching consequences beyond their position in the assemblage structure.

Large flood events can alter fish and macroinvertebrate communities depending on the magnitude of the event and size of the watershed where they occur (Hynes 1970; Matthews 1986; Resh et al. 1988; Lake 2003; Snyder and Johnson 2006; Petsch 2016). Macroinvertebrate community metrics (e.g., species richness, abundance, trophic guilds and their relationships, etc.), in flood affected systems show increasing impacts with increasing magnitude of floods. Lotic substrates and instream habitat can be altered by extreme flood events, which has the potential to directly affect species abundance and community composition (Robinson et al. 2004; Franssen et al. 2006). Although benthic macroinvertebrates can be displaced during high flow events, they are able to recolonize new habitats via downstream drift from upstream reaches, subterranean refugia, aerial dispersion from riparian habitats, and by reproduction of the survivors (Williams and Hynes 1976). Despite the resistance and resiliency of macroinvertebrates to extreme events, many assemblages are strongly affected by floods (Death 2008). The recovery time of macroinvertebrate communities can range from a few days to years depending on the timing of the year when the flood occurred, size of the waterbody, flood magnitude, and riparian vegetation (Death 2008). Given the importance of macroinvertebrates in the food chain in a riverine system, this could have direct implications on the recruitment of fish species that use them as food source.

The effects of floods on fish communities depends on factors such as fish age, species abundance, and the ability of fish to utilize velocity shelters (Bischoff and Wolter, 2001). Native fish populations are generally better adapted to flow pulses and can benefit from floodplain connectivity resulting from floods, which can increase recruitment and population growth (Barko et al. 2006; Stoffels et al. 2014). However, high floods and changes in flow regimes caused by altered land-use patterns can lead to significant habitat degradation and a decline in Guadalupe Bass populations (Grabowski 2014). The timing of catastrophic flood events, particularly during the juvenile stage of fish, in combination with altered habitat conditions and reduced macroinvertebrate abundances, can have negative impacts on Guadalupe Bass recruitment and year-class strength. While ensuring the preservation of healthy fish populations is the primary goal of fisheries management, with an emphasis on enhancing sport-fish production (Ludsin and DeVries, 1997; Sammons et al., 2001), it is important to consider the potential impacts of catastrophic flood events on fish recruitment and the strength of year-classes in making informed management decisions.

The Guadalupe Bass *Micropterus treculii* is a popular sport fish species in Central Texas, historically found in streams from the Edwards Plateau region to the lower Colorado River basin (Curtis et al., 2015). However, this species faces various threats, including rising stream temperatures (Sullivan et al., 2013), altered hydrological patterns (Ficke et al., 2007), and hybridization with Smallmouth Bass *Micropterus dolomieu* (Koppelman and Garrett, 2002; Bean et al., 2013). Higher water temperatures during drought years, especially above 30°C in shallow runs, can impact the optimal growth of Guadalupe Bass, affecting factors such as length, mass, and liver index (Sullivan et al., 2013). The combination of drought and subsequent flooding conditions can have compounding effects on fish recruitment. Understanding the three primary factors —recruitment, growth, and mortality — that determine the structure of the fish community is crucial for effective fisheries management.

On May 24th, 2015, Central Texas had a significant rainfall event (once in 500-year event) occurred that lasted for two weeks. This was followed by another significant rain event (500-year event) five months later on October 30th, that also lasted for about two weeks. This region of the Texas Hill Country from Austin-San Antonio corridor, also known as the "flash flood alley" is one of the flood prone regions in Texas (Saharia et al. 2017). These two historic rainfall events caused catastrophic flooding in multiple river systems throughout the state which drastically restructured terrestrial and instream habitats in several Central Texas streams including the Blanco and Colorado rivers.

The goal of this study was to investigate impacts following the second flooding event (Oct 30th, 2015) on the benthic macroinvertebrate communities and Guadalupe Bass recruitment in the Blanco and Colorado rivers. These goals were addressed by the following objectives: a) assess macroinvertebrate community metrics over time; b) assess response of macroinvertebrate community metrics to flow conditions; c) assess response of individual flow-sensitive macroinvertebrate taxa to discharge conditions during a recovery period, d) assess change in macroinvertebrate community structure over time, e) assess the effects of environmental variables on macroinvertebrate communities, f) identify and examine ecologically significant hydrological parameters for macroinvertebrate taxa, g) assess Guadalupe Bass length frequency distribution, and h) assess the recruitment of Guadalupe Bass by inspecting the year-class strength from otolith data.

METHODS

Study Area

The Blanco River watershed, a subbasin of the Guadalupe River Basin, covers 1,140 km^2 (GBRA 2018) and spans four counties (Kendall, Comal, Blanco and Hays) in Central Texas. It receives an average annual rainfall of 35 inches (US Climate data, 2023) with a mean discharge of 93 cubic feet per second (cfs; USGS gage 8171000). The upper segment of the Blanco River (upstream of Wimberley, TX) is largely spring fed and runs for 114 km through the Edwards Plateau which largely consists of karst topography with limestone bedrock as the primary substrate (Griffith et al. 2007). The Blanco River, downstream of Wimberley flows for 24 km through the Edwards Plateau before its confluence with the San Marcos River in the Blackland Prairies. The study area for the Blanco River (Figure 1) falls in the Balcones Canyonlands (30c, level iv) within the Edwards Plateau (30, level iii) ecoregion type, which is largely a karst topography with limestone bedrock as the primary substrate, with clear and cool stream waters (Griffith et al. 2007). Six sampling sites were selected on the Blanco River along a 64 km reach from downstream of Blanco State Park to Little Arkansas Road just outside of Wimberley (Figure 1).

The Colorado River is one of the longest rivers (1,387 km) in Texas with a drainage size of 64,000 km^2 and flows through 21 counties with headwaters starting from Dawson County to the river mouth at Matagorda Bay on the Gulf (TCEQ 2004). The Colorado River has five principal tributaries: the Concho, San Saba, Llano, James, and Pedernales Rivers. The Colorado River in Bastrop County receives an annual rainfall of 36 inches and experiences seasonal variation in discharge that peaks in the month of June (1,951 cfs: USGS 28-year median value) and is lowest in the month of December (471 cfs: USGS 28-year median value). This region falls in the Floodplains and Low Terraces (33f, level iv) within the East Central Texas Plains (33, level iii) ecoregion type, which is also known as the Post Oak Savanna, and was historically covered by post oak savanna vegetation. Six sampling sites were selected on the Colorado River along a 96-kilometer reach from Bastrop to La Grange (Figure 1).

Hydrologic Events

In 2015, the Blanco River crested at 36 ft in May (69,700 cfs) and 37 ft in October (70,000 cfs; Figure 2). The USGS estimated peak flows at the Wimberley station (USGS 0817100) at about 175,000 cfs using indirect slope area techniques, for the May event, and also estimated that the river peaked at about the same cfs for the October event (USACE, 2016). For the period of record for the Wimberley USGS gage (8171000) dating back to the year 1986, only two other previous flood events come close to or exceeded these amounts were in 1998 (23,300 cfs) and 1929 (no discharge data available, but National Weather Service provides information that water crested to 33.30 feet depth at Ranch Road 12 crossing on the Blanco River). In the Colorado River Basin, the discharge levels in Bastrop (USGS gage 8159200: 48,500 cfs in May and 61,600 cfs in October), Smithville (USGS gage 8159500: 68,000 cfs in May and 69,900 cfs in October), and La Grange (USGS gage 8160400: 60,500 cfs in May and 54,100 cfs in October) peaked at several orders of magnitude above the 15-year median levels (Figure 3, 4, 5).

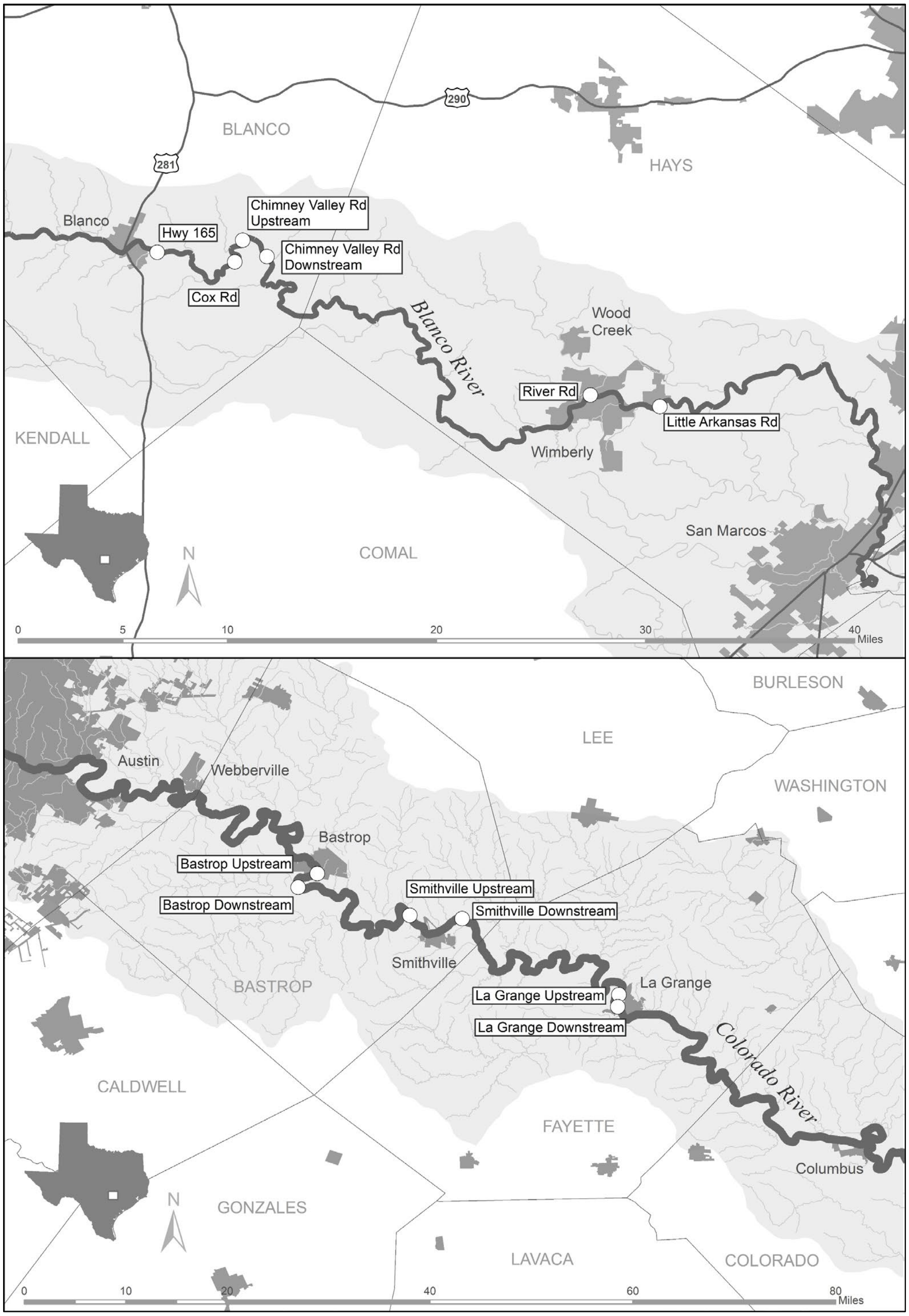


FIGURE 1.— Study area with sampling stations and USGS gages on the Blanco and Colorado Rivers in central Texas. The USGS stream gage on the Blanco River is located between the last two downstream sites (USGS gage: 8171000). The site names on the Colorado River are named up- and down-stream based on location of each stream gage (Bastrop USGS gage: 8159200, Smithville USGS gage: 8159500, and La Grange USGS gage: 8160400).

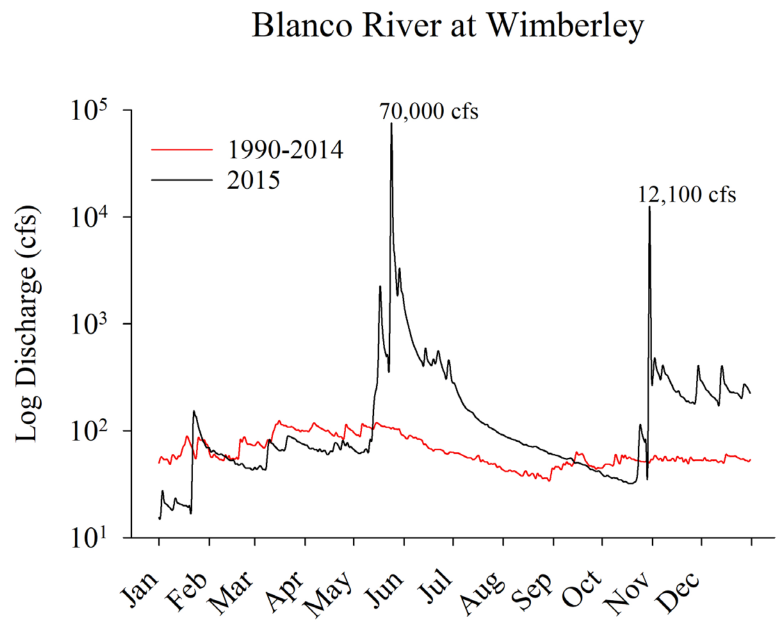


FIGURE 2.— Discharge (24-year median of daily means) from the Blanco River at Wimberley, Texas (USGS gage: 8171000) from years 1990 to 2014. Overlaid is the mean discharge for year 2015 with peak values during the catastrophic flood even in the months of May and October.

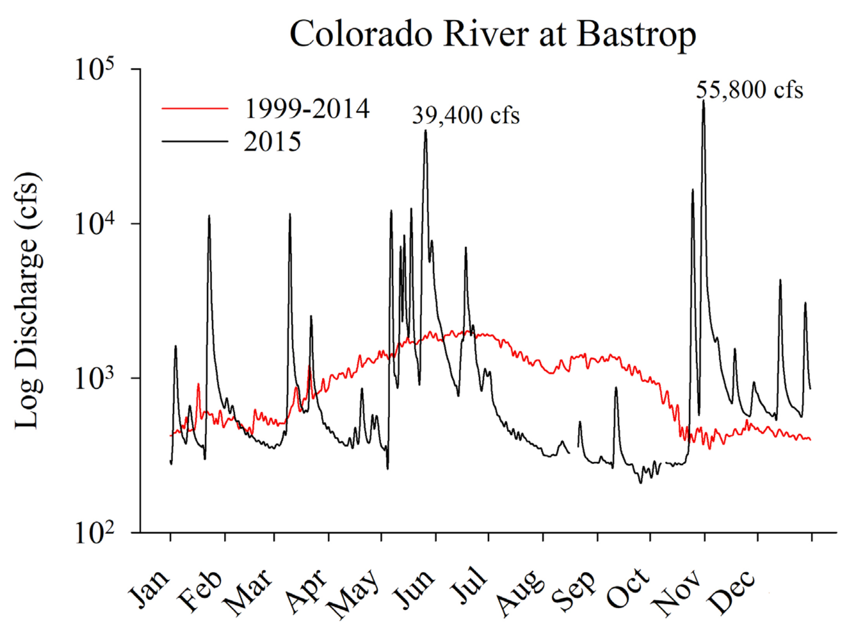


FIGURE 3.— Discharge (15-year median of daily means) from the Colorado River at Bastrop, (USGS gage: 8159200) in Texas from years 1999 to 2014. Overlaid is the mean discharge for year 2015 with peak values during the catastrophic flood even in the months of May and October.

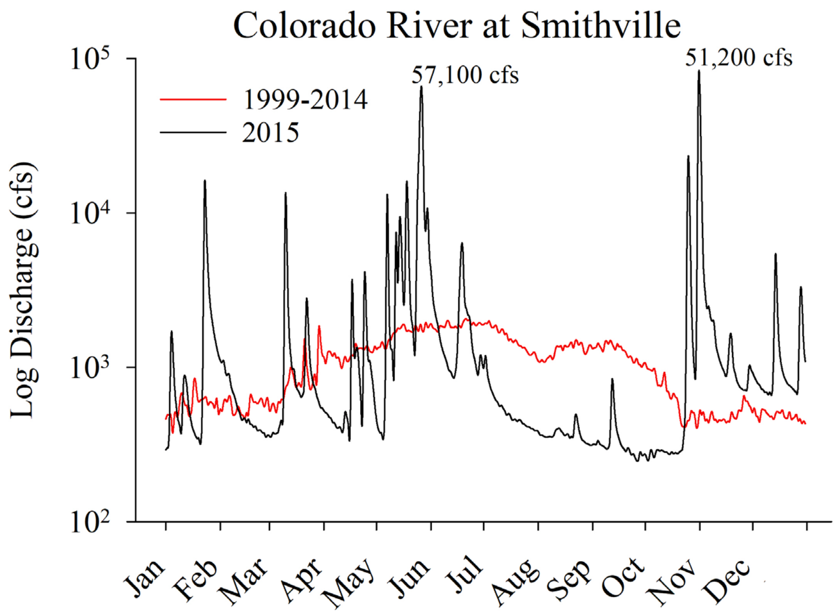


FIGURE 4.— Discharge (15-year median of daily means) from the Colorado River at Smithville (USGS gage: 8159500) in Texas from years 1999 to 2014. Overlaid is the mean discharge for year 2015 with peak values during the catastrophic flood even in the months of May and October.

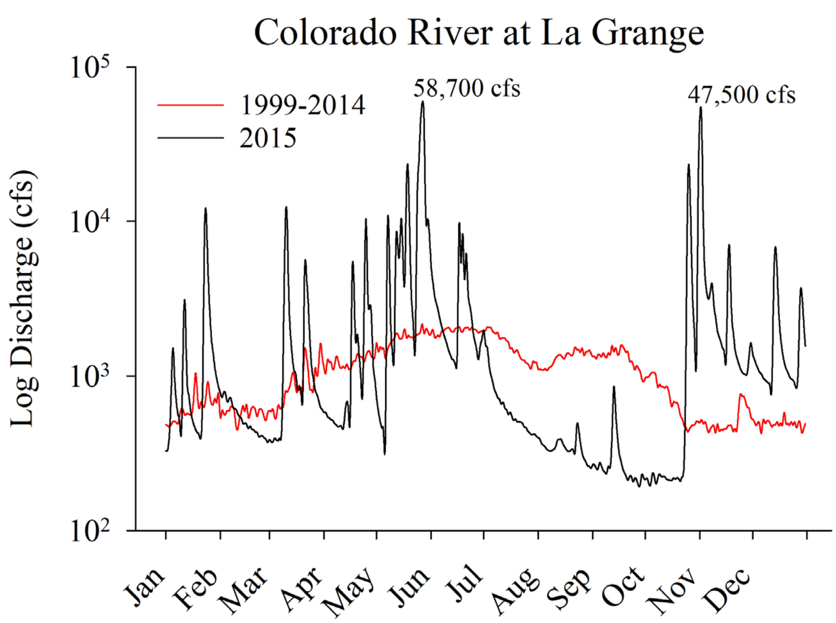


FIGURE 5.— Discharge (15-year median of daily means) from the Colorado River at La Grange (USGS gage: 8160400) in Texas from years 1999 to 2014. Overlaid is the mean discharge for year 2015 with peak values during the catastrophic flood even in the months of May and October.

Macroinvertebrate and Water quality parameters

Macroinvertebrate sampling was conducted at each of the six sites on the Blanco and Colorado rivers (Figure 1) during a six-month period from November 2015 to April 2016. Sampling occurred twice a month for the first three months and once a month for the next three months, resulting in a total of nine sampling events per site (Appendix A, B) from a suitable riffle habitat quadrant (6-30 square meters). Three macroinvertebrate samples were collected from each site using a Hess sampler (500 µm mesh size), following the Texas Commission on Environmental Quality's Surface Water Quality Monitoring Procedures Volume II (TCEQ 2014) and samples were preserved in 70% ethanol. The samples were sorted in the laboratory and later identified under a stereomicroscope to genus level (with the exception of orders Diptera and Entomobryomorpha - identified to family level, and Hirudinea and Oligochaeta - identified to order level using appropriate keys, and voucher specimens were verified independently by taxa specialists (Smith 2001; Merritt et al. 2019). Five point-measurements of depth (feet) and current velocity (feet/sec; using Marsh-McBirney Flo-Mate 2000, at 0.6 of the depth) were recorded from the habitat quadrant. Discharge data was collected from the nearest available USGS gage on Blanco River and Colorado Rivers gages (USGS gages: 8171000, 8159200, 8159500, 8160400). Substrate composition using a modified Wentworth scale (Wentworth 1922) was recorded at each site per sampling event. Water quality parameters including temperature (°C), conductivity (µS/cm), dissolved oxygen (mg/L), pH, and turbidity were measured using a YSI 600 XLM data sonde at each site per sampling event.

Hydrologic parameters

Hydrologic parameters were developed utilizing the daily flow component classification methodology derived from the Indicators of Hydrologic Alteration tool (IHA; TNC 2009) from 30-year USGS average daily flow data from Blanco and Colorado rivers gages (USGS gages: 8171000, 8159200, 8159500, 8160400). The daily flow component classification data found in the daily environmental flow component tab in the IHA analysis output was used to develop 'ecologically-relevant' hydrological variables defined in several hydro-ecological studies (Poff and Ward 1989; Jowett and Duncan 1990; Clausen and Biggs 1997; Richter, et al., 1997; Puckridge, et al., 1998; Robertson, et al. 2018; Meitzen, et al. 2023) that were grouped in five major categories (magnitude, frequency, duration, timing, and rate of change) as proposed in the Indicators of Hydrologic Alteration methodology and its derivatives (Richter, et al. 1996; Olden and Poff 2003).

A total of 57 ecologically relevant hydrological variables were derived (and z-score transformed; Appendix C, D) for the analysis. In order to capture the response of macroinvertebrates to the hydrological variables, these variables were calculated for day-15 and day-30 prior to the actual macroinvertebrate sampling event. Simplest form of flow descriptors were used for general applicability and to avoid redundancy (Olden and Poff 2003). Sampling site discharge was associated with USGS streamflow gages according to the following conditions: 1) distance less than 50-km from the sampling site, and 2) within same ecoregion. USGS 08171350 served as a surrogate discharge location for five sites on the Blanco River. On the Colorado River, USGS gages 08159200, 08159500, and 08160400 served as discharge locations for two macroinvertebrate sites closest to each discharge gage.

Study reaches include both free flowing and regulated streams. Dam structures on the Colorado River include large flood control and water supply reservoirs that influence downstream habitat, hydrology, and biotic communities. On the Blanco River there are numerous run-of-the river low-head dams that likely have a lesser effect on habitat and hydrology, especially during wet conditions. On the Colorado River, the distance between the nearest upstream dam to macroinvertebrate sampling sites ranged from 58-116 km, and the hydrograph showed average daily fluctuation of 50 cfs during the study period. For the Blanco River, the distance from the nearest upstream dam to macroinvertebrate sampling sites varied from 2-42km, and the average daily fluctuation was less than 5 cfs. The daily fluctuations recorded in the hydrograph can be attributed to several factors such as evapotranspiration, withdrawals, discharge from treatment plants, and/or timed releases for downstream use.

Guadalupe Bass Collection

The Colorado River, from Little Webberville Park to La Grange, was sampled for Guadalupe Bass with boat electrofishing equipment in October and December of 2016 (7 hours of total shock time across six days). The sampling sections were addressed as five sites for further analyses: Webberville, Bastrop upstream, Bastrop downstream, Smithville downstream, and La Grange upstream (Figure 1). The Guadalupe Bass (GB) sampling from the Blanco River (downstream of Blanco State Park to Wimberley area) was unsuccessful due to insufficient numbers collected (<30), and no GB related analyses were conducted from the Blanco River. The number of fish per inch class was recorded in the field to ensure enough individuals were collected for recruitment analyses. Potential Guadalupe x Smallmouth Bass hybrids were noted in the field and genetic analysis from fin clips was conducted to confirm species identification before further processing. All individuals were placed on ice and returned to the lab where each fish was measured to total length (inch), weighed (lbs) and sagittal otoliths were extracted for aging. Category 2 age and growth analysis was performed according to Texas Parks and Wildlife Department's Fishery Assessment Procedures (TPWD, Inland Fisheries Division, unpublished manual revised 2022). The number of growth rings were counted by two biologists independently to avoid bias and a third person was consulted to resolve any disagreements.

Data Analysis

Macroinvertebrate taxa diversity for each site was described by using Shannon's diversity index (Shannon and Weaver 1948) and Pielou's evenness index (Pielou 1966). Because the Colorado River is a non-wadable riverine ecosystem, the benthic index of biotic integrity composite scores (BIBI, TCEQ 2014) were not used in assessing the macroinvertebrate communities, but the eleven individual metrics that contribute to it were calculated to infer community level trends. The BIBI is developed with different metrics that take into account various traits (e.g., feeding guild, tolerance values, etc.) and abundances of the macroinvertebrates (TCEQ 2014). The Blanco River macroinvertebrate samples were analyzed in a similar fashion for comparative purposes across drainage basins. The BIBI is developed with different metrics that take into account various traits (e.g., feeding guild, tolerance values, etc.) and abundances of the macroinvertebrates (TCEQ 2014). Summary plots of the total abundance, taxa richness, diversity/evenness indices, few BIBI metrices, and the feeding guilds of macroinvertebrates were inspected for trends over time.

Habitat heterogeneity varies across different spatial scales, thus identifying the specific scale that affects macroinvertebrate assemblages can be challenging (Robson 1996), and this difficulty might account for the conflicting results observed in various studies (Downes et al. 1993; Boyero and Bailey 2001). Flow conditions have a scale dependent effect on macroinvertebrate assemblages in a lotic system (Li and Reynolds 1995; Boyero 2003; Brooks et al. 2005). Current velocity in this study is defined as a measurement of flow conditions measured by a hand-held flow meter, in the immediate habitat vicinity of the macroinvertebrate sample; whereas discharge is defined as a measurement of how much flow was passing through the stream or river reach recorded by the USGS gage.

The response of EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera), tolerant taxa and feeding guilds, to current velocity was explored using Spearman correlation. Flow sensitive macroinvertebrate taxa, and some abundant taxa that were found across all samples were identified and inspected for their recovery over time and response to discharge. Flow-sensitive genera were selected based on their requirement of continuous flow conditions and sufficient abundances (average abundance >25 count) throughout the samples to run statistical analyses (Extence et al. 1999; W. Harrison, Texas Commission on Environmental Quality, pers comm.). Although Chironomidae is not a flow-sensitive taxa, it was included in this analysis due to its high abundance and potential food source for several game and non-game fish species. The effects of discharge, and number of days since the flood event on selected taxa was graphically represented and assessed using generalized linear models (GLM using JMP vs.14). The GLM is widely used in ecological studies (Guisan et al. 2002) as it has proven its ability to study non-linear relationships as observed in the current data. The abundances of selected macroinvertebrate taxa from the Blanco River were summed across all six sites because discharge data was available only from Wimberley, TX (USGS gage: 8171000). The selected taxa abundances from the Colorado River were summed from sites close to each USGS gage station (two sites per USGS gage), and plotted and tested against time factor, and discharge data (Bastrop USGS gage: 8159200, Smithville USGS gage: 8159500, and La Grange USGS gage: 8160400).

The spatial distribution of macroinvertebrate community response metrics for the two river basins was explored separately with non-metric multidimensional scaling (nMDS), using the Bray-Curtis dissimilarity matrix on square root transformed macroinvertebrate response data to graphically represents similarity between sampling sites. To better understand the recovery of macroinvertebrate communities from the flood over time, a second nMDS analysis was run by grouping the replicate samples per site to filter out noise and was plotted by separating site scores for each site. Change in the community structure between sites and over time was tested with analysis of similarity (ANOSIM). ANOSIM calculates a R test statistic with values ranging from 0 to 1 (values close to 0 indicate weak separation, and 1 indicating a strong separation). Taxa contributing to the average Bray-Curtis similarity/dissimilarity among sites within each treatment type were quantified with similarity of percentage analysis (SIMPER). These set of analyses were conducted using PRIMER software v.7 (Clarke and Gorley 2015).

The relationships of benthic macroinvertebrate communities and environmental variables (z-score transformed) were evaluated independently for each river with canonical correspondence analysis using CANOCO software vs.5 (ter Braak and Šmilauer 2012). CCA is a direct gradient analysis that constrains species data to environmental data and its associations can be visualized graphically. In the resulting ordination plot, macroinvertebrate taxa are represented with open circles and the environmental variables by arrows. The region of the maximum variation in value of the corresponding environmental variable is pointed out by the arrows (ter Braak and Verdonschot 1995). A Monte Carlo permutation test with 499 iterations was performed for testing the relationship between the macroinvertebrate community and the environmental variables on the first four axes (ter Braak and Wiertz 1994). CCA simplifies complex datasets and is an effective method for exploring patterns of multiple environmental variables on macroinvertebrate communities.

The potential ecological significance of the hydrological variables on macroinvertebrate taxa was explored through forward selection stepwise regression, using Akaike information criterion with sample-size adjustment (AICc) as the selection criterion. It was used to obtain the parsimonious hydrological models for each macroinvertebrate taxa (that were collected in sufficient numbers through the sampling period). The selected hydrological variables were inspected for variance inflation factors (VIF) to examine multicollinearity amongst predictor variables. All hydrological variables that had VIF results under 2.5, provided reliable estimates of effects of each predictor hydrological variable, and the models with higher VIF values were approached with caution. The hydrological descriptors are explained in Appendices C and D.

Length-frequency distributions of GB were assessed at five sites on the lower Colorado River, and also compared across the sites for all size-classes. Proportional size distribution (PSD; Guy et al. 2007) was calculated to determine the quality of GB in the sampling reach using the stock, preferred, memorable, and trophy sizes proposed by Cummings (2018). Fish abundances, and age groups were compared between sites with two-way analysis of variance using JMP vs.14. Comparison of relative strengths of annual cohorts from a sample of adult fish population (using otolith data) can be used as an indirect measure to determine the year-class strength (Maceina and Pereira 2007; Maceina 1997). An index of year-class strength is developed from the residuals from catch-curve regressions, where a strong year-class is represented by positive residuals, and a weak year-class is represented by negative residuals. The residuals from catch-curve regressions for age- 0-4 fish collected in fall 2016 were used to describe year-class strength. An important caveat to this method is the assumption that variation in the catch curve is solely a function of recruitment variation. While catch-curve residuals may not be a reliable metric for predicting the relative strength of year-classes (Catalano et al. 2009), the relationship between catch-curve residuals and year-class strength is fairly strong and is used as an exploratory tool in this study in conjunction with other supporting evidence of availability of forage taxa (Micucci et al. 2003; Parkos III and Wahl 2010). Age 0 GB were included in the recruitment analysis in this study to address the main objective of determining the effects of the catastrophic flood. Although age 0 GB were not recruited (reproduction potential) by fall 2016, they were recruited (length) to the collection gear (boat electrofish). The average length of age 0 GB collected in this study was 5.73 inches, which is near the effective capture size of 5.9 inches for boat electrofish method (Jackson and Noble 1995).

RESULTS

Macroinvertebrate community metrics

During the course of this study, 321 Hess samples were collected and analyzed separately from the Blanco River and the Colorado River. The macroinvertebrate taxa abundances from the two rivers is summarized here, followed by specific objectives and analyses thereafter. The Blanco River produced a total of 11,060 individual organisms representing 14 orders, 37 families, and 63 genera (Appendix A). The Colorado River produced a total of 25,262 individual organisms representing 13 orders, 37 families, and 59 genera. Assemblages for both drainage basins were dominated by mayflies (Ephemeroptera) with the most genera (20), followed by beetles (Coleoptera) and caddisflies (Trichoptera). The Blanco River samples had fewer individuals per sample (average = 71.7) than the Colorado River (average = 163.9), although it supported a higher taxa diversity (62 genera). The two taxa with the highest abundances in the Blanco River were Chironomidae (true flies) and *Neochoroterpes* (mayfly).

The total abundance of macroinvertebrates for the first two sampling events post-flood was lower than the subsequent collections and this trend was observed at most sites in both the rivers (Figure 6a). The Shannon's diversity index and Pielou's evenness index did not show any particular trend over the sampling period across sites in both rivers (Figure. 6 b).

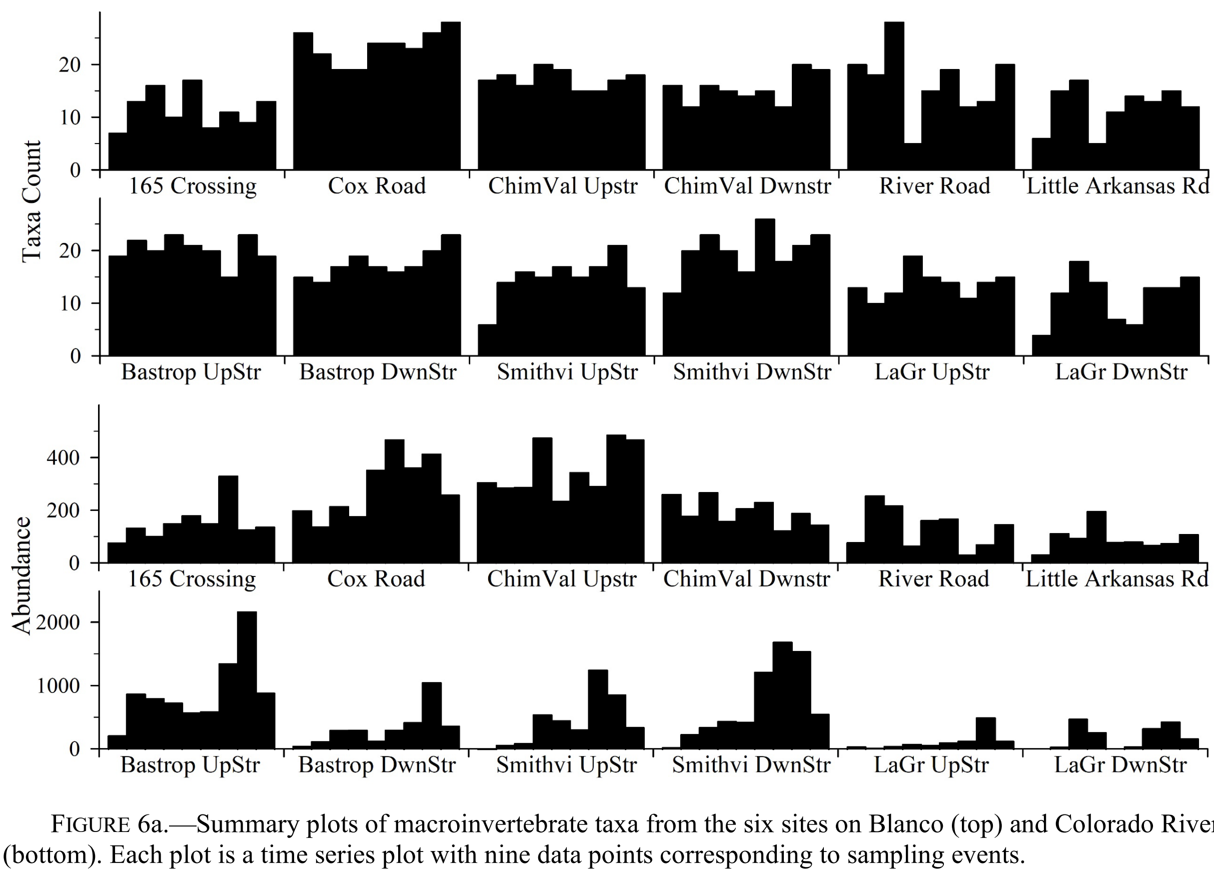


FIGURE 6a.—Summary plots of macroinvertebrate taxa from the six sites on Blanco (top) and Colorado Rivers (bottom). Each plot is a time series plot with nine data points corresponding to sampling events.

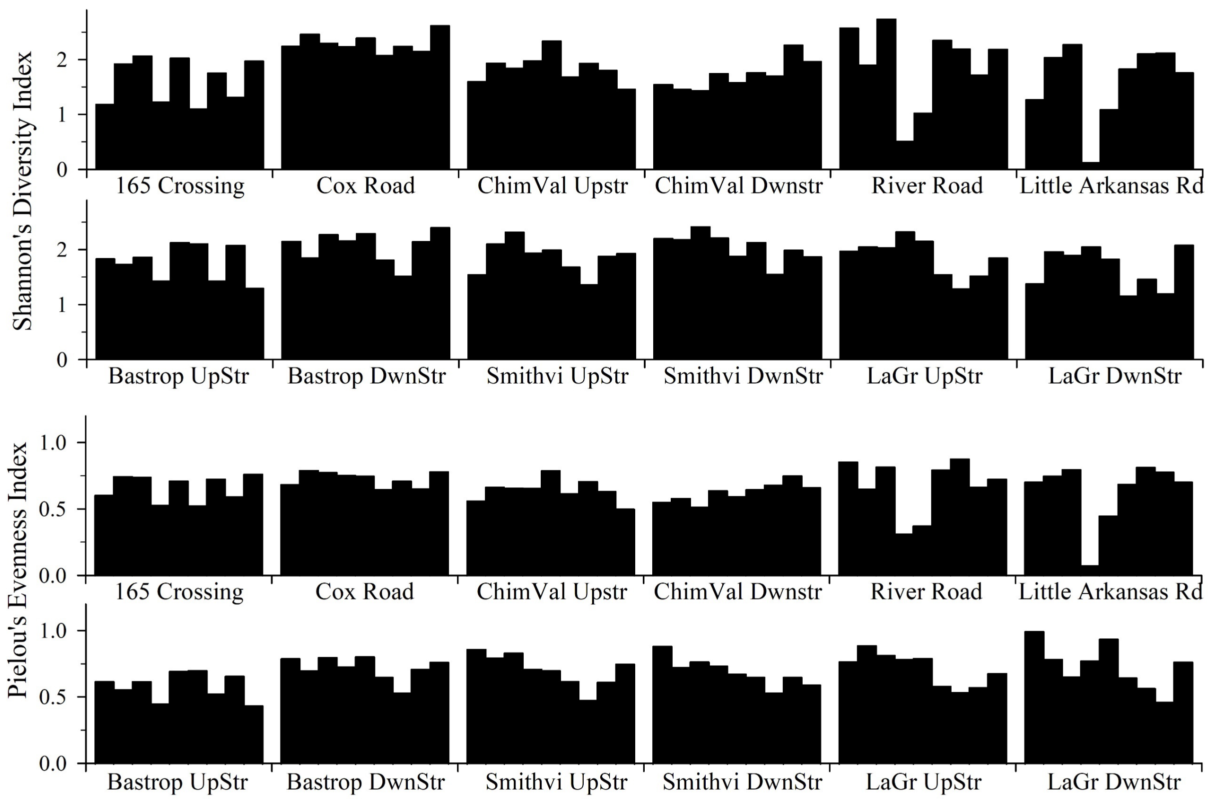


FIGURE 6b.—Summary plots of macroinvertebrate taxa from the six sites on Blanco (top) and Colorado Rivers (bottom). Each plot is a time series plot with nine data points corresponding to sampling events.

Each of the BIBI metrics showed an increase in values over time, with taxa count, percent EPT, and percent Chironomidae showing much slower recovery. The number of Diptera taxa showed some fluctuation over time in the Blanco River but did not vary much at the sites from the Colorado River. No specific trends over time were observed in the Ephemeroptera count, intolerant taxa count, and percent tolerant taxa. The filter feeding guild showed a gradual increase in percent abundance over time, with higher percent composition at two sites on the Blanco River (River Road and Little Arkansas Road), and one site on the Colorado River (Bastrop upstream). Percentages of the grazer and gatherer feeding guilds fluctuated over time but did not show any specific trends (Figures 7a, 7b, 8)

Response of macroinvertebrate metrics to current velocity

Total abundance and taxa count of macroinvertebrates showed a negative correlation to current velocity in the Blanco River but was positive in the Colorado River (Table 1 a, b). The percent metrices of EPT, tolerant taxa, and the two feeding guilds (grazer, gatherer) from the Blanco River showed strong negative correlation (p-value < 0.005) to current velocity (Figure 9). The percent metrics of EPT, tolerant taxa, and grazer-feeding guild from the Colorado River samples showed a weak correlation (non-significant, Figure 10) to current velocity. The percentage of filter feeders from the Blanco River and the Colorado River were positively correlated to current velocity (p-value < 0.001).

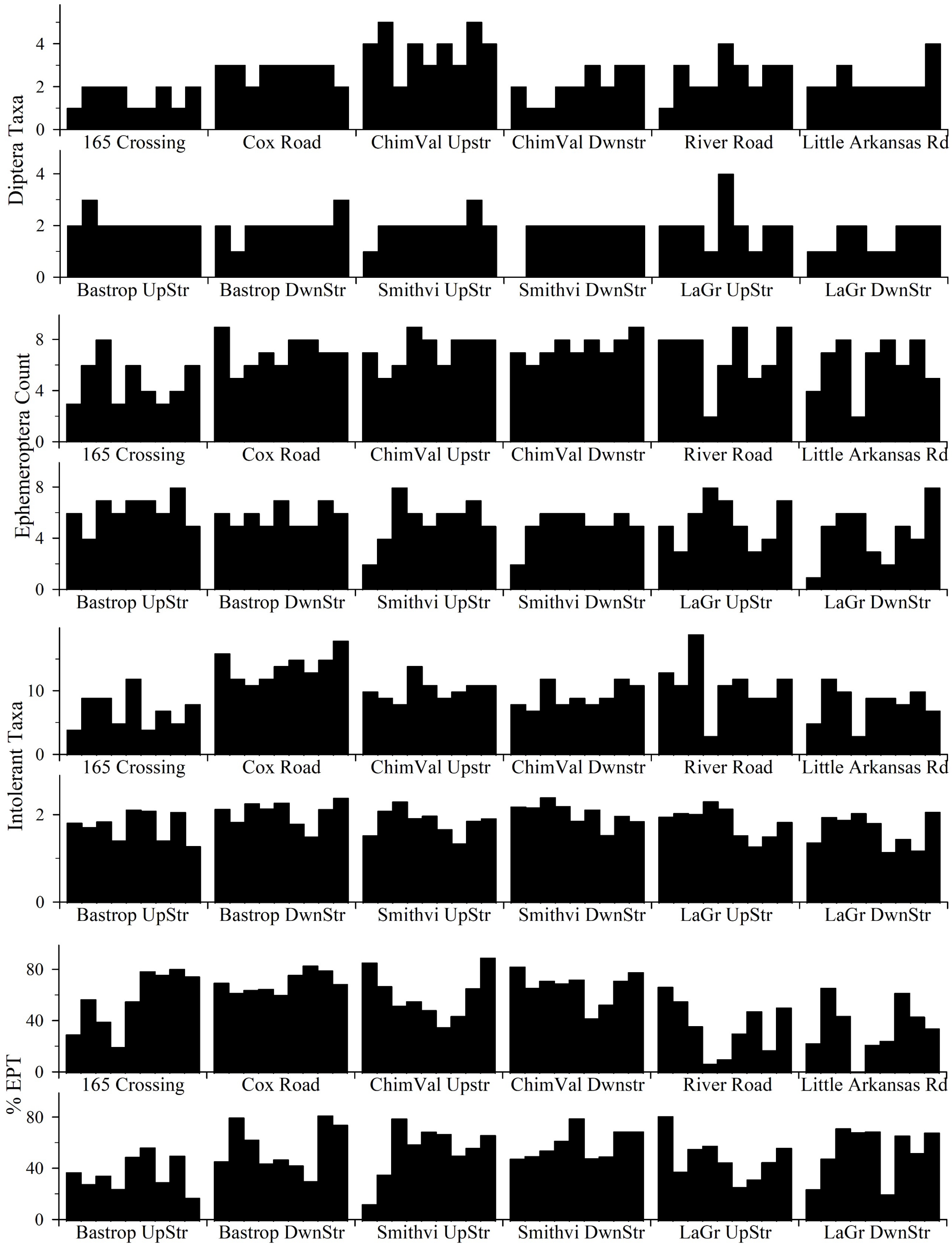


FIGURE 7a.—Summary plots of macroinvertebrate metrices used in the BIBI from six sites on Blanco (top) and Colorado Rivers (bottom). Each plot is a time series plot with nine data points corresponding to sampling events.

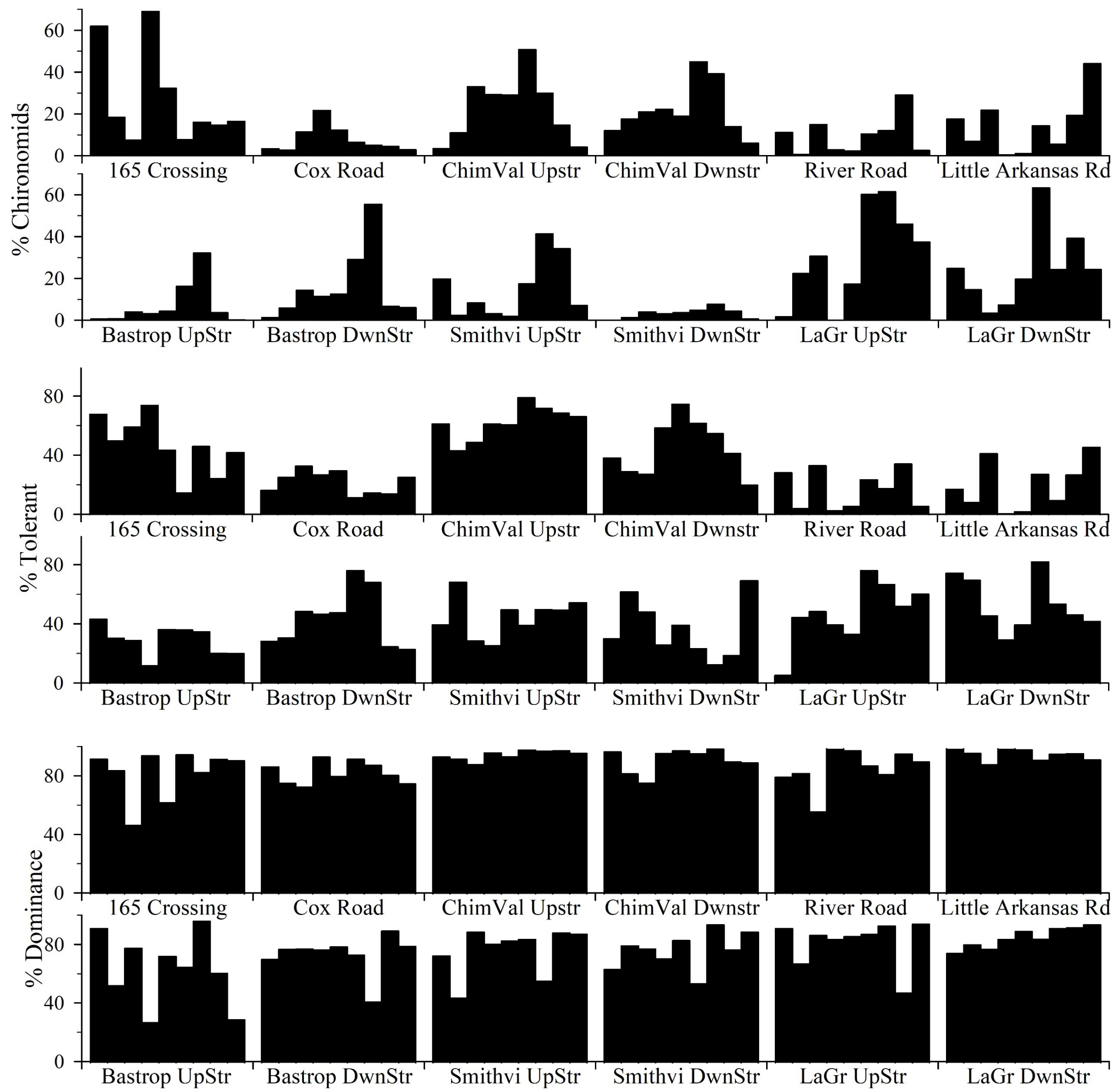


FIGURE 7b.—Summary plots of macroinvertebrate metrices used in the BIBI from six sites on Blanco (top) and Colorado (bottom) Rivers. Each plot is a time series plot with nine data points corresponding to sampling events.

Response of flow-sensitive macroinvertebrate genera to recovery period and discharge conditions

Each of the selected genera showed an increase in abundance during the initial seven post-flood sampling events and stabilized later with some fluctuation during consecutive sampling events (Figure 11). Generalized linear model (GLM) tests showed that recovery period (number of days from flood event) had a significant effect on *Stenelmis*, *Neoperla*, and *Chimarra* from the Blanco River. *Chimarra* abundances from Blanco River were significantly affected by both the recovery period and discharge. In the Colorado River, discharge had significant effect on *Stenelmis*, *Neoperla*, *Maccaffertium, Acentrella*, *Thraulodes*, and *Tricorythodes* (Tables 2 and 3). Although *Isonychia* is a flow-sensitive taxon, its abundance was not affected significantly by recovery period (number of days since flood event) or to change in discharge levels. Recovery period had a significant effect on Chironomidae from the Blanco River, and both recovery period, and discharge had significant effect on Chironomidae from the Colorado River.

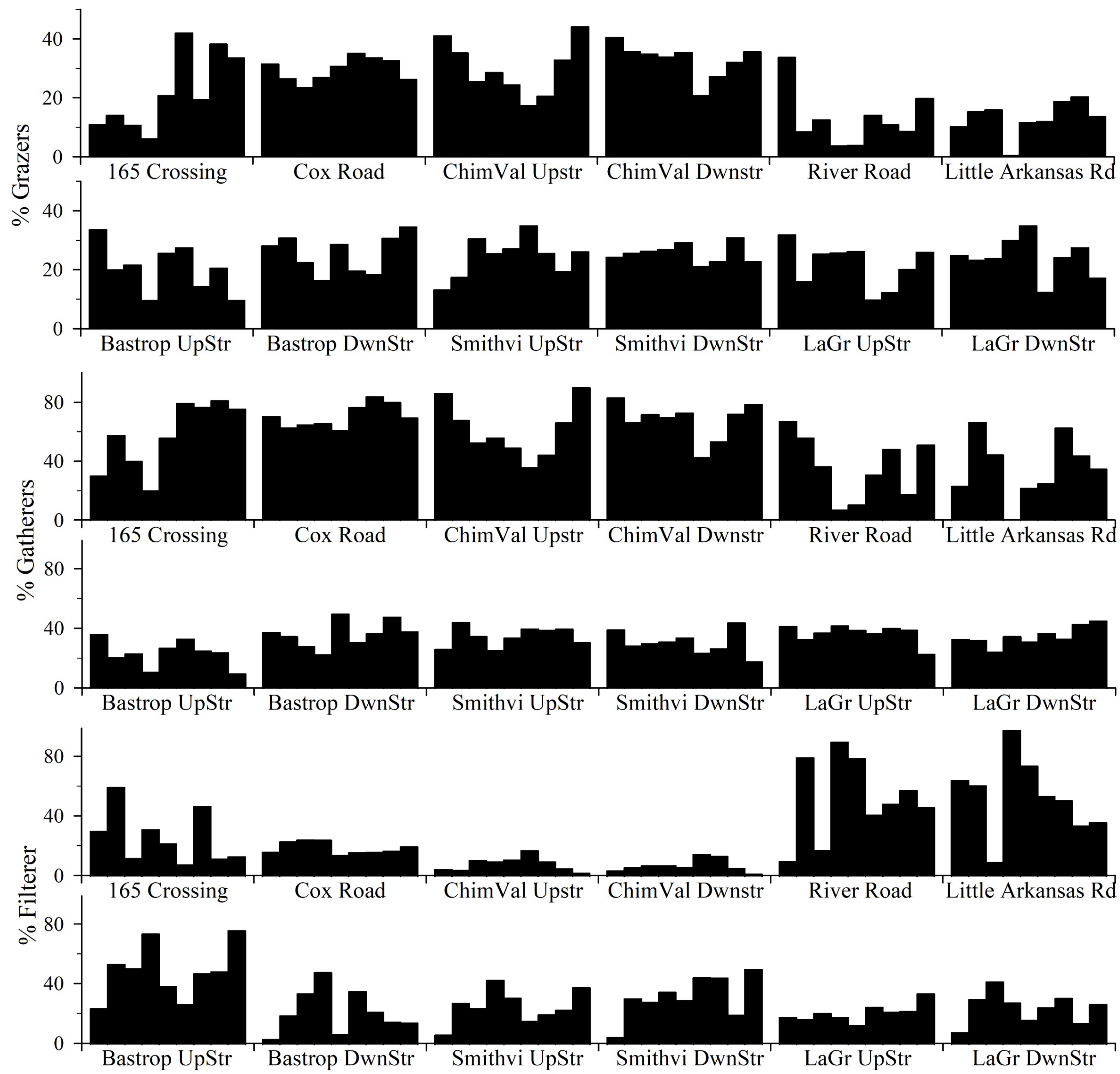


FIGURE 8.—Summary plots of feeding guilds of macroinvertebrate from six sites on Blanco (top) and Colorado (bottom) Rivers. Each plot is a time series plot with nine data points corresponding to sampling events.

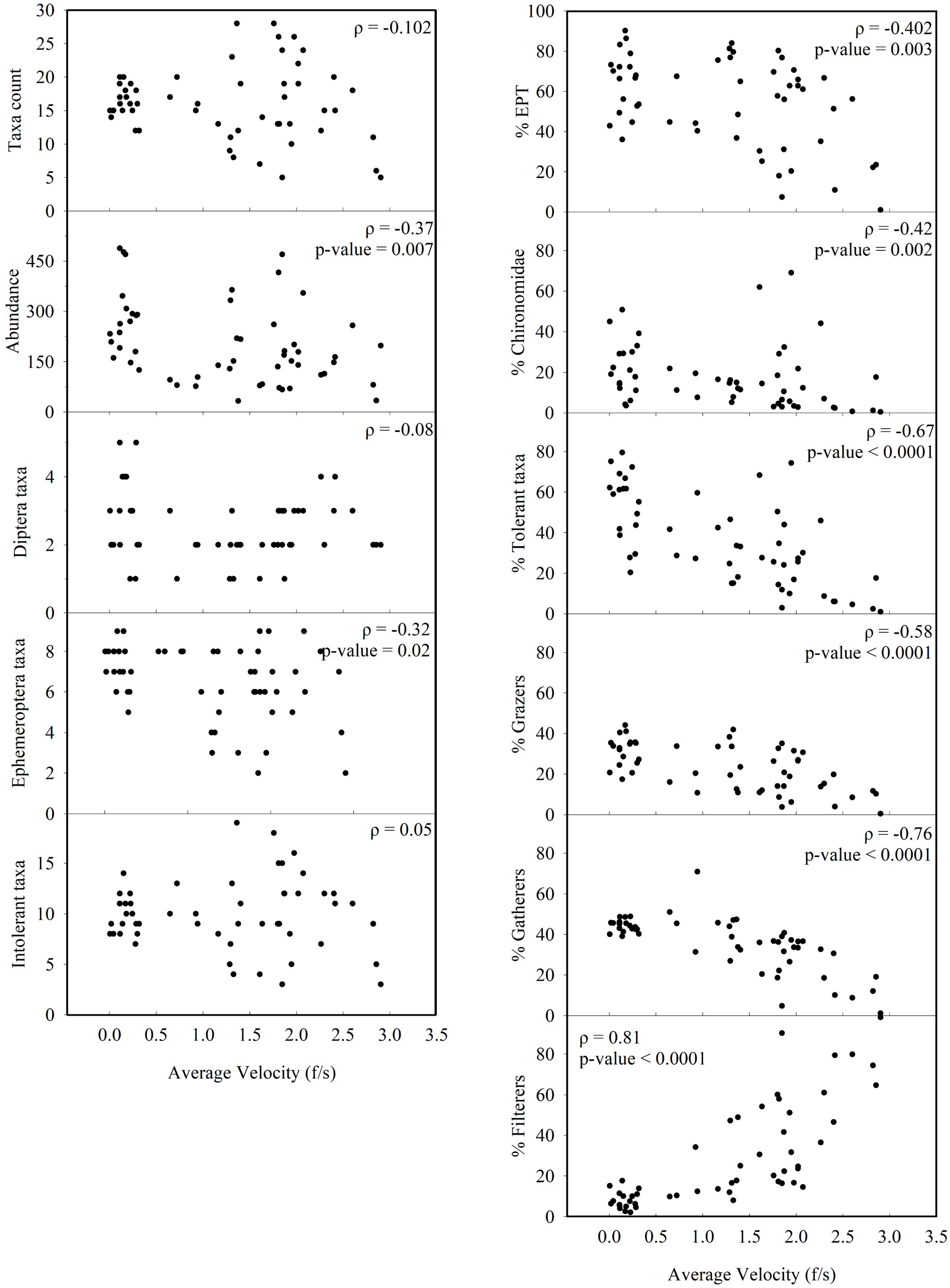


FIGURE 9.—Correlation plots (Spearman) of macroinvertebrate indices with average velocity from six sites on the Blanco River. P-values of significant correlations are depicted in the plots.

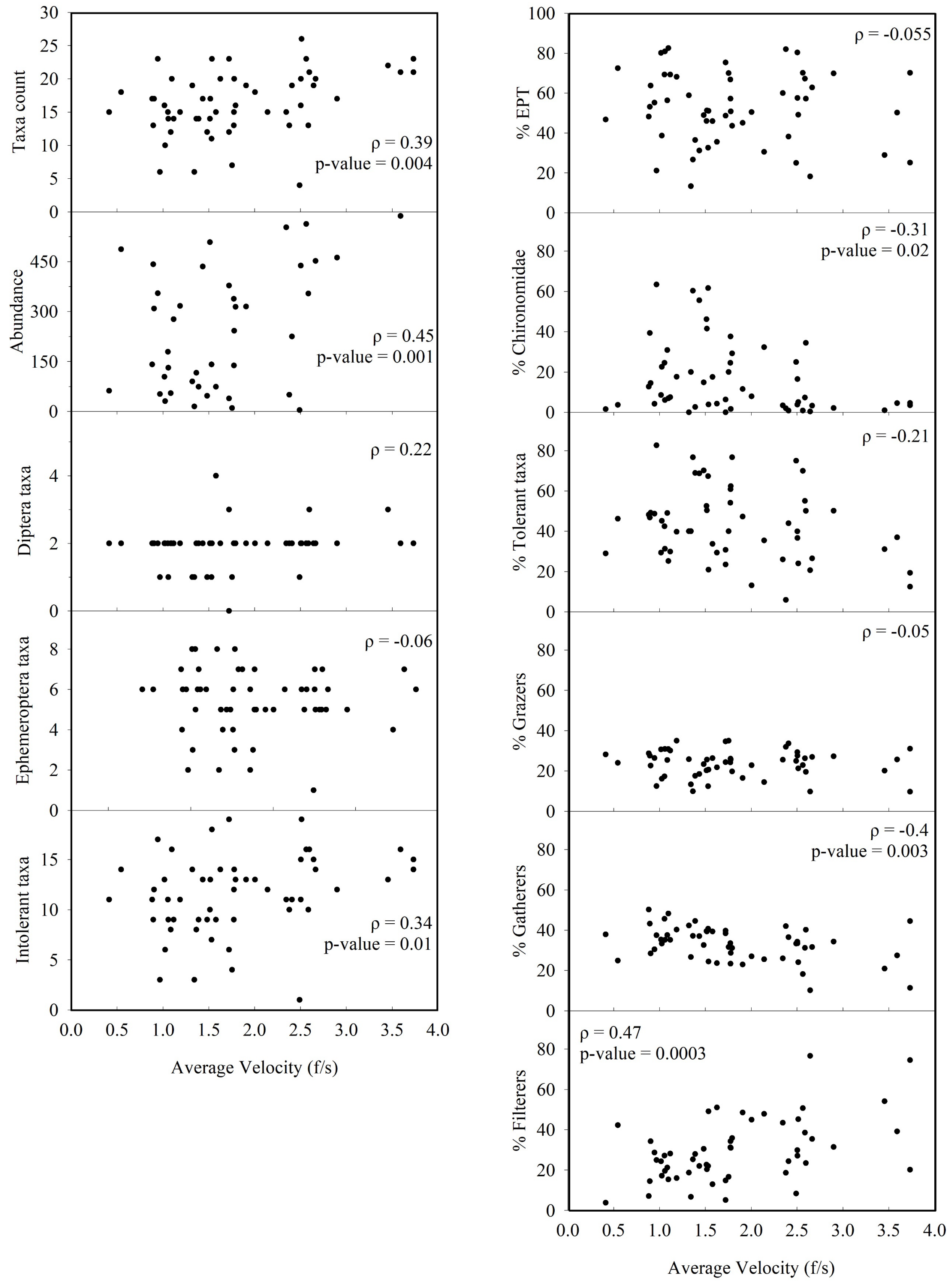


FIGURE 10.—Correlation plots (Spearman) of macroinvertebrate indices with average velocity from six sites on the Colorado River. P-values of significant correlations are depicted in the plots.

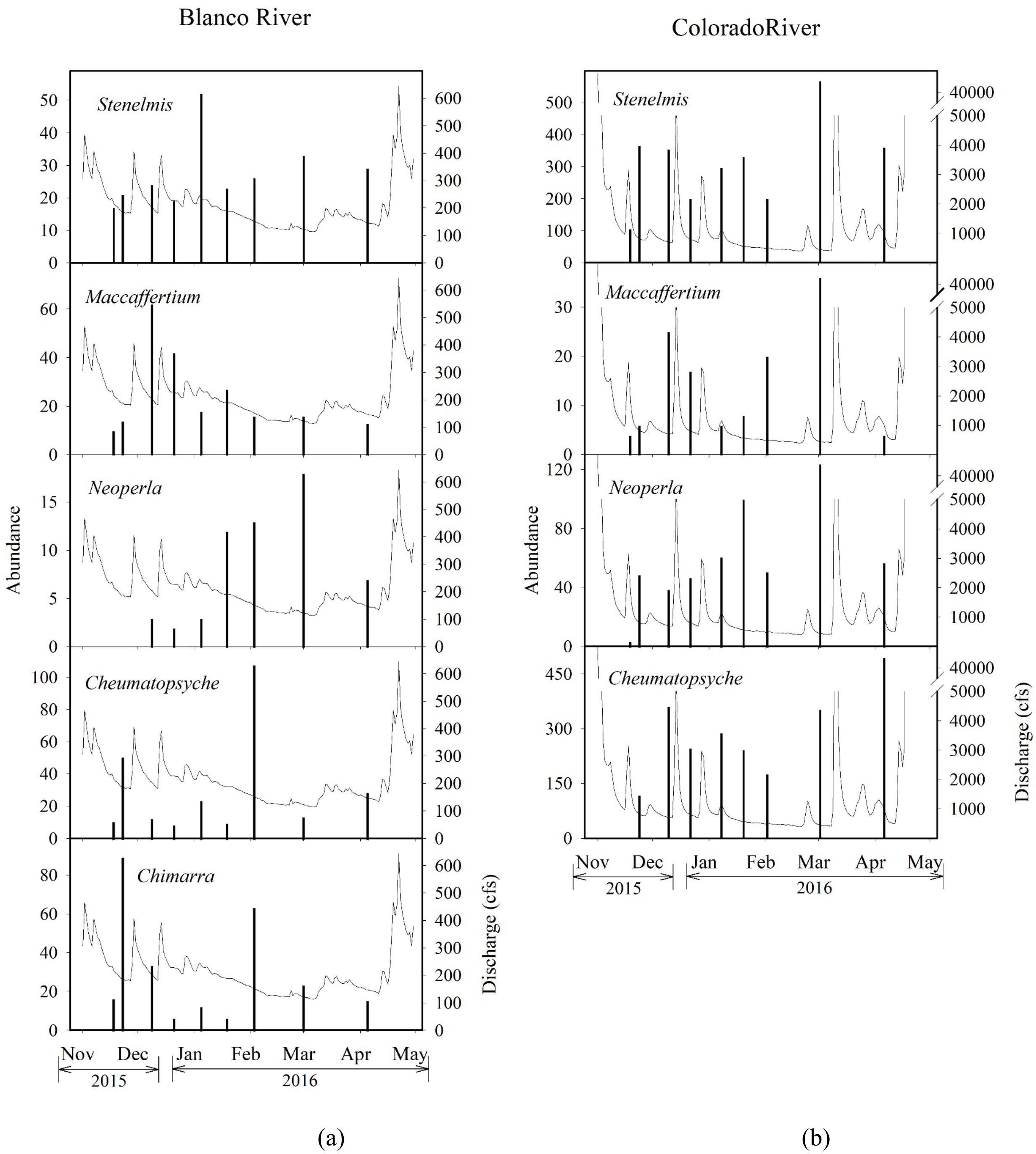


FIGURE 11.—Abundance plots of flow sensitive taxa over the sampling period (summed across six sites due to low numbers), overlaid with daily average hydrograph from November 2015 to May 2016 from the Blanco (a) and Colorado (b) Rivers. Discharge values from Wimberley (USGS gage: 8171000) were used for the Blanco River, and discharge values for the Colorado River were obtained by averaging discharge from three gages in the sampling area (USGS gages: 8159200, 8159500, and 8160400). Maccaffertium (mayfly) and Cheumatopsyche (caddisfly) were abbreviated in the plots.

Change in macroinvertebrate community structure over time

The nMDS plot of macroinvertebrate communities from the Blanco River and the Colorado River displayed a strong geographic pattern (Figure 12), with nMDS axis 1 mainly influencing the Colorado River community and nMDS axis 2 influencing the Blanco River community. Three upstream sites on the Blanco River loaded positively along axis 2. The three sites on Blanco River (165 crossing, River Rd, and Little Arkansas Rd.) that grouped together on axis 2, reflected the common bedrock substrate found at these sites. Figures 13 and 14 follow the time trajectories of the macroinvertebrate communities separately by site over the entire sampling period in the two rivers. In most of these individual nMDS plots, the distance between each data point decreases over time. The plots for upstream sites from each river basin shows a much tighter spread compared to the downstream sites. A two-way crossed ANOSIM tests on the Blanco River revealed a significant difference within the site and time factors (R=0.35, p-value=0.001) and R=0.23 (p-value=0.001) respectively). The two-way crossed ANOSIM on the Colorado River also revealed a significant difference within the site (R=0.36, p-value=0.001) and time (R=0.49, p-value=0.001) factors.

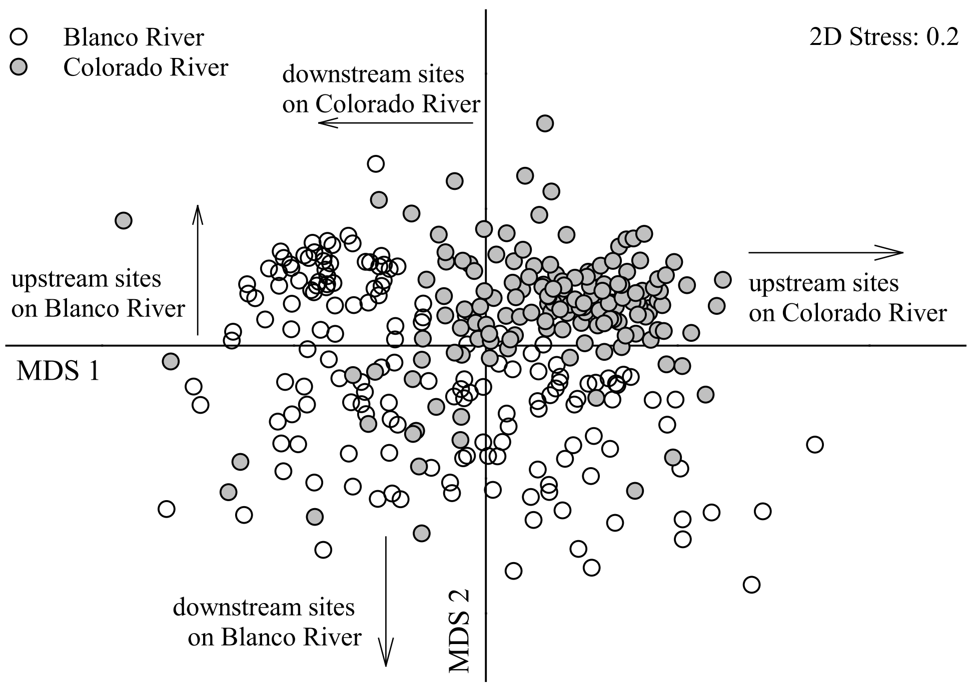


FIGURE 12.—Nonmetric multidimensional scaling (nMDS) ordination plot for aquatic macroinvertebrate communities from the Blanco River and the Colorado River. Open circles denote the communities that belong to samples from the Blanco River (n = 162), and the grey-filled circles are from the Colorado River (n = 159).

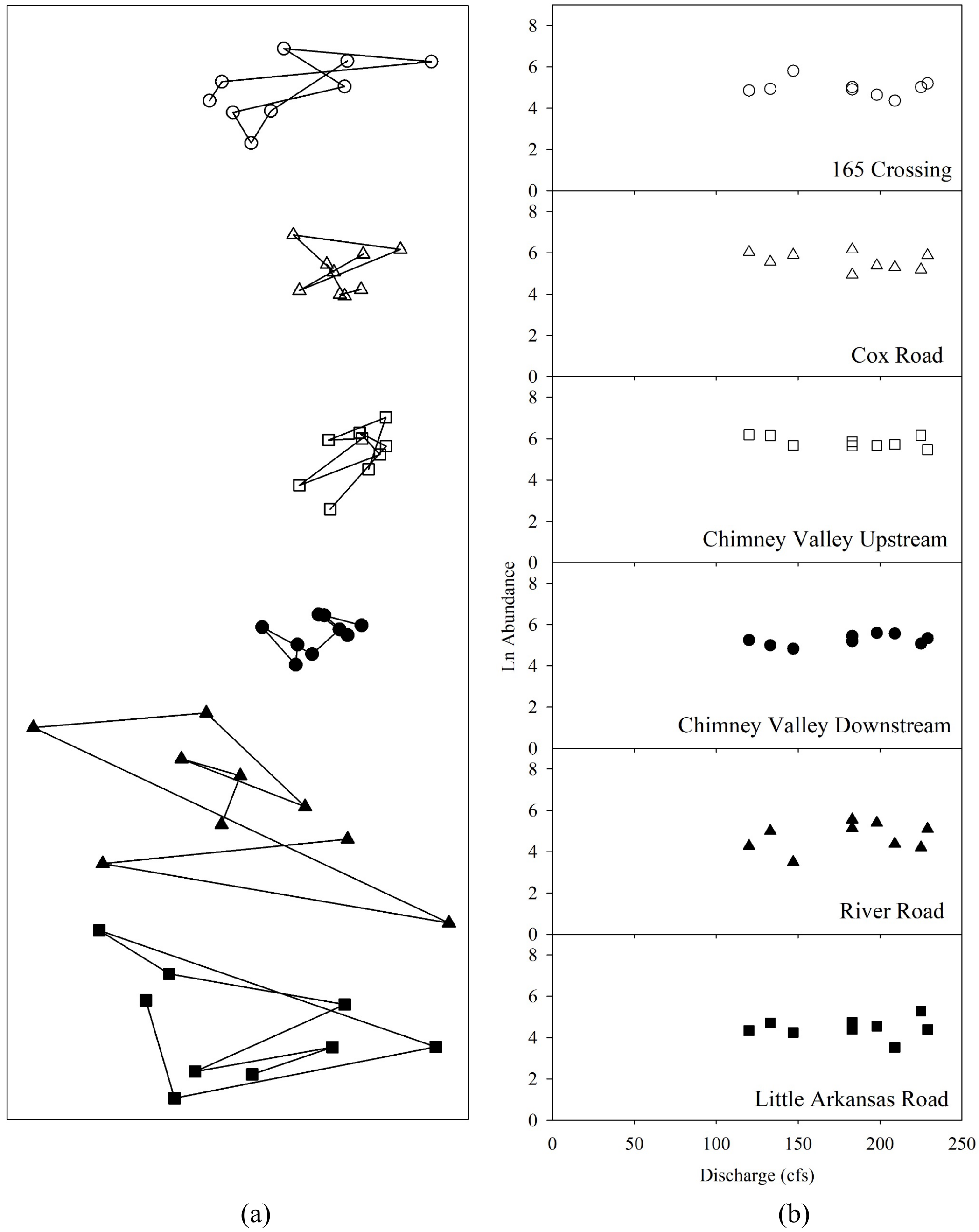


FIGURE 13.—Nonmetric multidimensional scaling (nMDS; (stress value=0.07) of macroinvertebrate community structure from six sites on the Blanco River. a) nMDS plot is exploded by site, and b) Total macroinvertebrate abundance (natural log transformed) plotted against discharge collected from USGS gage: 8171000.

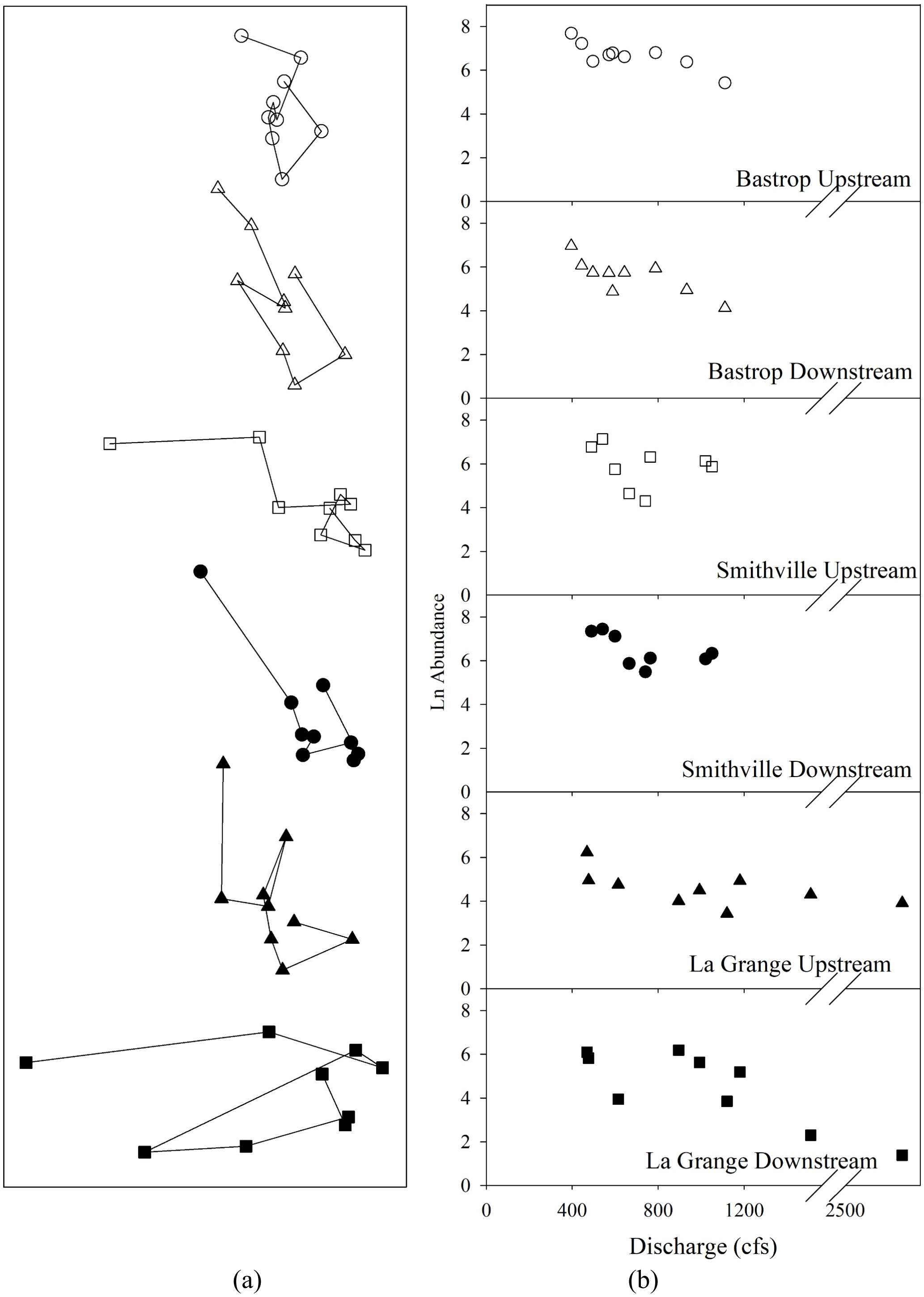


FIGURE 14.—Nonmetric multidimensional scaling (nMDS; stress value=0.11) of macroinvertebrate community structure from six sites on the Colorado River. a) nMDS plot is exploded by site, and b) Total macroinvertebrate abundance (natural log transformed) plotted against discharge collected from USGS gages: 8159200, 8159500, and 8160400.

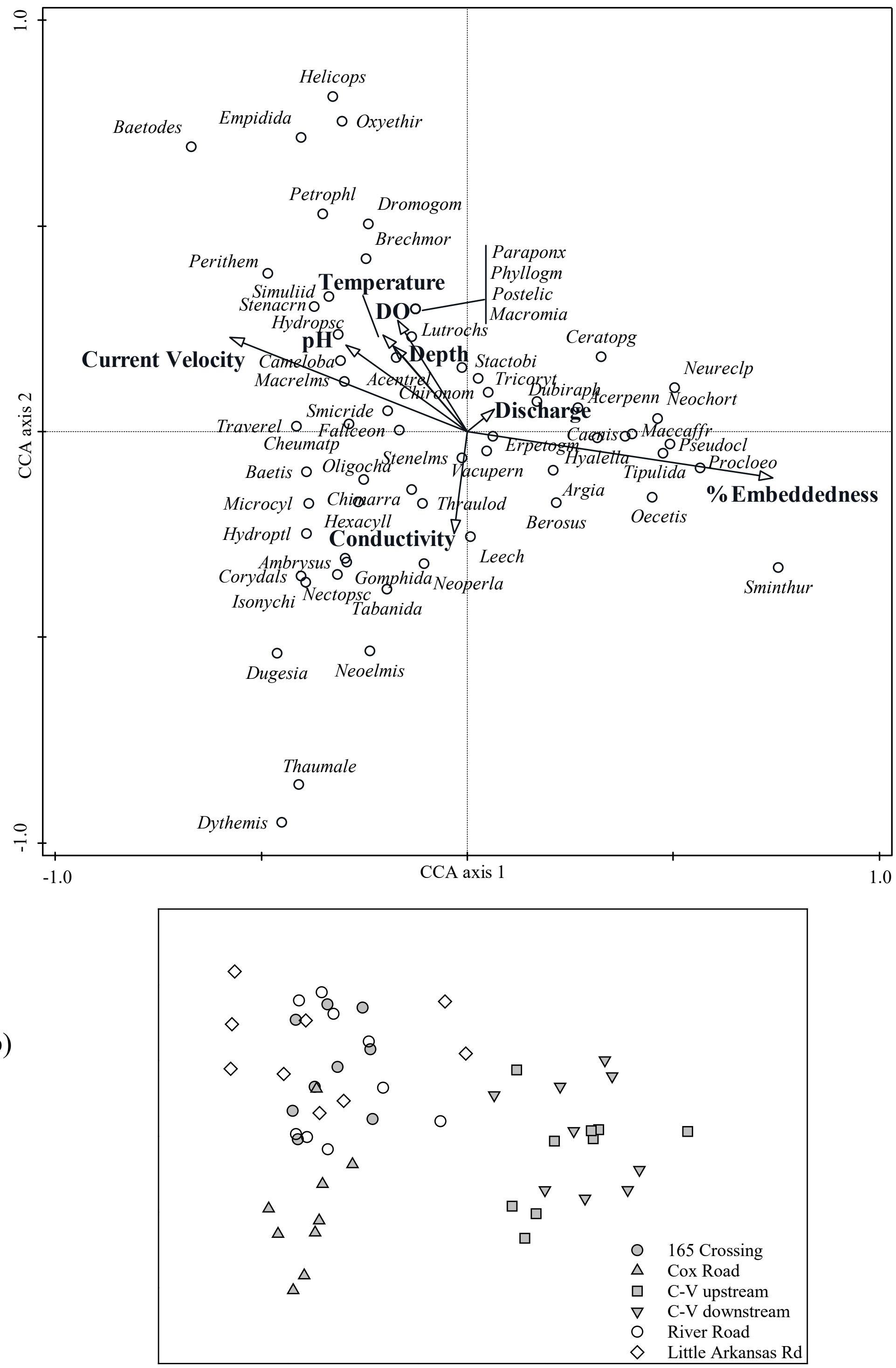
Within the Blanco River, the greatest dissimilarity (SIMPER analysis) between sites was between Chimney Valley upstream and Little Arkansas Road sites (73.78%) due to higher average abundances of *Caenis*, *Neochoroterpes*, and Chironomidae at Chimney Valley upstream site. (Table 4 a, b). The greatest dissimilarity between sampling events on the Blanco River was seen between the third and fourth sampling events at 55.4%, but the dissimilarity between the first and nineth sampling event was 40.4% and was due to greater abundances of mayflies (*Caenis*, *Camelobaetidius*, *Fallceon*) and Dipterans (Chironomidae and Simuliidae) on the ninth sampling event. In the Colorado River, the highest dissimilarity between sites was between the upstream site near Bastrop, and the upstream site near La Grange (61.4%), due to higher average abundances of Simuliidae, *Stenelmis*, and *Thraulodes* at the upstream site near Bastrop (Table 5 a, b). The greatest dissimilarity between sampling events on the Colorado River was seen between the first and eighth sampling event (77.7%) which was recorded by a marked increase in abundance of several macroinvertebrate taxa (*Acentrella*, Chironomidae, *Tricorythodes*, *Cheumatopsyche, Stenelmis,* and Simuliidae) in the latter event.

Effects of environmental variables on macroinvertebrate communities

Macroinvertebrate abundances from sites on Blanco River and Colorado River were constrained against all measured environmental variables (including substrate types) using CCA analysis. This analysis was rerun after addressing multicollinearity in the environmental variables by inspecting variance inflation factor (>10 has multicollinearity), and the environmental variables having significant effect (t-value < 2.1) in the model were selected. This CCA was run on all the macroinvertebrate genera collected at each watershed against eight environmental variables (Figure 16, 17; separate for each river).

In the Blanco River watershed, the first two axes of the CCA accounted for 31% of the variance, of which 76.2% was explained by the environmental variables. The sum of the eigenvalues of the first four axes was 1.5, with the Monte Carlo test being statistically significant for macroinvertebrate taxa (F-ratio = 3.86, P = 0.002). From the correlations of the environmental variables and the axes scores, current velocity and percent embeddedness showed the strongest correlations (-0.55, and 0.71 respectively) to the first CCA axis, and were polar opposites to each other (Tables 6, 7). The macroinvertebrates that showed strong association to current velocity are mayflies (*Camelobaetidius*, *Traverella*, *Acentrella*, *Fallceon*), riffle beetles (*Macroelmis*), and caddisflies (*Cheumatopsyche*, *Hydropsyche*). *Oecetis*, *Pseudocloeon*, *Caenis* and *Maccaffertium* showed greater association with percent embeddedness (Figure 15). Although the vector length of discharge variable plotted short, it was significant (t-value > 2.1) along the second CCA axis and the taxa associated with it are *Tricorythodes*, *Dubiraphia*, Ceratopogonidae, and *Acerpenna*.

The site scores in the CCA analysis (Figure 15) show three separate groupings: a) Cox Road samples grouped tightly on bottom left, b) Chimney Valley upstream and downstream sites grouped together on the right side, and c) sites 165 Crossing, River Road, and Little Arkansas Road on top left with the greatest spread. The two downstream sites and the most upstream site (165 Crossing; grouped on the top left quadrant) had higher score-loadings of current velocity, temperature, dissolved oxygen, pH, and average depth. Some of the taxa associated with these environmental variables and sites were dragonflies (*Dromogomphus*, *Brechmorhoga*, *Phyllogomphoides*, *Macromia*, and *Perithemis*), caddisflies (*Helicopsyche*, *Oxyethira*, and *Hydropsyche*), and beetles (*Lutrochus*, *Postelichus*, and *Macrelmis*).



b)

FIGURE 15.—Results of canonical correspondence analysis performed between taxa abundance and environmental features in the Blanco River watershed. a) taxa and environmental variable scores, and b) site scores. Full names of the macroinvertebrates are in Appendix A. Chimney Valley upstream and downstream sites are abbreviated as C-V upstream and C-V downstream.

For the Colorado River watershed, the first two axes of the CCA accounted for 12.2% of the variance, of which 53.1% was explained by the environmental variables (Figure 17 a, b). The sum of the eigenvalues of the first four axes was 0.88, with the Monte Carlo test being statistically significant for macroinvertebrate taxa (F-ratio = 1.68, P = 0.002). From the correlations of the environmental variables and the axes scores, percent embeddedness showed the strongest correlation (0.46) along the first CCA axis, and conductivity, depth, current velocity and discharge (-0.56, 0.59, 0.61, and 0.54 respectively) along the second CCA axis (Tables 6, 7). The majority of the macroinvertebrate taxa were positioned around the center of the plot showing no affinity to any of the environmental factors However, Hirudinea, Ceratopogonidae, *Protoptila*, *Heterelmis*, and Gomphidae showed a strong association to percent embeddedness. Some of the taxa that grouped closer to current velocity, depth, and dissolved oxygen were some baetids (*Baetis*, *Pseudocloeon*, and *Camelobaetidae*), riffle beetles (*Macrelmis*, and *Postelichus*), caddisflies (*Helicopsyche*), and true flies (Tipulidae, and Empididae). The sites on the Colorado River were not tightly grouped by site scores in the CCA analysis (Figure 17 b), but the scores of the downstream sites (La Grange upstream and downstream) showed a much bigger spread on the right half of the plot.

Relationship of Hydrologic Parameters and Macroinvertebrate Taxa

Relationship of all the hydrologic parameters and macroinvertebrate taxa is summarized in Appendix E. Most Mayflies are flow sensitive species and their response to hydrologic parameters are described here. The most abundant mayfly genera were from the Blanco and Colorado Rivers were *Fallceon*, *Isonychia*, and *Thraulodes*. For the Blanco River, no hydrological variables were identified as significant in a model for any of these three taxa (Appendix E10, 12, 14). In the Colorado River, cumulative duration during base flow conditions was shown to have positive effect on *Fallceon* abundance, whereas no other hydrological parameters were selected under any other flow conditions to be significant. No significant model was selected in the Colorado River that affected *Isonychia*. For *Thraulodes*, a 15-day cumulative discharge was selected in the base flow category, whereas total duration of average discharge in 30-day period was selected in the high flow pulse category in the Colorado River (Appendix E11, E13, E15, F5, F6, F7).

The next abundant mayfly genus from the Blanco and Colorado Rivers was *Maccaffertium*. In the Blanco River, magnitude of rise and median rate of rise was identified in the regression model (Appendix E16). In the Colorado River, under baseflow conditions several parameters were identified as important, but due to high variance inflation factor, this model should be considered with caution. Under the rate of change category, the duration of recession and rate of recession were identified in the model (Appendix E17, F8, F9). Effects of hydrological parameters on the next abundant genus, *Tricorythodes*, from the Blanco and Colorado Rivers are as follows. In the Blanco River, under small flood pulse and rate of change categories, two parameters were identified as significant to *Tricorythodes* abundance (Appendix E18, F10). In the Colorado River, cumulative duration and total duration were selected in the model under base flow conditions for *Tricorythodes* (Appendix E19, F11).

Other mayfly genera that were abundant throughout the samples in the Blanco and Colorado Rivers were *Caenis*, *Camelobaetidius*, *Neochoroterpes*, and *Procloeon*. In the Blanco River, a single variable was identified under small flood (15-day duration of peak discharge), and rate of change category (magnitude of rise; Appendix F12) each, in the regression model (Appendix E20, E21, E22, E23). For *Caenis*, *Neochoroterpes*, and *Procloeon*, no hydrological variables were selected in the regression model. None of

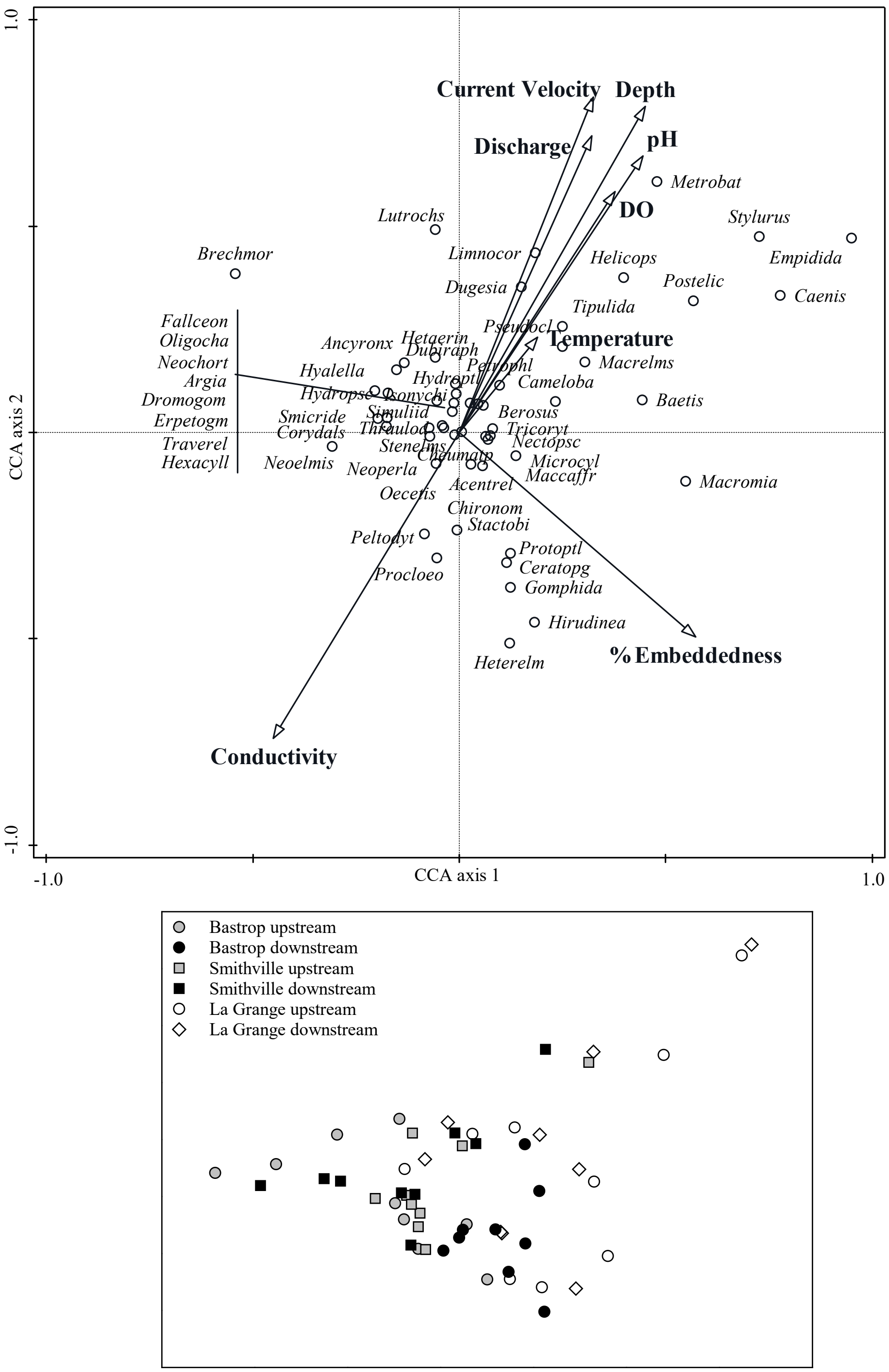


FIGURE 16.—Results of canonical correspondence analysis performed between taxa abundance and environmental features in the Colorado River Basin. Taxa and environmental variable scores are plotted on the first plot (a), and the site scores are plotted on the second plot (b). Full names of the macroinvertebrates are in Appendix B.

these taxa were collected in sufficient numbers in the Colorado River, hence no regression models were tested. The least abundant mayfly (flow-sensitive taxa) from the Blanco and Colorado Rivers *Acentrella*. It was not collected in sufficient numbers in the Blanco River to run further analyses. In the Colorado River, various hydrological parameters were identified in the regression model under base flow, high flow pulse, large flood, and rate of change categories (Appendix E24, F13).

Of all the stoneflies (rarest taxa collected in both river systems), *Neoperla* was selected for regression models as it was collected in sufficient numbers from the Colorado River. The stepwise regression models identified two hydrological flow parameters under the rate of change category (median rate of recession and number of flow reversals), and one from baseflow category (30-day total duration of average discharge), Appendix E29, F15.

The Caddisfly family was fairly represented in both the rivers. The genus *Cheumatopsyche* was the most abundant Caddisfly taxa in the Blanco and Colorado Rivers, however significant trends were observed only in the Colorado River (Appendix E30). In the Colorado River, several hydrological parameters were selected by the regression model under base flow, high flow pulse, and rate of change categories (Appendix E31, F16). The genus Chimarra was collected in most samples from the Blanco River but was not present in several samples from the Colorado River, hence no tests were run for this system. In the Blanco River, three hydrologic parameters were identified in the regression model (30-day number of pulses, 30-day duration of peak discharge, and duration of average discharge), however due to high variance inflation factor, these results should be viewed with caution. Two important parameters were identified in the rate of change category for *Chimarra*: duration of recession and median rate of recession (Appendix E32, F17).

The next abundant Caddisfly genera in the Blanco and Colorado Rivers was H*ydroptila* and *Nectopsyche*. These two taxa were not collected from the Blanco River in sufficient numbers, so were excluded from regression analyses. In the Colorado River, some hydrological parameters under the three flow categories of base flow (30-day cumulative duration), high flow pulse (15-day duration of average discharge, and 30-day cumulative duration of peak discharge), and rate of change (number of flow reversals), were selected by the regression model as significantly affecting these caddisfly taxa. For *Nectopsyche*, three hydrological parameters under rate of change category (duration of recession, magnitude of recession, and median rate of recession) were selected in the regression model (Appendix E33, E34, F18, F19).

The flow sensitive Coleopterans (families Elmidae and Lutrochidae) that were tested for responses to hydrologic parameters. In the family Elmidae, the genus *Stenelmis* were tested from the Blanco and Colorado Rivers. Hydrologic parameters from the Blanco River did not show any significant relationship with *Stenelmis* (Appendix E1). In the Colorado River, at base flow conditions the best model selected by AICc suggested that a 15-day period of magnitude and duration of flow conditions had a positive effect on *Stenelmis* abundance, and 30-day duration had a negative effect. For high flow pulse conditions, best model showed that higher number of flow pulses in 15-day period had negative effect (Appendix E2, F1). Neither small flood events nor large flood events had significant effect on Stenelmis abundance. No significant hydrologic parameters within the rate of change category were selected by stepwise regression model for *Stenelmis* in both waterbodies. In the family Lutrochidae, the genus Lutrochus collected from the Blanco and Colorado Rivers was inspected for response to hydrologic parameters. *Lutrochus* was not collected in the Colorado River during the sampling period but did occur in sufficient numbers in the

Blanco River. However, no significant models were identified in the stepwise regression analyses (Appendix E3).

Although Odonata, Diptera, and Oligochaeta are not flow-sensitive taxa, their relationship to hydrologic parameters was explored as they were found in abundant numbers throughout all the samples. *Argia* (order: Odonata) was only collected from the Blanco River in sufficient numbers, but no hydrological parameters were identified as significant in the regression model (Appendix E25). *Erpetogomphus* (order: Odonata) was only collected from the Colorado River in sufficient numbers, but no hydrological parameters were identified as significant in the regression model (Appendix E26).

For Chironomidae (Order: Diptera) from the Blanco River, cumulative discharge during small flood pulse event was selected as the parsimonious model (Appendix E4). Under base flow and high flow pulse conditions in the Colorado River, Chironomidae responded negatively to 30-day discharge conditions (magnitude; Appendix E5). Under the rate of change category, the best model selected consisted of duration of rise, duration of recession, and median rate of recession (Appendix F2, F3). The next abundant Dipteran in the Blanco and Colorado Rivers was the genus Simuliidae. No significant hydrologic models were identified in the Blanco River (Appendix E6). Only one hydrological parameter was identified to negatively affect Simuliidae under base flow conditions (cumulative average discharge during 30-day period) in the Colorado River (Appendix E7, F4). The other two genera under the order Diptera from the Blanco and Colorado Rivers explored were, Tabanidae and Tipulidae. For Tabanidae, no hydrological parameters were identified in the regression analysis in the Blanco River. Neither of these two taxa were collected in sufficient numbers in the Colorado River, hence no models were tested for this River (Appendix E8, E9).

The Subclass Oligochaeta from the Blanco and Colorado Rivers was explored for its relationship with hydrologic parameters. In the Blanco River, several hydrological flow parameters were identified in small flood pulse and the rate of change categories, however, due to higher variance of inflation factor values, these results should be considered carefully (Appendix E27, F14). In the Colorado River, three hydrological flow parameters from rate of change category were identified in the regression model (magnitude of recession, median rate of recession, and number of flow reversals; Appendix E28).

Guadalupe Bass Growth and Recruitment

A total of 112 GB were collected from the Colorado River, across five sites, with an average catch rate of 16 fish per hour electrofishing. The sampling conducted on the Blanco River for GB did not yield sufficient numbers (<30 individuals), so this data was not included in further analyses in this section. Average length of GB specimens from the Colorado River was 9.5 inches, with an average weight of 224 grams. The length frequency plots from the entire sampled reach on the Colorado River and even within individual sites, showed bimodal distribution (Figures 17 and 18). A PSD value of 71 was obtained, indicating a good proportion of larger-sized GB present in the sampled reach on the Colorado River. The PSD calculations show that the fishery in this section of the Colorado River has considerable, preferred, and memorable sized fish during fall of 2016 (Figure 18).

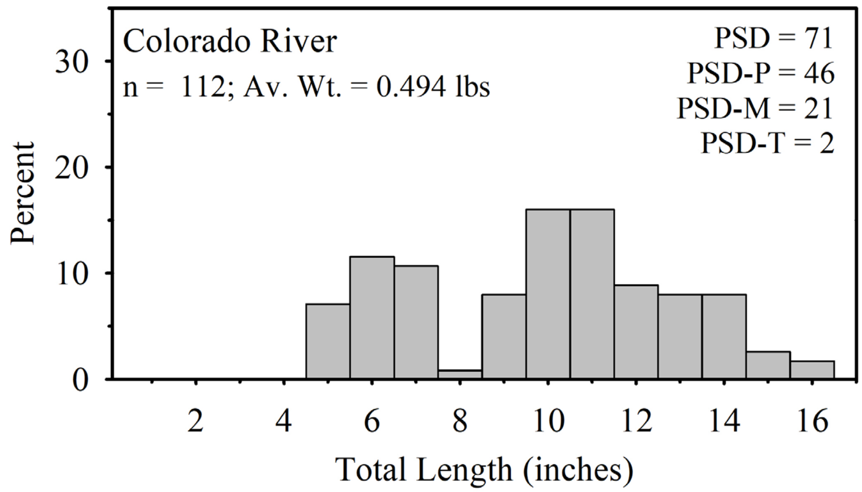


FIGURE 17.—Length-frequency distributions (1-inch groups) of Guadalupe Bass collected from the Colorado River using boat electrofishing during fall 2016. Total sample size (n), average weight, and proportional size distributions (preferred, memorable, and trophy) are displayed.

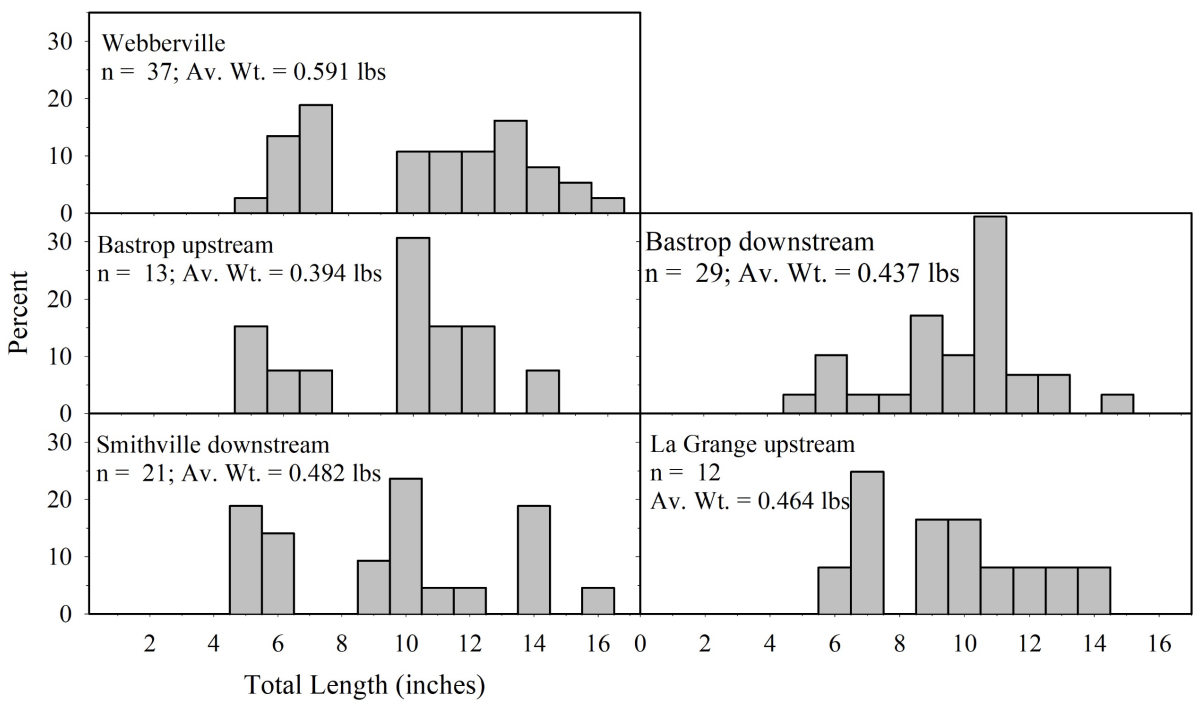


FIGURE 18.—Length-frequency distributions (1-inch groups) of Guadalupe Bass collected from five individual sites on the Colorado River using boat electrofishing during fall 2016. Total sample size (n) and average weight are displayed.

The length-frequency plots were represented by groupings of smaller fish that occurred in 5-7” slot, and rest of the fish that occurred in 9-16” slot. The category 2 age and growth analysis showed GB to have reached 14 inches by age 3 (Figure 19), and the collection was dominated by age 0 and age 1 fish. The spread of residual plot based on the year class strength showed that the recruitment was lowest during the drought year 2012. The recruitment during the following two years (2013, and 2014) was weakly positive, and was fairly strong in 2015 (Figure 20). The GB recruitment was very weak after the flood in 2015 as seen in the negative residual values in year 2016.

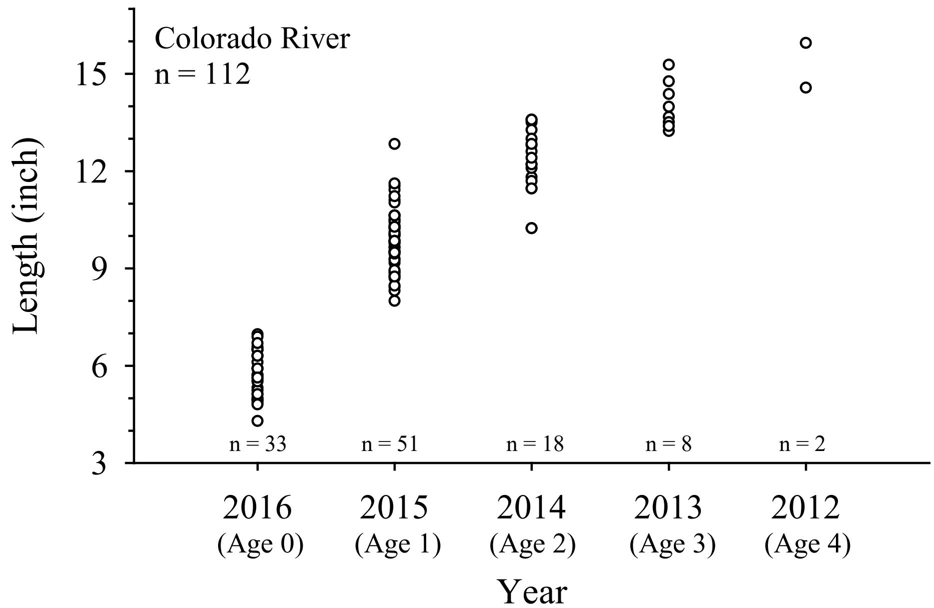


FIGURE 19.—Age vs length plot of Guadalupe Bass collected from the lower Colorado River in fall 2016.

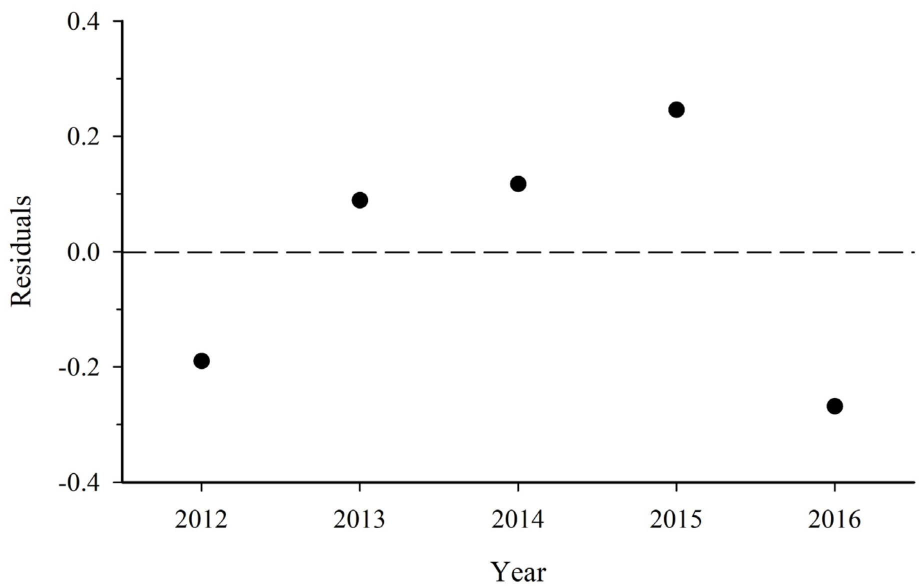


FIGURE 20.—Residuals computed from catch-curve regressions from lower Colorado River versus years for indexing fish year class strength.

DISCUSSION

Heavy rainfall received in a short period of time in October 2015 in Central Texas caused severe flooding and was categorized as a 500-year flood event by National Weather Service. This was further supported by the peaks in discharge levels recorded at USGS gages from the study areas from the Blanco River at Wimberley, TX and from the Colorado River at Bastrop, Smithville and La Grange, TX. After the flood event, the discharge levels from both the river basins stayed above the long-term average with several peaks in discharge events through the sampling period (April 2016). Identifying the effects of catastrophic flood events on macroinvertebrate communities and the recovery period for stabilization of macroinvertebrate diversity and abundance, is critically significant for environmental monitoring and ecosystem conservation. The recovery of biotic organisms from Central Texas due to catastrophic flooding is not expected to take long because these benthic communities are adapted to habitat-altering flood disturbances (Omernik 1987; Cobb et al. 1992; Theodoropoulos et al. 2017).

Macroinvertebrate community metrics

Significant differences were observed in the taxa richness, diversity indices, and macroinvertebrate abundance after the 500-year flood event in 2015, with fairly low number of individuals and taxa diversity collected in the initial samples. These results are consistent with other investigations (Angradi 1997; Lake 2000; Poff and Zimmerman 2010; Calderon et al. 2017) that experienced loss of taxa diversity and abundances after a major disturbance. The benthic macroinvertebrate taxa diversity and abundance recovered anywhere from 42 to 82 days after the major flood event at the two river basins. BIBI metrics that recovered the quickest can be attributed to several colonizer taxa that rapidly increase in newly disturbed habitat. The effect of disturbance is reflected by diversity indices without regard to ecoregion level differences because they rely heavily on the quality of available habitat (Resh et al. 1995; Barbour 1999). The community structure index (BIBI metrics) is a synthetic measurement for biological structure which incorporates two important aspects: taxa richness and the distribution of individuals among taxa (evenness). The continued (but reduced) fluctuation after the 82-day mark in the diversity indices, community metrics, and the feeding guilds can be attributed to a number of factors including imbalance of suitable habitat due to several smaller high flow pulse events that occurred through the study period, with 2016 still being a fairly wet year (TWDB 2021). Finally, despite the minor fluctuations in community metrics, these two river basins took 82 days to recover in abundance and diversity after this catastrophic flood event. TCEQ guidelines indicate a two-week recovery period after a flood event before resuming normal macroinvertebrate community sampling. Information gathered from these analyses can serve as supporting evidence for reassessment of TCEQ macroinvertebrate assemblage recovery guidelines, and reassessment based on magnitude of the disturbance event, and size of the watershed.

Some of the taxa that rapidly increased in numbers (e.g., blackflies, midges, mayflies {*Camelobaetidius*, *Neochoroterpes*, *Caenis*, and *Isonychia*}) indicate opportunistic strategy, whereas some others i.e., mayflies (*Tricorythodes*, *Fallceon*, and *Acentrella*), caddisflies (*Cheumatopsyche*) and damselflies (*Argia*) were slower to recovery in numbers. Blackflies are opportunistic taxa that colonize suitable habitat rapidly in absence of other competing taxa and prefer clean substrates for attachment (Hemphill and Cooper 1983). Baetidae and some Leptophlebiidae are known to be early colonizers in most parts of the world (Mackay 1992; Minshall et al. 1983) due to their ability to scrape off thin organic film that initially starts developing on substrates after disturbance. McElravy et al. (1989) noted that Chironomidae were the first to colonize after a scouring spate. The early arrival of these collector gatherers is consistent with their ability to utilize the biofilm on bare substrates. Later in the recovery process, a grazing and filtering habit may be adopted by scrapers and filterers as noted here by steady increase in abundance of *Tricorythodes* and *Cheumatopsyche*, which is a shifting feeding adaptation seen in most macroinvertebrate taxa in response to available forage and habitat conditions (Mackay 1992; Benke 1993; Benke 2018). The occurrence of EPT, tolerant taxa, grazers, and gatherers in lower percentages (albeit higher percentage of Simuliidae: filterer guild) at the two downstream sites on the Blanco River (River Road and Little Arkansas Road) could be attributed to lack of habitat heterogeneity due to the primary substrate being bedrock. The paucity in abundance of *Isonychia*, *Fallceon*, *Thraulodes*, *Cheumatopsyche*, and Simuliidae (typically found in cleaner waters, TCEQ 2014) at the two sites at La Grange on the Colorado River could be attributed to presence of higher sediment and lower water quality in that stretch.

Though the macroinvertebrate abundance and BIBI metrics at the study sites decreased, changes in community composition or structure (Figures 6-9) reached a steady state after about 82 days, suggesting that resident populations and communities were fairly resilient to the October 2015 flood. Several other studies also support the recovery of macroinvertebrate communities from huge floods within a short period of time (Eagle et al. 2021; Fritz and Dodds 2004; Molles Jr. 1985), by either recolonization through drift, or oviposition by adults (Death 2008), however, this greatly depends on the flood magnitude and frequency, disturbance history, effects on the riparian vegetation, size of substrate, and antecedent conditions. Regional studies are important for understanding the complex relationships between macroinvertebrate assemblages and floods, which varies by waterbodies and stream geomorphology (Calderon et al. 2017).

Response of macroinvertebrate metrics to current velocity

Influence of hydrologic characteristics such as streamflow variability (e.g., flood pulses) on macroinvertebrate community composition was demonstrated by Konrad et al. (2008), and its role in life-history traits adaptation (Poff et al. 2006; Verberk et al. 2008). Specifically, current velocity is an important explanatory variable for the spatial distribution and patterns of macroinvertebrates within riffle habitats (Brooks et al. 2005) and the particular types of hydraulic preferences was successfully demonstrated. Five BIBI metrics (percentages of EPT, Chironomidae, tolerant taxa, grazer guild, and gatherer guild) in both the watersheds showed a negative correlation to current velocity, suggesting their preference of low to moderate flow conditions. In contrast, percent filterer guild preferred higher current velocity as seen by their higher abundance in those areas. Examination of the strength of correlations of BIBI metrics from the Blanco River to current velocity, showed stronger association of macroinvertebrate communities to flow conditions at local scale in a smaller watershed. There were fewer significant correlations among the BIBI metrics to current velocity (for the Colorado River data), suggesting either it has a weaker effect in a larger water body, or other factors are having a greater influence on the macroinvertebrate community.

Response of flow-sensitive macroinvertebrate genera to recovery period and discharge conditions

In this study, a difference in the effects of duration of recovery period, and variation in discharge conditions on the flow-sensitive taxa was observed between the two watersheds. This can be attributed to the difference in the size, magnitude of water flowing through, and substrate composition (Kennen et al 2010). For the Blanco River, the correlation of the flow-sensitive and selected taxa from all sites together vs. discharge data collected from a single gage on the Blanco River (at Wimberley, TX; USGS gage: 8171000) should be interpreted with caution as it could be a limiting factor, but the ecological information gleaned regarding the response of selected taxa for the waterbody is very informative. These selected taxa were either not seriously impaired by this flood event (peaked at 69,700 cfs) in October 2015, or that other local factors were driving the communities (e.g., current velocity in immediate vicinity). On the other hand, the significant response of flow-sensitive and other selected taxa from the Colorado River to number of days from flood event, and discharge (peaked at 61,600 cfs at Bastrop) suggests that these factors have stronger effect on macroinvertebrate communities in the larger waterbody.

Water discharge levels above a certain threshold has a negative effect on macroinvertebrate communities (Death 2008). The taxa count and abundance of macroinvertebrates started dropping at discharge levels above 200 cfs in the Blanco River (Figures 13, 14), which coincides with the classification of flows at these levels as a high flow pulse event (194 cfs) in our IHA analysis for the Blanco River (Figure 21). The macroinvertebrate taxa count and abundance from the Colorado River showed a downward abundance trend above 700 cfs of discharge, which is much lower than the 'high flow pulse event' flow level classification from the IHA analysis at Bastrop, Smithville, and La Grange (3,180 cfs, 3,410 cfs, and 3,460 cfs respectively). This is evidence that macroinvertebrate communities are either exiting the sites via drift or seeking shelter deep in the substrate as an avoidance mechanism to higher discharge levels in the Colorado River as seen in other river systems (Death 2008). In a similar study, macroinvertebrate taxa abundances from the Brazos, Guadalupe, and San Antonio Rivers in Texas (Maikoetter 2018) after a flood event seemed to have successfully recovered but showed fair amount of variation by site. The flood-effect event on macroinvertebrate community structure may not have been detected by the authors due to a considerable time-gap in sampling after the flood (about two years), and also due to inter-annual variation in the community structure. Thus, consideration of the magnitude of the flood event, size of the waterbody, and duration of recovery time are important factors in determining the biological condition of a lotic ecosystem after a flood event.

Change in macroinvertebrate community structure over time

The community level analyses on the Blanco and the Colorado rivers yielded interesting results and were spatially distinct to the two watersheds. The colonization patterns were strongly driven by location (site) and time factor (sampling event), as seen by difference in recovery of the macroinvertebrate communities across different sites. The macroinvertebrate community at the upstream sites in the Blanco River were dominated by square-gilled and prong-gilled mayflies (*Caenis* and *Neochoroterpes*), and midges (Chironomidae); and the upstream sites in the Colorado River were dominated by blackfly (Simuliidae), riffle beetles (Elmidae) and prong-gilled mayflies (*Thraulodes*). This difference between the upstream and downstream sites could be influenced by input from three tributaries (Little Blanco River, Capers Creek, and Cypress Creek) and presence of four low water dams on the Blanco River. The study sites on the Colorado River did not have any impoundments but had discharge input from three tributaries (Alum

Creek, Pin Oak Creek, and Rabbs Creek) between the upstream and downstream sites. A combination of the effects of impoundments and discharge input from tributaries influences hydrology and thereby affecting the macroinvertebrate community. Several studies have demonstrated the macroinvertebrate communities are structured by hydrology, which is strongly correlated to geomorphology, land use, and water quality (Poff 1996; Poff et al. 2006; McManamay and Frimpong 2015). The findings show greater variability in communities at downstream sites which is probably due to altered habitat caused by the cumulative effect of impoundments and higher discharge levels.

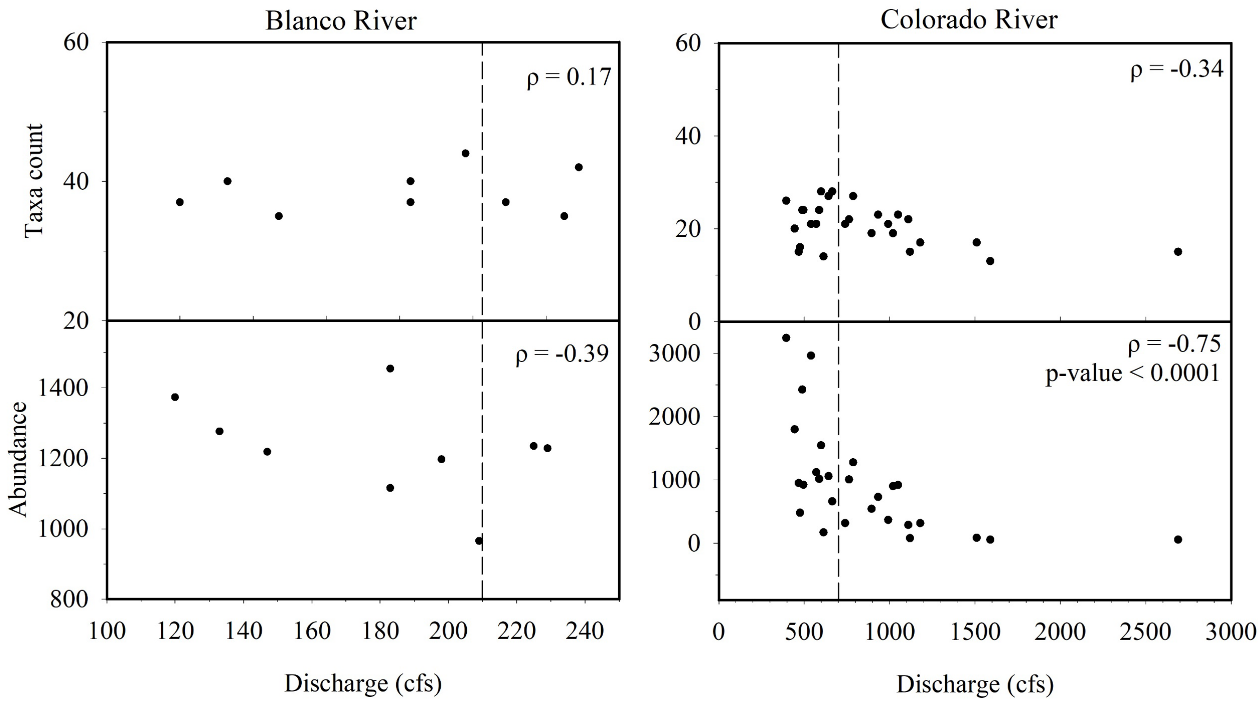


FIGURE 21.—Taxa count and abundance plots against discharge during the sampling period from November 2015 to April 2016 from the Blanco and the Colorado Rivers. Dashed vertical line represents the threshold discharge level where taxa count and abundance starts to drop down. Discharge values from Wimberley (USGS gage: 8171000) were used for the Blanco River, and discharge values for the Colorado River were obtained from three gages in the sampling area (USGS gages: 8159200, 8159500, and 8160400).

The considerable shift in macroinvertebrate community structure across the sampling period was seen by the trajectory plots (Figures 14a, 15a). The Colorado River showed a higher magnitude of increase (77.7% dissimilarity) in macroinvertebrate numbers from initial and final sampling events, when compared to the Blanco River (40.4% dissimilarity). While local factors affect the recolonization rate of macroinvertebrates inhabiting streams and rivers, they are in a continuous state of redistribution via active and passive drift mechanisms, and repopulation via adults laying eggs in the aquatic system (Lancaster 1999). The recovery rate of macroinvertebrates in previous studies varies from a few days to several months after an extreme flood event (Molles Jr. 1985; Fritz and Dodds 2004) and can be reestablished via four pathways including (a) aerial movements, (b) downstream drift, (c) upstream movement, and (d) vertical movement from gravel beds (Williams and Hynes 1976). The rate of recolonization of macroinvertebrates differs in available habitat patches and food resources and is in a constant dynamic state due to interactions between competition and predation (Mackay 1992). The Blanco River is a spring-fed system and is characterized by bedrock shallow runs, leading to lower primary productivity. This might explain the relatively slower recolonization and lower abundances in general in this watershed. Studies have shown that macroinvertebrate numbers can be higher in open canopy sections that allows for increased primary production (Quinn et al. 1997; Eckert et al. 2020) as seen in the larger waterbody (Colorado River). In contrast, the Colorado River (sampled section) has less canopy cover due to the greater distance between the two river banks, has medium-size gravel as primary substrate, providing greater surface area for macroinvertebrates to occupy, and has greater volume of water moving through the system due to it being a higher order river.

Effects of environmental variables on macroinvertebrate communities

Environmental variables accounted for a high percentage of the macroinvertebrate species composition variability (76% for the Blanco River, and 53% for the Colorado River). In frequently flooded streams and wetlands, generalist species that are resistant and resilient to disturbance are abundant and are dominated by insect species from Trichoptera and Ephemeroptera families (Townsend et al. 1997; Gallardo et al. 2008). The presence of a number of pollution sensitive taxa (*Isonychia*, *Corydalus*, *Neoelmis*, *Ambrysus*, *Nectopsyche*, *Neoperla* and) at the Cox Road site is consistent the presence of a healthy riffle habitat with heterogenous substrate types. Typically, insects of Megaloptera, Coleoptera, and Plecoptera families specialize in habitat and resource exploitation in stable habitats (Townsend et al. 1997; Gallardo et al. 2008). The surface water and groundwater in the Blanco River watershed is linked by the karst limestone geology and is strongly influenced by clear water from the springs (Bowles and Arsuffi 1993). This was indicated by the presence of "travertine beetles" (*Lutrochus*) at the downstream sites on the Blanco River, that generally occur in springs and streams with travertine deposits (Arnett et al. 2002). The abundance of Hirudinea, Oligochaetes, Tipulidae and Chironomids at the downstream sites at the Colorado River may be related to the higher nutrient concentration in the river. The stronger groupings of several taxa along the different environmental gradients in the Blanco River indicates that the macroinvertebrate community a) was not affected drastically by the October 2015 flood event, and/or b) it recovered in a relatively short period. In contrast, the majority of taxa from the Colorado River showed clustering around the center of the plot suggesting their non-association to the environmental variables due to the macroinvertebrate community being a) strongly altered by the October 2015 flood event, and/or b) it was still in a state of disturbance and the system had not stabilized enough for the numbers to have recovered.

Relationship of hydrologic parameters and macroinvertebrate taxa

Several hydrological flow parameters affected macroinvertebrate taxa (e.g., number of days of base flow, duration of peak discharge during small flood pulse event, duration of recession, magnitude of rise, rate of median recession, and number of flow reversals) and were significantly correlated to the hydrologic disturbance gradient (Appendix D). Base flow condition is the amount of discharge that remains sustained in between precipitation events. This continuous, low flow level determines the wetted perimeter of the river channel and corresponds to available habitat for macroinvertebrates and their bioavailability to predation by fish. The stability of base flow conditions (i.e., duration) is also important in maintaining water quality parameters such as oxygen, temperature, pH, and conductivity. The duration of base flow conditions is correlated positively to density and richness in macroinvertebrate communities (Clausen et al. 2000). This allows opportunities for stabilization of population through predation and competition

(Mathews 1988). The 15-day cumulative duration of base flow conditions was strongly significant to abundance of several taxa in the Colorado River. In addition, the 30-day total duration average discharge (magnitude) ranked high but had a negative impact on *Neoperla* and Chironomidae. The hydrologic parameters from the Blanco River did not affect the macroinvertebrate taxa significantly.

Flow pulse effects: Moderate flooding is defined as a flow event that is at least three times the median annual discharge level and this increase in magnitude can alter bed material by moving sit and gravel (Clausen et al. 2000). The three increase flow pulses are described as a) high flow pulse - that occurs during rain storms where the water level rises above the base flow conditions; b) small flood event - the water rises above the main channel bank, and these flood pulses give access to fish and macroinvertebrates to floodplains, backwaters, and habitats not occurring in the main channel; and c) large flood event – occurs rarely, but is important in a river ecosystem. These overbanking flows will move significant amounts of sediment and large woody debris and will reset the biotic seral stages. In the current study, in the high flow pulse condition, the 30-day total duration average discharge (magnitude) negatively affected *Thraulodes*, *Acentrella* and *Cheumatopsyche*. Interestingly, the 30-day cumulative duration peak discharge (duration) positively affected caddisflies (*Cheumatopsyche* and *Hydroptila*). During small flood events, frequency and duration had a positive effect, whereas the magnitude had a negative effect. Number of pulses (frequency) and cumulative duration (duration) positively affected *Chimarra*, *Maccaffertium*, and Dipterans (Tipulidae and Chironomidae). However, the 30-day peak discharge levels (magnitude) had a negative impact on mayflies (*Camelobaetidius* and *Tricorythodes*) Two hydrologic parameters during the large flood events (number of pulses and peak discharge) significantly negatively affected the mayflies (*Maccaffertium* and *Acentrella*).

Change in hydrologic parameters: The rate of rise and recession is a measure of how long it takes for the discharge to rise or recede in a stream channel, and depending on size of the waterbody, it could have habitat-limiting impacts on fish and macroinvertebrate communities occupying the various meso-habitats. Although many aquatic macroinvertebrates cannot swim as fast as fish in stream channel to evade unfavorable flow condition, they engage in longitudinal, downstream movement in the form of active and passive drift that mostly occurs after dark. Thus, the rate of- rise or recession of discharge and its frequently can impact macroinvertebrate survival. Rapid recession can strand fish in isolated pools and oxbows and thus affect fish passage to spawning and feeding areas. This stranding effect to freshwater organisms with reduced hydrologic connectivity was proposed by Freeman et al. (2007). The concept of stranding that impedes fish and macroinvertebrate movement during periods of rapid recession, is reinforced by previous studies (Cushman 1985; Moog 1993). These studies also propose that the increase in discharge recession leads to heightened drift or movement, ultimately depleting the limited food resources. The current study showed median rate of recession negatively impacted several macroinvertebrate taxa including, *Maccaffertium*, *Acentrella*, *Nectopsyche*, Chironomidae, and Oligochaeta. Synonymously, the magnitude of rise also had a negative effect on *Camelobaetidius*, *Acentrella*, *Cheumatospyche*, and *Stenelmis*, On the other hand, the number of flow reversals had a positive effect on *Acentrella*, Oligochaeta, *Neoperla*, *Cheumatopsyche*, and *Hydroptila*, indicating preference of intermediate disturbance in flow levels for these taxa.

The importance of annual streamflow variability for supporting native stream communities was emphasized by Poff et al. (1997). The ability to adapt to a specific flow regime relies on the predictability, frequency, and magnitude of flow events that can cause mortality. The timing of these flow events is essential for synchronizing life-history processes, maximizing reproductive success, and minimizing mortality during extreme events such as floods or droughts (Lytle and Poff 2004). Flow variability, including maximum and average monthly flows, annual streamflow variability, and annual maximum monthly flow, has a significant impact on the aquatic invertebrate assemblage. While aquatic macroinvertebrates demonstrate resilience to short-term reductions in streamflow and discrete high-flow events, landscape changes related to urbanization in the Northeastern US can surpass the assemblage's ability to recover (Kennen et al. 2010). This has important implications for managing future growth and development in streams and smaller rivers. To safeguard healthy aquatic assemblages while allowing for further development, it is essential to promote longer durations of high flows and greater magnitudes of low flows. Reducing the effect of urban runoff through increased infiltration can help mitigate the impact of high-flow events. Long-term studies are crucial for assessing the cumulative effect of hydrologic changes on aquatic assemblages, especially considering the growing anthropogenic disturbances like urbanization and its impact on central Texas.

Guadalupe Bass growth and recruitment

The GB at five sites on Colorado River showed bimodal size distribution and similar trend was observed individually at the five upstream sites. Although relative abundance of age 1 GB was lower, the average length was greater in the current study (9.91 in.), compared to previous studies (5.07 in., Pease et al. 2018). The larger size of GB in this study could be due to difference in sampling efficiency (boat electrofish vs. seine), collection time period (GB most probably grew in size between March and November), and inter-annual growth variation (2014 and 2016). The sampling efficiency in this study was robust, considering a high catch rate of GB (16 GB/hr.) than what was observed in previous studies of 1.88 GB/hr. in headwater streams, and 1.20 GB/hr. in mainstem Colorado River (Pease 2018). This previous study used a combination of gear types (seine, backpack electrofish, and boat electrofish) to address the morphometric relationship to environmental gradients, whereas the current study only deployed boat electrofish to address GB length frequency, and recruitment objectives. Integration of different gear types would facilitate collection of all sized GB, however, there are inherent limitations with combining data from different gears resulting in differing patterns of abundance and covariation (Jackson and Harvey 1997). The recruitment analysis with boat electrofish data was conducted because the other age classes were appropriately represented with the collection method, with the caveat that age 0 GB may be underrepresented.

The recruitment of GB based on the year-class strength in 2012, ’13, and ’14 was weak, and could be a result of severe drought conditions in central Texas (Bean et al. 2013, TWDB 2021) from years 2011 to 2014. Lower discharge levels and increased vegetation density (Water Hyacinth and Hydrilla) was observed in years 2013 and 2014 in the sampled reach of lower Colorado River (pers comm. Stephen Magnelia, TPWD). GB prefer a combination of open-water habitats and vegetated areas in the current study and similar trends were observed from the Colorado and Llano Rivers (Groeschel-Taylor et al 2020, Perkin et al 2010). Increased vegetation concentration in the water column is known to reduce piscivory among black bass (Bettoli et al. 1992; Savino and Stein 1989), so the GB may not have experienced higher than normal mortality due to intraspecific predation. However, during the drought years the lower water levels and increased vegetation could have negatively impacted available nesting habitats, thus resulting in lower recruitment.

By 2014, central Texas was coming out of the drought phase, as was seen in the positive recruitment in the GB populations. Unfortunately, this positive recruitment was short-lived due to excessive flooding the following year in 2015. Large flood pulses can negatively impact (Fritz and Dodds 2004) and ultimately affect the growth and survival of juvenile bass (Paragamian and Wiley 1987). The current study and another study (Pease 2018), shows that increased flow conditions can negatively affect GB year class strength. The catch-curve data from 2016 (age 0) was included in the year-class strength regression analyses and showed negative correlations. While interpretation of this analysis should be considered with caution due to possible underrepresentation of age 0 GB, this data was included for two reasons: a) fish size (size range: 4.3-6.9 in.) was fully recruited to the collection gear (Jackson and Noble 1995), and b) the age 0 fish collected late in the year (Nov. and Dec. 2016) are potential recruits from that year's cohort.

The success of bass recruitment is dependent on fish and macroinvertebrate prey availability during spawning season for age 0 fish (Samons 2012; Garvey et al. 2002). While black bass are piscivorous, they consume copious amounts of macroinvertebrates and crayfish during the juvenile and subadult stages (Sammons 2012). The gut contents of GB up to size 13.58 in. from this study had considerable number of mayflies, caddisflies, riffle beetles, and dobsonflies (pers comm., Carly Rotzler, TPWD). These prey macroinvertebrate taxa are also flow sensitive (Extence et al. 1999), and were negatively impacted by the catastrophic flood event, with a recovery period of approximately 82 days. The findings from the current study suggest that the October 2015 flood had a negative impact on the GB recruitment, potentially due to lack of availability of macroinvertebrates, which were affected by the habitat altering flood event.

The results of this study suggest that management of GB in the lower Colorado River system after a major flood event should include a) assessment of habitat structures, including large woody debris that is necessary for both fish and macroinvertebrate communities, b) annual monitoring of recruitment of age 0 GB, consecutive to the flood years would be helpful in understanding the recovery time period of strong year class, c) assessment of GB populations from mainstem and tributaries will give an understanding of source and sink populations, and d) use of multi-gear sampling approach to adequately sample all age classes of GB. These objectives will inform the management biologists on how the GB populations are affected by a major flood event, and if GB need to be stocked to address the loss of the particular year class. This continual long term monitoring effort of GB populations will help understand the effects of extreme environmental conditions in river systems that support pure GB populations over long term.

CONCLUSION

Environmental conditions affect the biotic communities in a lotic system in the form of natural stressors such as floods and droughts, causing the communities to be in a constant state of non-equilibrium (Wallace 1990). The predictability of the response of macroinvertebrate communities to these disturbances goes down with the magnitude and intensity. If the communities are overburdened with doubling of natural and anthropogenic disturbances, they may not have the capacity to recover and in the long term, can shift to a new equilibrium state with loss of certain intolerant taxa (Cardoso et al., 2008). Long term studies will prove beneficial in understanding the relationship between macroinvertebrate communities and various forms of disturbances, and its implication to sportfish recruitment.

These results provide guidance for the management and restoration of rivers and should take into account the forces driving the ecosystem integrity by collection of data from different habitat types and waterbodies of different sizes during extreme weather conditions such as floods, droughts, and freezes. The shifts in climatic conditions in the northeastern US is expected to affect the magnitude, duration, and frequency of extreme floods and droughts, and can threaten macroinvertebrate communities (Calderon et al. 2017). According to Lake 2000, the macroinvertebrate community recovery after flooding can be fairly short, but not all metrics recover at the same rate because different taxa recover at different rates with successional progression (Molles Jr. 1985). The magnitude of impact of this catastrophic event on the benthic macroinvertebrate communities could not be captured appropriately due to lack of pre-flood data, and potential recovery period of the ecosystem could be upwards of 5 years after severe floods as noted by Death (2008). This extended recovery of the macroinvertebrate communities could potentially affect the recovery of GB recruitment as well. Although the macroinvertebrate communities in the two watersheds are resilient and appear to have recovered, they may still be healing from the debilitating effects of the catastrophic flood and can be better understood with continued annual monitoring.

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TABLES

Table 1a. Spearman's correlations on various BIBI metrics against current velocity (f/s) and discharge (cfs) from the six sites each from the Blanco River. P-values <0.05 are in bold.

	Velocity		Discharge	
	Spearman	Prob>|ρ|	Spearman	Prob>|ρ|
Taxa count	-0.102	0.464	-0.053	0.702
Abundance	-0.365	**0.007**	0.011	0.935
Diptera taxa	-0.078	0.574	-0.167	0.227
Ephemeroptera taxa	-0.323	**0.017**	-0.124	0.372
Intolerant taxa	0.053	0.702	-0.042	0.764
% EPT taxa	-0.402	**0.003**	-0.286	**0.036**
% Chironomidae	-0.418	**0.002**	0.055	0.692
% Tolerant taxa	-0.674	**<.0001**	0.055	0.695
% Grazers	-0.579	**<.0001**	-0.174	0.21
% Gatherers	-0.755	**<.0001**	-0.051	0.714
% Filterers	0.806	**<.0001**	0.09	0.518

Table 1b. Spearman's correlations on various BIBI metrics against current velocity (f/s) and discharge (cfs) from the six sites each from the Colorado River. P-values <0.05 are in bold.

	Velocity		Discharge	
	Spearman	Prob>|ρ|	Spearman	Prob>|ρ|
Taxa count	0.385	**0.004**	-0.336	**0.013**
Abundance	0.45	**0.001**	-0.647	**<.0001**
Diptera taxa	0.225	0.103	-0.231	0.093
Ephemeroptera taxa	-0.06	0.665	-0.104	0.454
Intolerant taxa	0.344	**0.011**	-0.371	**0.006**
% EPT taxa	-0.055	0.691	0.069	0.621
% Chironomidae	-0.311	**0.022**	-0.317	**0.02**
% Tolerant taxa	-0.211	0.126	0.022	0.873
% Grazers	-0.053	0.706	0.223	0.106
% Gatherers	-0.4	**0.003**	-0.029	0.837
% Filterers	0.474	**<.001**	-0.251	0.067

Table 2a. Generalized linear model (GLM) tests on effects of time factor (no.of days from flood event), and discharge on flow-sensitive genera from the Blanco River (n=9). P-values (probability of Chi-square) <0.05 are in bold.

Taxa	GLM		-ve LogLikelihood	Likelihood ChiSquare	DF	Prob>ChiSq
Stenelmis	Whole Model	Difference	2.04	4.08	3	0.253
		Full	28.29			
		Reduced	30.33			
	Effect Tests	No. Days		4	1	**0.046**
		Discharge		1.98	1	0.159
		No.Days*Discharge		0.52	1	0.469
Maccaffertium	Whole Model	Difference	0.75	1.51	3	0.68
		Full	33.95			
		Reduced	34.71			
	Effect Tests	No. Days		0.03	1	0.863
		Discharge		0.43	1	0.512
		No.Days*Discharge		0.15	1	0.699
Neoperla	Whole Model	Difference	6.24	12.48	3	**0.006**
		Full	19.68			
		Reduced	25.92			
	Effect Tests	No. Days		3.52	1	0.061
		Discharge		4.55	1	**0.033**
		No.Days*Discharge		3.78	1	0.052
Cheumatopsyche	Whole Model	Difference	2.16	4.32	3	0.229
		Full	38.22			
		Reduced	40.38			
	Effect Tests	No. Days		0.02	1	0.881
		Discharge		2.82	1	0.093
		No.Days*Discharge		2.66	1	0.103
Chimarra	Whole Model	Difference	4.31	8.62	3	**0.035**
		Full	34.98			
		Reduced	39.29			
	Effect Tests	No. Days		4.03	1	**0.045**
		Discharge		7.84	1	**0.005**
		No.Days*Discharge		1.89	1	0.169

Table 2b. Generalized linear model tests on effects of time factor (no.of days from flood event), and discharge on flow-sensitive genera from the Colorado River (n=27). P-values (probability of Chi-square) <0.05 are in bold.

Taxa	GLM	Model	-ve LogLikelihood	Likelihood ChiSquare	DF	Prob>ChiSq
Stenelmis	Whole Model	Difference	3.62	7.24	3	0.065
		Full	144.86			
		Reduced	148.48			
	Effect Tests	No. Days		0.36	1	0.546
		Discharge		4.67	1	**0.031**
		No.Days*Discharge		0.27	1	0.605
Maccaffertium	Whole Model	Difference	2.5	5	3	0.172
		Full	68.36			
		Reduced	70.86			
	Effect Tests	No. Days		0.37	1	0.541
		Discharge		3.64	1	0.056
		No.Days*Discharge		3.38	1	0.066
Neoperla	Whole Model	Difference	4.93	9.86	3	**0.02**
		Full	103.9			
		Reduced	108.83			
	Effect Tests	No. Days		1.62	1	0.204
		Discharge		6.59	1	**0.01**
		No.Days*Discharge		1.99	1	0.159
Cheumatopsyche	Whole Model	Difference	3.61	7.21	3	0.065
		Full	143.39			
		Reduced	146.99			
	Effect Tests	No. Days		4.1	1	**0.043**
		Discharge		0	1	0.991
		No.Days*Discharge		1.05	1	0.305

Table 3a. Generalized linear model tests on effects of time factor (no.of days from flood event), and discharge on taxa that correlated strongly with discharge from the Blanco River (n=9). P-values (probability of Chi-square) <0.05 are in bold.

Taxa	GLM	Model	-ve LogLikelihood	Likelihood ChiSquare	DF	Prob>ChiSq
Acentrella	Whole Model	Difference	0.44	0.88	3	0.83
		Full	18.04			
		Reduced	18.48			
	Effect Tests	No. Days		**0.01**	1	0.938
		Discharge		0.61	1	0.434
		No.Days*Discharge		0.08	1	0.777
Isonychia	Whole Model	Difference	3.47	6.95	3	0.074
		Full	22.58			
		Reduced	26.05			
	Effect Tests	No. Days		0.34	1	0.563
		Discharge		2.52	1	0.112
		No.Days*Discharge		0.13	1	0.724
Thraulodes	Whole Model	Difference	0.62	1.23	3	0.746
		Full	45.75			
		Reduced	46.37			
	Effect Tests	No. Days		0.03	1	0.864
		Discharge		0.69	1	0.405
		No.Days*Discharge		0.55	1	0.46
Tricorythodes	Whole Model	Difference	0.46	0.92	3	0.821
		Full	36.37			
		Reduced	36.83			
	Effect Tests	No. Days		0.38	1	0.538
		Discharge		0.5	1	0.48
		No.Days*Discharge		0.19	1	0.662
Chironomidae	Whole Model	Difference	3.52	7.05	3	0.07
		Full	46.17			
		Reduced	49.69			
	Effect Tests	No. Days		4.65	1	**0.031**
		Discharge		1.97	1	0.16
		No.Days*Discharge		4.72	1	**0.03**

Table 3b. Generalized linear model tests on effects of time factor (no.of days from flood event), and discharge on taxa that correlated strongly with discharge from the Colorado River (n=27). P-values (probability of Chi-square) <0.05 are in bold.

Taxa	GLM	Model	-ve LogLikelihood	Likelihood ChiSquare	DF	Prob>ChiSq
Acentrella	Whole Model	Difference	8.11	16.22	3	**0.001**
		Full	173.35			
		Reduced	181.46			
	Effect Tests	No. Days		3.35	1	0.067
		Discharge		11.43	1	**0.001**
		No.Days*Discharge		8.13	1	**0.004**
Isonychia	Whole Model	Difference	1.19	2.38	3	0.498
		Full	100.13			
		Reduced	101.32			
	Effect Tests	No. Days		1.86	1	0.173
		Discharge		0.07	1	0.798
		No.Days*Discharge		0.01	1	0.923
Thraulodes	Whole Model	Difference	5.19	10.38	3	0.016
		Full	140.75			
		Reduced	145.94			
	Effect Tests	No. Days		0.72	1	0.397
		Discharge		8.53	1	**0.004**
		No.Days*Discharge		3.95	1	**0.047**
Tricorythodes	Whole Model	Difference	6.5	13.01	3	0.005
		Full	130.45			
		Reduced	136.95			
	Effect Tests	No. Days		6.15	1	**0.013**
		Discharge		4.96	1	**0.026**
		No.Days*Discharge		6.62	1	**0.01**
Chironomidae	Whole Model	Difference	8.14	16.27	3	**0.001**
		Full	161.68			
		Reduced	169.82			
	Effect Tests	No. Days		3.64	1	0.057
		Discharge		11.21	1	**0.001**
		No.Days*Discharge		7.92	1	**0.005**

Table 4a. Top 70% of macroinvertebrate genera contributing to the dissimilarity between the sites at the Blanco River generated by a two-way similarity of percentages analysis (SIMPER). Average dissimilarity between Chimney Valley upstream site and the Little Arkansas Rd was the greatest (73.78%) among all sites.

Species	Chimney Valley upstream	Little Arkansas Road	Percent contributed
Caenis	9.15	0.84	13.55
Neochoroterpes	7.58	0.74	10.71
Chironomidae	8.28	3.13	9.18
Simuliidae	0.58	5.69	8.27
Tipulidae	4.44	0.11	7.39
Procloeon	3.18	0	5.11
Thraulodes	3.26	0.78	4.51
Maccaffertium	3.29	0.67	4.22
Argia	3.36	0.94	4.03
Fallceon	0.92	1.55	3.25

Table 4b. Results from two-way SIMPER on the Blanco River showed an average dissimilarity of 40.41% between first and nineth sampling events.

Species	Sampling Event 1	Sampling Event 9	Percent contributed
Caenis	4.07	4.11	10.06
Chironomidae	4.01	4.02	8.34
Camelobaetidius	1.96	3.37	7.33
Simuliidae	1.22	1.93	6.19
Fallceon	1.52	3.43	5.75
Thraulodes	3.73	2.3	5.52
Neochoroterpes	2.64	3.2	5.27
Hydropsyche	0.17	1.05	4.11
Lutrochus	1.1	1.52	4.04
Stenelmis	1.14	1.97	3.92
Vacupernius	0.37	1.82	3.5
Baetis	0.17	0.98	3.11
Oligochaeta	0.4	1.07	2.74
Tricorythodes	1.63	1.9	2.69

Table 5a. Top 70% of macroinvertebrate genera contributing to the dissimilarity between the sites at the Colorado River watershed generated by similarity of percentages analysis (SIMPER). Average dissimilarity between Bastrop upstream site and the La Grange upstream site was the greatest (61.42%) among all sites.

Species	Bastrop Upstream	La Grange Upstream	Percent contributed
Simuliidae	17.52	1.63	21.27
Stenelmis	10.52	2.47	11.55
Thraulodes	8.18	1.03	10.08
Acentrella	8.93	3.94	6.87
Isonychia	6.01	0.55	6.69
Cheumatopsyche	6.11	2.09	5.47
Chironomidae	6.99	5.73	4.79
Neoperla	4.13	0.81	4.62

Table 5b. Results from two-way SIMPER on the Colorado showed an average dissimilarity of 77.6% between first and eight sampling events.

Species	Sampling Event 1	Sampling Event 8	Percent contributed
Acentrella	0	17.48	20.79
Chironomidae	1.02	12.03	15.15
Tricorythodes	1.31	8	7.27
Cheumatopsyche	0.52	7.08	7.08
Stenelmis	2.85	8.81	6.82
Simuliidae	1.53	8.66	6.13
Thraulodes	2.6	8.29	5.67
Isonychia	1.09	5.05	4

Table 6. Canonical correspondence analysis (CCA) eigen values and Monte Carlo significance from the Blanco River and the Colorado River. The constrained ordination analyses were conducted on normalized environmental data, and log (x+1) transformed macroinvertebrate data and was down-weighted for rare species. Explained variation is variation explained by the macroinvertebrate response data. Explained fitted variation is the variation explained by the environmental variables used in the model.

Rivers	Axes	1	2	3	4
~Blanco River	Eigenvalues	0.345	0.12	0.05	0.037
	*Explained variation	23	31	34.4	36.8
	*Explained fitted variation	56.5	76.2	84.4	90.5
~Colorado River	Eigenvalues	0.064	0.044	0.027	0.023
	*Explained variation	7.2	12.2	15.3	17.9
	*Explained fitted variation	31.3	53.1	66.5	77.8

~Blanco River: Total inertia = 1.501, F-ratio = 3.86, *P*-value = 0.002
~Colorado River: Total inertia = 0.88, F-ratio = 1.68, *P*-value = 0.002

Table 7. The correlation coefficients of the explanatory environmental variables to the first two CCA axes for the Blanco River and the Colorado River.

Environmental Variables	Blanco River		Colorado River	
	Response axis 1	Response axis 2	Response axis 1	Response axis 2
pH	-0.281	0.164	0.360	0.502
Dissolved Oxygen (mg/L)	-0.162	0.211	0.305	0.437
Conductivity (µs/cm)	-0.031	-0.194	-0.365	-0.555
Temperature (°C)	-0.195	0.184	0.154	0.173
Depth (ft)	-0.171	0.163	0.364	0.592
Current Velocity (f/s)	-0.549	0.178	0.263	0.608
Discharge (cfs)	0.063	0.042	0.260	0.538
Percent Embeddedness	0.708	-0.088	0.462	-0.371

APPENDIX A

List of macroinvertebrate taxa from the Blanco River. Sampling events (1-9) correspond to the following sampling dates: 11/18/15, 11/23/15, 12/9/15, 12/21/15, 1/5/16, 1/19/16, 2/3/16, 3/1/16, 4/5/16.

Order	Family	Genus	Trophic Guild	1	2	3	4	5	6	7	8	9
Amphipoda	Taltridae	*Hyalella*	CG/SHR	✓		✓						
Coleoptera	Dryopidae	*Postelichus*	SCR/CG			✓						
	Elmidae	*Dubiraphia*	SCR/CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Hexacylloepus	SCR/CG	✓	✓	✓					✓	✓
		Macrelmis	SCR/CG			✓	✓	✓	✓			✓
		Microcylloepus	SCR/CG	✓	✓			✓	✓	✓		✓
		Neoelmis	SCR/CG		✓			✓	✓			✓
		Stenelmis	SCR/CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Hydrophilidae	*Berosus*	P	✓	✓	✓	✓	✓	✓			
	Lutrochidae	*Lutrochus*	SHR	✓	✓	✓	✓	✓	✓	✓	✓	✓
Diptera	Ceratopogonidae		P/CG		✓	✓	✓	✓	✓	✓	✓	✓
	Chironomidae		P/CG/FC	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Empididae		P									✓
	Simuliidae		FC	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Tabanidae		P	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Tipulidae		SHR/P/CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Thaumaleidae									✓		
Entomobryom-orpha	Sminthuridae		CG	✓								
Ephemeroptera	Baetidae	*Acentrella*	SCR/CG	✓	✓		✓	✓	✓	✓	✓	✓
		Acerpenna	SCR/CG	✓			✓					
		Baetis	SCR/CG	✓	✓	✓		✓	✓	✓	✓	✓
		Baetodes	SCR					✓				
		Camelobaetidius	SCR/CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Fallceon	SCR/CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Procloeon	CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Pseudocloeon	SCR/CG				✓					
	Caenidae	*Caenis*	SCR/CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Heptageniidae	*Maccaffertium*	SCR/CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Stenacron	SCR/CG		✓							
	Leptohyphidae	*Vacupernius*	CG	✓	✓	✓	✓	✓	✓	✓	✓	✓

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Order	Family	Genus	Trophic Guild	1	2	3	4	5	6	7	8	9
Ephemero-ptera	Leptophlebiidae	*Neochoroterpes*	CG/SCR	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Thraulodes	CG/SCR	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Traverella	FC	✓	✓		✓		✓			✓
	Oligoneuriidae	*Isonychia*	FC	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Tricorythidae	*Tricorythodes*	CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hemiptera	Naucoridae	*Ambrysus*	P	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hirudinea			P			✓			✓			
Lepidoptera	Pyralidae	*Paraponyx*	SCR			✓						
		Petrophila	SCR		✓			✓				
Megaloptera	Corydalidae	*Corydalus*	P	✓	✓	✓	✓	✓	✓	✓	✓	✓
Odonata	Coenagrionidae	*Argia*	P	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Gomphidae	*Dromogomphus*	P			✓		✓				
		Erpetogomphus	P	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Phyllogomphoides	P			✓						
	Libellulidae	*Brechmorhoga*	P			✓		✓			✓	
		Perithemis	P		✓							
		Dythemis	P						✓			
	Macromiidae	*Macromia*	P			✓						
Oligochaeta			CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
Planariidae	Dugesiidae	*Dugesia*	P		✓			✓		✓	✓	✓
Plecoptera	Perlidae	*Neoperla*	P			✓	✓	✓	✓	✓	✓	✓
Trichoptera	Helicopsychidae	*Helicopsyche*	SCR					✓				
	Hydropsychidae	*Cheumatopsyche*	FC	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Hydropsyche	FC	✓	✓	✓		✓		✓	✓	✓
		Smicridea	FC	✓		✓						
	Hydroptilidae	*Hydroptila*	SCR		✓	✓	✓	✓	✓		✓	✓
		Oxyethira	CG/SCR								✓	
		Stactobiella	SHR			✓	✓	✓			✓	
	Leptoceridae	*Nectopsyche*	SHR/CG/P		✓					✓	✓	✓
		Oecetis	P/SHR			✓				✓		
	Philopotamidae	*Chimarra*	FC	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Polycentropodidae	*Neureclipsis*	FC/SHR/P	✓	✓		✓	✓	✓	✓	✓	✓

APPENDIX B

List of macroinvertebrate taxa from the Colorado River. Sampling events (1-9) correspond to the following sampling dates: 11/19/15, 11/24/15, 12/10/15, 12/22/15, 1/8/16, 1/20/16, 2/2/16, 3/2/16, 4/6/16.

Order	Family	Genus	Trophic Guild	1	2	3	4	5	6	7	8	9
Amphipoda	Taltridae	*Hyalella*	CG/SHR		✓		✓					✓
Coleoptera	Dryopidae	*Postelichus*	SCR/CG	✓	✓		✓					
	Elmidae	*Ancyronyx*	SCR/CG						✓			
		Dubiraphia	SCR/CG	✓	✓	✓	✓		✓	✓		
		Heterelmis	SCR/CG							✓	✓	
		Hexacylloepus	SCR/CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Macrelmis	SCR/CG				✓					✓
		Microcylloepus	SCR/CG									✓
		Neoelmis	SCR/CG				✓		✓			
		Stenelmis	SCR/CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Haliplidae	*Peltodytes*	SHR/P				✓					
	Hydrophilidae	*Berosus*	P		✓	✓	✓				✓	
	Lutrochidae	*Lutrochus*	SHR	✓								
Diptera	Ceratopogonidae		P/CG							✓	✓	
	Chironomidae		P/CG/FC	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Empididae		P					✓				
	Simuliidae		FC	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Tipulidae		SHR/P/CG		✓			✓				✓
Ephemeroptera	Baetidae	*Acentrella*	SCR/CG		✓	✓	✓	✓	✓	✓	✓	✓
		Baetis	SCR/CG	✓			✓					
		Camelobaetidius	SCR/CG	✓					✓			✓
		Fallceon	SCR/CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Procloeon	CG						✓			
		Pseudocloeon	SCR/CG			✓		✓				✓
	Caenidae	*Caenis*	SCR/CG	✓			✓	✓	✓			
	Heptageniidae	*Maccaffertium*	SCR/CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Leptophlebiidae	*Neochoroterpes*	CG/SCR	✓		✓	✓	✓	✓		✓	
		Thraulodes	CG/SCR	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Traverella	FC	✓							✓	
	Oligoneuriidae	*Isonychia*	FC	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Tricorythidae	*Tricorythodes*	CG	✓	✓	✓	✓	✓	✓	✓	✓	✓

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Order	Family	Genus	Trophic Guild	1	2	3	4	5	6	7	8	9
Hemiptera	Gerridae	*Metrobates*	P	✓								
	Naucoridae	*Limnocoris*	P	✓			✓					✓
Hirudinea			P						✓			
Lepidoptera	Pyralidae	*Petrophila*	SCR									✓
Megaloptera	Corydalidae	*Corydalus*	P	✓	✓	✓	✓	✓	✓	✓	✓	
Odonata	Calopterygidae	*Hetaerina*	P	✓	✓		✓		✓	✓	✓	
	Coenagrionidae	*Argia*	P	✓	✓	✓	✓	✓	✓	✓	✓	
	Gomphidae	*Dromogomphus*	P	✓		✓		✓	✓		✓	✓
		Erpetogomphus	P	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Stylurus	P	✓								✓
	Libellulidae	*Brechmorhoga*	P				✓					
	Macromiidae	*Macromia*	P				✓					
Oligochaeta			CG	✓	✓	✓	✓	✓	✓	✓	✓	✓
Planariidae	Dugesiidae	*Dugesia*	P									✓
Plecoptera	Perlidae	*Neoperla*	P	✓	✓	✓	✓	✓	✓	✓	✓	✓
Trichoptera	Glossosomatidae	*Protoptila*	SCR						✓	✓	✓	✓
	Helicopsychidae	*Helicopsyche*	SCR	✓				✓	✓			✓
	Hydropsychidae	*Cheumatopsyche*	FC	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Hydropsyche	FC		✓	✓	✓	✓	✓	✓	✓	✓
		Smicridea	FC		✓	✓	✓	✓	✓	✓	✓	✓
	Hydroptilidae	*Hydroptila*	SCR	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Stactobiella	SHR		✓	✓	✓	✓	✓	✓	✓	✓
	Leptoceridae	*Nectopsyche*	SHR/CG/P	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Oecetis	P/SHR		✓	✓	✓	✓	✓	✓	✓	✓

APPENDIX C

List of indicators of hydrological alterations parameters (IHA) used for assessing their relationship to macroinvertebrate taxa abundance in the Blanco and the Colorado Rivers. The hydrologic values were constrained to the sampling period (October 2015 - April 2016), but trends were extracted from a 30-year period.

Qualifier	Hydrologic parameter	Explanation	Number of Variables
Duration	Total duration	Number of days of the flow type prior to sampling date	8
	Cumulative duration	Total number of days the flow event occurred. This was regardless of the 15- or 30- day study period window.	8
Magnitude	Total duration peak discharge	Peak discharge recorded in the described flow event. This was from the 15- or 30- day study period window.	6
	Cumulative duration peak discharge	Peak discharge recorded in the described flow event. This was regardless of the 15- or 30- day study period window.	6
	Total duration average discharge	Average discharge recorded in the described flow period. This was from the 15- or 30- day study period window.	8
	Cumulative duration average discharge	Average discharge recorded in the described flow period. This was regardless of the 15- or 30- day study period window.	8
Frequency	Number of pulses	Number of flow pulses detected	6
Rate Change	Duration of recession	Number of days in the receding limb of hydrograph	1
	Duration of rise	Number of days in the rising limb of hydrograph	1
	Magnitude of recession	Maximum difference in discharge in the receding limb of hydrograph	1
	Magnitude of rise	Maximum difference in discharge in the rising limb of hydrograph	1
	Rate of recession median	Number of days in the receding limb of hydrograph over time	1
	Rate of rise median	Median of Number of days in the rising limb of hydrograph over time	1
	Number of flow reversals	Number of rise/recession switch overs in 30-day window	1

APPENDIX D

Full list of IHA hydrologic parameters (along with the abbreviations used throughout the text body) used for assessing their relationship to macroinvertebrate taxa abundance in the Blanco and the Colorado Rivers. Listed are the number times each hydrologic parameter was selected by the stepwise regression for each waterbody, and which ones showed positive or negative relationships to macroinvertebrate taxa.

No.	Flow Conditions	Qualifier	Days	Hydrologic parameter	Abbreviation	No. of times selected	Blanco River	Colorado River	Positive relationships	Negative relationships
1	Base Flow	Duration	15	Total duration	BF15TD	2	0	2	1	-1
2		Duration	15	Cumulative duration	BF15CD	6	0	6	6	0
3		Magnitude	15	Total duration average discharge	BF15TDAD	2	0	2	0	-2
4		Magnitude	15	Cumulative duration average discharge	BF15CDAD	1	0	1	0	-1
5		Duration	30	Total duration	BF30TD	3	0	3	1	-2
6		Duration	30	Cumulative duration	BF30CD	3	0	3	3	0
7		Magnitude	30	Total duration average discharge	BF30TDAD	3	0	3	1	-2
8		Magnitude	30	Cumulative duration average discharge	BF30CDAD	2	0	2	1	-1
9	High Flow Pulse	Duration	15	Total duration	HFP15TD	0	0	0	0	0
10		Duration	15	Cumulative duration	HFP15CD	0	0	0	0	0
11		Magnitude	15	Total duration peak discharge	HFP15TDPD	0	0	0	0	0
12		Magnitude	15	Cumulative duration peak discharge	HFP15CDPD	0	0	0	0	0
13		Magnitude	15	Total duration average discharge	HFP15TDAD	1	0	1	0	-1
14		Magnitude	15	Cumulative duration average discharge	HFP15CDAD	0	0	0	0	0
15		Frequency	15	Number of pulses	HFP15NOP	1	0	1	0	-1
16		Duration	30	Total duration	HFP30TD	0	0	0	0	0
17		Duration	30	Cumulative duration	HFP30CD	0	0	0	0	0
18		Magnitude	30	Total duration peak discharge	HFP30TDPD	1	0	1	0	-1
19		Magnitude	30	Cumulative duration peak discharge	HFP30CDPD	2	0	2	2	0
20		Magnitude	30	Total duration average discharge	HFP30TDAD	3	0	3	0	-3
21		Magnitude	30	Cumulative duration average discharge	HFP30CDAD	0	0	0	0	0
22		Frequency	30	Number of pulses	HFP30NOP	1	0	1	0	-1
23	Small Flood	Duration	15	Total duration	SFP15TD	0	0	0	0	0
24		Duration	15	Cumulative duration	SFP15CD	1	1	0	1	0
25		Magnitude	15	Total duration peak discharge	SFP15TDPD	1	1	0	0	-1
26		Duration	15	Cumulative duration peak discharge	SFP15CDPD	0	0	0	0	0
27		Magnitude	15	Total duration average discharge	SFP15TDAD	0	0	0	0	0

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No.	Flow Conditions	Qualifier	Days	Hydrologic parameter	Abbreviation	No. of times selected	Blanco River	Colorado River	Positive relationship	Negative relationship
28	Small Flood	Magnitude	15	Cumulative duration average discharge	SFP15CDAD	1	1	0	1	0
29		Frequency	15	Number of pulses	SFP15NOP	0	0	0	0	0
30		Duration	30	Total duration	SFP30TD	1	0	1	0	-1
31		Duration	30	Cumulative duration	SFP30CD	2	2	0	1	-1
32		Magnitude	30	Total duration peak discharge	SFP30TDPD	3	3	0	1	-2
33		Duration	30	Cumulative duration peak discharge	SFP30CDPD	0	0	0	0	0
34		Magnitude	30	Total duration average discharge	SFP30TDAD	1	1	0	0	-1
35		Magnitude	30	Cumulative duration average discharge	SFP30CDAD	1	1	0	1	0
36		Frequency	30	Number of pulses	SFP30NOP	2	1	1	2	0
37	Large Flood	Duration	15	Total duration	LFP15TD	0	0	0	0	0
38		Duration	15	Cumulative duration	LFP15CD	0	0	0	0	0
39		Magnitude	15	Total duration peak discharge	LFP15TDPD	0	0	0	0	0
40		Magnitude	15	Cumulative duration peak discharge	LFP15CDPD	0	0	0	0	0
41		Magnitude	15	Total duration average discharge	LFP15TDAD	0	0	0	0	0
42		Magnitude	15	Cumulative duration average discharge	LFP15CDAD	0	0	0	0	0
43		Frequency	15	Number of pulses	LFP15NOP	0	0	0	0	0
44		Duration	30	Total duration	LFP30TD	0	0	0	0	0
45		Duration	30	Cumulative duration	LFP30CD	0	0	0	0	0
46		Magnitude	30	Total duration peak discharge	LFP30TDPD	1	0	1	0	-1
47		Magnitude	30	Cumulative duration peak discharge	LFP30CDPD	0	0	0	0	0
48		Magnitude	30	Total duration average discharge	LFP30TDAD	0	0	0	0	0
49		Magnitude	30	Cumulative duration average discharge	LFP30CDAD	0	0	0	0	0
50		Frequency	30	Number of pulses	LFP30NOP	1	0	1	0	-1
51	Rate of change		30	Duration	RC30Dre	4	1	3	3	-1
52			30	Duration of rise	RC30DRi	1	0	1	1	0
53			30	Magnitude of recession	RC30MRe	3	1	2	1	-2
54			30	Magnitude of rise	RC30MRi	7	4	3	3	-4
55			30	Rate of recession median	RC30RReMd	8	2	6	3	-5
56			30	Rate of rise median	RC30RRiMd	3	3	0	0	-3
57			30	Number of flow reversals	RC30NFR	6	1	5	5	-1

APPENDIX E

Appendix E1: Stepwise regression models of hydrologic parameters selected for *Stenelmis* (Family: Elmidae) in the Blanco River; significant models are denoted with bold font.

Flow	Model	Number	RSquare	RMSE	AICc
Base flow	BF30TD	1	0.0038	6.0133	351.435
	BF30TDAD,BF30CD	2	0.0041	6.0709	353.754
High flow pulse	HFP15NOP	1	0.0034	6.0144	351.456
	HFP15CDAD,HFP30TDPD	2	0.0041	6.0709	353.754
	HFP15TD,HFP15CD,HFP30NOP	3	0.0041	6.1313	356.188
Small flood	SFP30TDPD	1	0.0149	5.9798	350.833
	SFP15TDPD,SFP30TD	2	0.0221	6.016	352.773
	SFP15TDPD,SFP15TDAD,SFP15CDAD	3	0.0299	6.0516	354.773
	SFP15TDPD,SFP15CD,SFP15CDPD,SFP30TDPD	4	0.0642	6.004	355.367
	SFP15TDPD,SFP15TDAD,SFP30NOP,SFP30TDAD,SFP30C	5	0.0684	6.0525	357.771
Rate of change	RC30NFR	1	0.012	5.9885	350.989
	RC30DRe,RC30NFR	2	0.0299	5.992	352.341
	RC30DRe,RC30MRi,RC30NFR	3	0.0448	6.005	353.939
	RC30DRi,RC30DRe,RC30MRi,RC30NFR	4	0.0528	6.0405	356.022
	RC30DRi,RC30DRe,RC30MRi,RC30MRe,RC30NFR	5	0.0609	6.077	358.206

Appendix E2: Stepwise regression models of hydrologic parameters selected for *Stenelmis* (Family: Elmidae) in the Colorado River; significant models are denoted with bold font.

Flow	Model	Num.	RSquare	RMSE	AICc
Base flow	**BF15TD,BF15TDAD,BF30TD,BF30CD**	**4**	**0.3307**	**47.474**	**578.68**
	BF15TD,BF15TDAD,BF30TD,BF30CD,BF30CDAD	5	0.35	47.270	579.75
	BF15TD,BF30TD,BF30CD	3	0.2768	48.851	580.32
	BF15TD,BF30CD	2	0.242	49.522	580.43
	BF30CD	**1**	**0.1923**	**50.625**	**581.52**
	BF15TD,BF15TDAD,BF15CD,BF30TD,BF30CD,BF30CDAD	6	0.3593	47.427	581.74
High flow pulse	**HFP15NOP**	**1**	**0.1056**	**53.274**	**587.03**
	HFP15NOP,HFP30TDAD	2	0.1286	53.098	587.96
	HFP15TDAD,HFP15CDAD,HFP30TDAD,HFP30CDAD	4	0.1887	52.268	589.07
	HFP15TDAD,HFP30TDAD,HFP30CDAD	3	0.1488	53.001	589.13
	HFP15NOP,HFP15TD,HFP15CD,HFP30TDAD,HFP30CDAD	5	0.2049	52.280	590.63
	HFP15TDPD,HFP15TDAD,HFP15CDPD,HFP15CDAD,HFP30TDAD,HFP30CDAD	6	0.2067	52.7745	593.2792
Small flood	SFP30NOP	1	0.0602	54.609	589.71
	SFP30CD	1	0.0602	54.609	589.71
	SFP15TDPD,SFP30NOP	2	0.0649	55.005	591.77
	SFP15TDPD,SFP30CD	2	0.0649	55.005	591.77
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.0649	55.552	594.20
Large flood	LFP15TDPD,LFP30TDAD	2	0.0898	54.267	590.31
	LFP15TDPD,LFP30CDAD	2	0.0898	54.267	590.31
	LFP15TD	1	0.0256	55.604	591.66
	LFP15TD,LFP15CD,LFP30NOP	3	0.09	54.800	592.74
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30TD	4	0.09	55.357	595.27
Rate of change	RC30MRi	1	0.0184	55.809	592.05
	RC30DRe,RC30NFR	2	0.0375	55.804	593.33
	RC30DRi,RC30MRe,RC30RRiMd	3	0.069	55.430	593.97
	RC30MRi,RC30MRe,RC30RRiMd,RC30NFR	4	0.0969	55.146	594.86
	RC30DRe,RC30MRi,RC30MRe,RC30RRiMd,RC30NFR	5	0.1133	55.209	596.52

Appendix E3: Stepwise regression models of hydrologic parameters selected for *Loutrochus* (Family: Lutrochidae) in the Blanco River; this taxa was not collected in the Colorado River.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30TD	1	0.0189	5.0116	331.7569
	BF30TDAD,BF30CD	2	0.019	5.0604	334.0907
High flow pulse	HFP15NOP	1	0.0099	5.0345	332.2483
	HFP30NOP	1	0.0099	5.0345	332.2483
	HFP15CDAD,HFP30TDPD	2	0.019	5.0604	334.0907
	HFP15TD,HFP15CD,HFP30NOP	3	0.019	5.1107	336.5244
Small flood	SFP30CDPD	1	0.0186	5.0124	331.7742
	SFP30NOP,SFP30TD	2	0.0198	5.0582	334.0442
	SFP30TD,SFP30TDPD,SFP30TDAD	3	0.0477	5.0353	334.9193
	SFP15TDAD,SFP30TD,SFP30TDAD,SFP30CD	4	0.0521	5.0745	337.2027
Rate of change	RC30RRiMd	1	0.0082	5.0388	332.3418
	RC30RRiMd,RC30RReMd	2	0.0679	4.9325	331.3264
	RC30MRi,RC30RRiMd,RC30RReMd	3	0.0862	4.9325	332.6913
	RC30DRi,RC30MRi,RC30RRiMd,RC30RReMd	4	0.0901	4.9719	334.9964

Appendix E4: Stepwise regression models of hydrologic parameters selected for Chironomidae in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30CDAD	1	0.0238	36.3778	545.8348
	BF30TDAD,BF30CD	2	0.0285	36.6449	547.9128
High flow pulse	HFP15CDPD	1	0.0279	36.3023	545.6107
	HFP30CDPD	1	0.0279	36.3023	545.6107
	HFP15CDAD,HFP30TDPD	2	0.0285	36.6449	547.9128
	HFP15TD,HFP15CD,HFP30NOP	3	0.0285	37.0095	550.3464
Small flood	**SFP15CD**	**1**	**0.0721**	**35.4672**	**543.0971**
	SFP15TDAD,SFP15CDAD	2	0.1201	34.8731	542.5605
	SFP15TDPD,SFP15CD,SFP15CDPD	3	0.1253	35.117	544.6775
	SFP15TDPD,SFP30TD,SFP30CD,SFP30CDAD	4	0.1307	35.3639	546.8805
Rate of change	RC30RRiMd	1	0.0302	36.2592	545.4823
	RC30MRe,RC30RReMd	2	0.0502	36.2325	546.6906
	RC30DRe,RC30RReMd,RC30NFR	3	0.1146	35.3316	545.3354
	RC30DRi,RC30DRe,RC30RReMd,RC30NFR	4	0.1285	35.409	547.0181

Appendix E5: Stepwise regression models of hydrologic parameters selected for Chironomidae in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	**BF30TDAD**	**1**	**0.3169**	**87.6566**	**640.8175**
	BF15CD,BF15CDAD	2	0.3302	87.649	642.0959
	BF15CD,BF30CD,BF30CDAD	3	0.3583	86.6432	642.2137
	BF15TD,BF15CD,BF30CD,BF30CDAD	4	0.3606	87.3663	644.5576
High flow pulse	**HFP30TDPD**	**1**	**0.1241**	**99.2585**	**654.242**
	HFP15TDPD,HFP30TDPD	2	0.137	99.488	655.7792
	HFP15NOP,HFP15CDAD,HFP30TD	3	0.1608	99.0794	656.699
	HFP15NOP,HFP15TDPD,HFP30TD,HFP30CD	4	0.1781	99.049	658.1121
Small flood	SFP30NOP	1	0.0344	104.2176	659.5074
	SFP30CD	1	0.0344	104.2176	659.5074
	SFP15TDPD,SFP30NOP	2	0.0349	105.2085	661.8171
	SFP15TDPD,SFP30CD	2	0.0349	105.2085	661.8171
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.0349	106.2553	664.2507
Large flood	LFP30NOP	1	0.0568	103.0018	658.24
	LFP15TDAD,LFP30NOP	2	0.0569	104.0006	660.57
	LFP15TDAD,LFP30NOP,LFP30TD	3	0.0569	105.0353	663.0035
	LFP15TDAD,LFP30NOP,LFP30TDPD	3	0.0569	105.0353	663.0035
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30TD	4	0.0569	106.1017	665.5407
Rate of change	**RC30DRi,RC30DRe,RC30RReMd**	**3**	**0.4674**	**78.9319**	**632.1466**
	RC30DRi,RC30DRe,RC30RRiMd,RC30RReMd	4	0.474	79.2407	634.0147
	RC30DRi,RC30DRe,RC30MRe,RC30RRiMd,RC30RReMd	5	0.4909	78.7678	634.9023
	RC30DRi,RC30RReMd	2	0.3821	84.1846	637.7405
	RC30RReMd	1	0.2786	90.0834	643.7669

Appendix E6: Stepwise regression models of hydrologic parameters selected for Simuliidae in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30CD	1	0.0106	35.559	543.3762
	BF15TD,BF30TD	2	0.0106	35.9059	545.7125
	BF15TD,BF30TDAD	2	0.0106	35.9059	545.7125
	BF15TD,BF30CD	2	0.0106	35.9059	545.7125
High flow pulse	HFP15NOP	1	0.0106	35.5601	543.3796
	HFP30NOP	1	0.0106	35.5601	543.3796
	HFP15CDAD,HFP30TDPD	2	0.0106	35.9059	545.7125
	HFP15TD,HFP15CD,HFP30NOP	3	0.0106	36.2632	548.1462
Small flood	SFP30TD	1	0.0183	35.4203	542.9542
	SFP15TDAD,SFP15CDAD	2	0.0432	35.3104	543.9064
	SFP15TDAD,SFP15CDAD,SFP30TDPD	3	0.0923	34.7348	543.4955
	SFP15TDPD,SFP15TDAD,SFP15CDAD,SFP30TDPD	4	0.1386	34.1805	543.2044
Rate of change	RC30MRe	1	0.0296	35.2162	542.33
	RC30MRe,RC30NFR	2	0.0533	35.1231	543.3318
	RC30DRe,RC30MRe,RC30RReMd	3	0.0968	34.6477	543.2246
	RC30DRe,RC30MRi,RC30MRe,RC30RReMd	4	0.1357	34.2376	543.3849

Appendix E7: Stepwise regression models of hydrologic parameters selected for Simuliidae in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	**BF30CDAD**	**1**	**0.1203**	**171.2311**	**713.1329**
	BF15CDAD,BF30TDAD	2	0.1519	169.7635	713.491
	BF15CDAD,BF30TDAD,BF30CDAD	3	0.176	169.0042	714.3712
	BF15TDAD,BF15CDAD,BF30TDAD,BF30CDAD	4	0.2002	168.1946	715.2989
	BF15TDAD,BF15CD,BF15CDAD,BF30TDAD,BF30CDAD	5	0.2078	169.1313	717.4328
High flow pulse	HFP30NOP	1	0.0525	177.7063	717.1417
	HFP15TDAD,HFP30NOP	2	0.0582	178.9017	719.1535
	HFP15TDPD,HFP15CD,HFP30NOP	3	0.0645	180.0749	721.2237
	HFP30NOP,HFP30TD,HFP30TDPD,HFP30CDAD	4	0.0731	181.0634	723.2612
	HFP15TD,HFP15TDAD,HFP30NOP,HFP30TDPD,HFP30CDAD	5	0.0919	181.0764	724.8031
Small flood	SFP30NOP	1	0.0281	179.9787	718.5139
	SFP30CD	1	0.0281	179.9787	718.5139
	SFP15NOP,SFP30TD	2	0.0283	181.7173	720.84
	SFP15CD,SFP30TD	2	0.0283	181.7173	720.84
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.0283	183.5254	723.2736
Large flood	LFP15CD	1	0.0266	180.1231	718.6005
	LFP15NOP,LFP30TDAD	2	0.0349	181.1035	720.4745
	LFP15NOP,LFP30CDAD	2	0.0349	181.1035	720.4745
	LFP15TDAD,LFP15CD,LFP30CD	3	0.0349	182.9002	722.905
Rate of change	RC30RRiMd	1	0.0631	176.7081	716.5333
	RC30DRi,RC30RRiMd	2	0.0719	177.5935	718.3608
	RC30DRi,RC30MRe,RC30RRiMd	3	0.0903	177.5741	719.7134
	RC30DRi,RC30MRi,RC30MRe,RC30RRiMd	4	0.1013	178.2909	721.5947
	RC30DRi,RC30MRi,RC30MRe,RC30RRiMd,RC30RReMd	5	0.1056	179.7073	723.9835

Appendix E8: Stepwise regression models of hydrologic parameters selected for Tabanidae in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30CDAD	1	0.0015	5.144	334.5739
	BF15TD,BF30TD	2	0.0015	5.1942	336.9102
	BF15TD,BF30TDAD	2	0.0015	5.1942	336.9102
	BF15TD,BF30CD	2	0.0015	5.1942	336.9102
High flow pulse	HFP15NOP	1	0.0015	5.144	334.5738
	HFP30NOP	1	0.0015	5.144	334.5738
	HFP15NOP,HFP15TD	2	0.0015	5.1942	336.9102
	HFP15NOP,HFP15TDPD	2	0.0015	5.1942	336.9102
	HFP15TD,HFP15CD,HFP30NOP	3	0.0015	5.2459	339.3438
	HFP15TD,HFP15CD,HFP30TDAD	3	0.0015	5.2459	339.3438
Small flood	SFP30TDPD	1	0.0067	5.1306	334.2923
	SFP15TDPD,SFP15CDAD	2	0.0191	5.1485	335.9543
	SFP15TDPD,SFP15TDAD,SFP15CD	3	0.0385	5.148	337.3087
	SFP15TDPD,SFP15TDAD,SFP15CD,SFP15CDAD	4	0.0435	5.1865	339.5599
Rate of change	RC30NFR	1	0.0181	5.1011	333.6687
	RC30DRi,RC30NFR	2	0.0359	5.104	335.0182
	RC30DRi,RC30DRe,RC30NFR	3	0.0374	5.1509	337.3705
	RC30DRi,RC30DRe,RC30RRiMd,RC30NFR	4	0.0414	5.1924	339.6833

Appendix E9: Stepwise regression models of hydrologic parameters selected for Tipulidae in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF15TD	1	0.026	12.9876	434.5989
	BF15TDAD	1	0.026	12.9876	434.5989
	BF15CD	1	0.026	12.9876	434.5989
	BF15CDAD	1	0.026	12.9876	434.5989
	BF30TDAD,BF30CD	2	0.0347	13.0558	436.4522
High flow pulse	HFP15CD	1	0.0115	13.0842	435.3992
	HFP15CDAD,HFP30TDPD	2	0.0347	13.0558	436.4522
	HFP15TD,HFP15CD,HFP30NOP	3	0.0347	13.1857	438.8859
Small flood	SFP30CD	1	0.0644	12.7287	432.4242
	SFP30TD,SFP30CD	2	0.0682	12.8273	434.5452
	SFP30TDPD,SFP30CD,SFP30CDAD	3	0.0734	12.9185	436.675
	SFP15NOP,SFP15CDAD,SFP30TDPD,SFP30CD	4	0.0736	13.0482	439.1997
Rate of change	RC30DRe	1	0.0405	12.8904	433.7875
	RC30DRi,RC30RReMd	2	0.0626	12.8655	434.8667
	RC30MRi,RC30MRe,RC30RReMd	3	0.0711	12.9342	436.806
	RC30DRi,RC30MRi,RC30MRe,RC30RReMd	4	0.0747	13.0402	439.1341

Appendix E10: Stepwise regression models of hydrologic parameters selected for *Fallceon* (Family: Baetidae) in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30CDAD	1	0.0163	12.2925	428.658
	BF30TDAD,BF30CD	2	0.0173	12.4061	430.9396
High flow pulse	HFP15CDPD	1	0.0173	12.2863	428.604
	HFP30CDPD	1	0.0173	12.2863	428.604
	HFP15TDPD,HFP15TDAD	2	0.0173	12.4061	430.9396
	HFP15TDPD,HFP15CD	2	0.0173	12.4061	430.9396
	HFP15TD,HFP15CD,HFP30NOP	3	0.0173	12.5296	433.3733
Small flood	SFP15TDPD	1	0.052	12.0672	426.6605
	SFP15NOP,SFP15TDPD	2	0.0753	12.034	427.6507
	SFP15TD,SFP15TDPD	2	0.0753	12.034	427.6507
	SFP15NOP,SFP15TDPD,SFP30TDPD	3	0.0777	12.1382	429.9458
	SFP15NOP,SFP15TDPD,SFP30TDPD,SFP30TDAD	4	0.079	12.2526	432.4058
Rate of change	RC30MRi	1	0.0539	12.055	426.5512
	RC30MRi,RC30NFR	2	0.059	12.1402	428.5997
	RC30DRe,RC30MRi,RC30NFR	3	0.0688	12.1969	430.4668
	RC30DRe,RC30MRi,RC30MRe,RC30NFR	4	0.0693	12.3174	432.9749

Appendix E11: Stepwise regression models of hydrologic parameters selected for *Fallceon* (Family: Baetidae) in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	**BF15CD**	**1**	**0.0877**	**13.2927**	**437.1067**
	BF15CD,BF30TD	2	0.1086	13.268	438.1938
	BF15CD,BF30TD,BF30CD	3	0.1247	13.2785	439.6429
	BF15TD,BF15CD,BF30TD,BF30CD	4	0.1327	13.3516	441.6824
	BF15TD,BF15CD,BF30TD,BF30CD,BF30CDAD	5	0.1346	13.4755	444.2138
High flow pulse	HFP30NOP	1	0.0317	13.6945	440.323
	HFP30CD,HFP30CDPD	2	0.035	13.8047	442.4764
	HFP15TDPD,HFP15CDAD,HFP30NOP	3	0.0376	13.9232	444.7638
	HFP30NOP,HFP30TD,HFP30CD,HFP30CDAD	4	0.0444	14.0146	446.9168
Small flood	SFP30NOP	1	0.0042	13.8878	441.8367
	SFP30CD	1	0.0042	13.8878	441.8367
	SFP15TDAD,SFP30TDAD	2	0.0143	13.9521	443.6229
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.0143	14.0904	446.0528
Large flood	LFP15TD	1	0.0118	13.8345	441.4215
	LFP15TDPD,LFP30TDAD	2	0.0346	13.8074	442.497
	LFP15TDPD,LFP30CDAD	2	0.0346	13.8074	442.497
	LFP15TD,LFP15TDPD,LFP30TDAD	3	0.035	13.9421	444.9103
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30TD	4	0.035	14.0836	447.4473
Rate of change	RC30DRe	1	0.0094	13.8515	441.5542
	RC30RRiMd,RC30RReMd	2	0.0259	13.8696	442.9824
	RC30DRe,RC30RRiMd,RC30RReMd	3	0.041	13.8983	444.5705
	RC30DRi,RC30DRe,RC30RRiMd,RC30RReMd	4	0.0441	14.0169	446.9346

Appendix E12: Stepwise regression models of hydrologic parameters selected for *Isonychia* (Family: Isonychiidae) in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30TD	1	0.0123	7.8705	380.5046
	BF30TDAD,BF30CD	2	0.0123	7.9473	382.8407
High flow pulse	HFP15NOP	1	0.0073	7.8904	380.7775
	HFP30NOP	1	0.0073	7.8904	380.7775
	HFP15CDAD,HFP30TDPD	2	0.0123	7.9473	382.8407
	HFP15TD,HFP15CD,HFP30NOP	3	0.0123	8.0264	385.2744
	HFP15TD,HFP15CD,HFP30TDAD	3	0.0123	8.0264	385.2744
Small flood	SFP30CDPD	1	0.0118	7.8726	380.5328
	SFP15TDAD,SFP30NOP	2	0.0145	7.9382	382.7175
	SFP15TDPD,SFP30TDAD,SFP30CDAD	3	0.0166	8.0089	385.0387
	SFP15TDPD,SFP30TDAD,SFP30CDPD,SFP30CDAD	4	0.0171	8.0882	387.5491
Rate of change	RC30MRe	1	0.0095	7.8814	380.6543
	RC30DRi,RC30MRe	2	0.0123	7.9473	382.8406
	RC30DRi,RC30MRi,RC30MRe	3	0.0143	8.0181	385.1629
	RC30DRi,RC30DRe,RC30MRi,RC30MRe	4	0.0148	8.0975	387.6734
	RC30DRi,RC30DRe,RC30MRi,RC30MRe,RC30NFR	5	0.0167	8.1736	390.2186

Appendix E13: Stepwise regression models of hydrologic parameters selected for *Isonychia* (Family: Isonychiidae) in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	**BF15CD**	1	0.2139	31.8028	531.3193
	BF15CD,BF30TD	2	0.2307	31.7675	532.4871
	BF15TD,BF15CD,BF30TD	3	0.2423	31.8425	534.1061
	BF15TD,BF15CD,BF30TD,BF30CD	4	0.2466	32.0733	536.3322
High flow pulse	HFP30NOP	1	0.066	34.6665	540.6311
	HFP30NOP,HFP30TDAD	2	0.0761	34.8145	542.3787
	HFP30NOP,HFP30TD,HFP30CD	3	0.0855	34.9815	544.2601
	HFP15TD,HFP30NOP,HFP30TD,HFP30CD	4	0.0876	35.2952	546.6705
	HFP30NOP,HFP30TDPD,HFP30TDAD,HFP30CDPD,HFP30CDAD	5	0.0919	35.577	549.0635
Small flood	SFP30NOP	1	0.0121	35.6519	543.6579
	SFP30CD	1	0.0121	35.6519	543.6579
	SFP15NOP,SFP30NOP	2	0.0126	35.9906	545.967
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.0127	36.3476	548.3974
Large flood	LFP15TDPD	1	0.0121	35.6522	543.6589
	LFP15TDAD,LFP30TDAD	2	0.0164	35.9217	545.76
	LFP15TDAD,LFP30NOP,LFP30TD	3	0.0165	36.2781	548.1906
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30TD	4	0.0165	36.6464	550.7278
Rate of change	RC30DRe	1	0.0312	35.3054	542.6033
	RC30DRe,RC30RRiMd	2	0.0507	35.2898	543.8432
	RC30DRe,RC30RRiMd,RC30RReMd	3	0.0602	35.4613	545.7311
	RC30DRe,RC30MRi,RC30RRiMd,RC30RReMd	4	0.0648	35.7347	548.007
	RC30DRe,RC30MRi,RC30RRiMd,RC30RReMd,RC30NFR	5	0.0694	36.0166	550.3896

Appendix E14: Stepwise regression models of hydrologic parameters selected for *Thraulodes* (Family: Leptophlebiidae) in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF15TD	1	0.0084	45.0975	569.0408
	BF15TDAD	1	0.0084	45.0975	569.0408
	BF15CD	1	0.0084	45.0975	569.0408
	BF15CDAD	1	0.0084	45.0975	569.0408
	BF30TDAD,BF30CD	2	0.011	45.4779	571.2355
High flow pulse	HFP15CD	1	0.0035	45.2102	569.3102
	HFP30TD	1	0.0035	45.2102	569.3102
	HFP30CD	1	0.0035	45.2102	569.3102
	HFP15CDAD,HFP30TDPD	2	0.011	45.4779	571.2355
	HFP15TD,HFP15CD,HFP30NOP	3	0.011	45.9304	573.6692
	HFP15TD,HFP15CD,HFP30TDAD	3	0.011	45.9304	573.6692
Small flood	SFP30CD	1	0.0143	44.9637	568.7197
	SFP15TDPD,SFP15TDAD	2	0.0219	45.2262	570.6363
	SFP15TDPD,SFP30TDPD,SFP30TDAD	3	0.036	45.3476	572.2901
	SFP15TDPD,SFP15TDAD,SFP30TDPD,SFP30TDAD	4	0.0381	45.7579	574.7091
Rate of change	RC30MRi	1	0.0215	44.7982	568.3215
	RC30DRi,RC30MRe	2	0.0316	45.0017	570.0987
	RC30DRi,RC30DRe,RC30MRe	3	0.0442	45.1529	571.8255
	RC30DRi,RC30DRe,RC30MRe,RC30RRiMd	4	0.045	45.5927	574.3186

Appendix E15: Stepwise regression models of hydrologic parameters selected for *Thraulodes* (Family: Leptophlebiidae) in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	**BF15CD**	**1**	**0.3109**	**38.728**	**552.597**
	BF15TD,BF15CD,BF30TD	3	0.361	38.031	553.288
	BF15TD,BF15CD,BF30TD,BF30TDAD	4	0.3838	37.729	553.872
	BF15CD,BF30TD	2	0.3224	38.779	554.028
	BF15TD,BF15TDAD,BF15CD,BF30TD,BF30CD	5	0.4059	37.428	554.543
High flow pulse	**HFP30TDAD**	**1**	**0.1196**	**43.776**	**565.828**
	HFP15NOP,HFP30TDAD	2	0.1462	43.530	566.509
	HFP15NOP,HFP30TDAD,HFP30CDAD	3	0.1516	43.824	568.599
	HFP15TDAD,HFP15CDAD,HFP30TDAD,HFP30CDAD	4	0.1753	43.645	569.604
Small flood	SFP30NOP	1	0.0605	45.221	569.336
	SFP30CD	1	0.0605	45.221	569.336
	SFP15TDAD,SFP30NOP	2	0.0607	45.657	571.661
	SFP15TDAD,SFP30CD	2	0.0607	45.657	571.661
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.0607	46.111	574.095
Large flood	LFP15CD	1	0.0173	46.250	571.766
	LFP15CD,LFP30TDAD	2	0.0525	45.855	572.128
	LFP15TDPD,LFP15CDPD,LFP30CDAD	3	0.0532	46.296	574.526
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30TD	4	0.0532	46.766	577.063
Rate of change	RC30RRiMd	1	0.0428	45.644	570.342
	RC30MRe,RC30RRiMd	2	0.0596	45.684	571.725
	RC30DRi,RC30MRe,RC30RRiMd	3	0.076	45.735	573.208
	RC30MRi,RC30MRe,RC30RRiMd,RC30NFR	4	0.091	45.822	574.861

Appendix E16: Stepwise regression models of hydrologic parameters selected for *Maccaffertium* (Family: Heptageniidae) in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30CDAD	1	0.0166	6.7762	364.3357
	BF30TDAD,BF30CD	2	0.017	6.8409	366.6498
High flow pulse	HFP15TDPD	1	0.017	6.7748	364.3135
	HFP15NOP,HFP15TD	2	0.017	6.8409	366.6498
	HFP15NOP,HFP15TDPD	2	0.017	6.8409	366.6498
	HFP15TD,HFP15CD,HFP30NOP	3	0.017	6.9089	369.0835
	HFP15TD,HFP15CD,HFP30TDAD	3	0.017	6.9089	369.0835
Small flood	SFP15TDPD,SFP30TD,SFP30TDPD	3	0.1312	6.4953	362.4156
	SFP30TD	1	0.0364	6.7074	363.2346
	SFP15TDPD,SFP15CDAD	2	0.1306	6.4332	360.0149
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.1496	6.426	361.2581
	SFP15TDPD,SFP15TDAD,SFP15CDAD,SFP30TDPD	4	0.1526	6.4799	363.6066
Rate of change	**RC30MRi,RC30RRiMd**	**2**	**0.1092**	**6.5122**	**361.3325**
	RC30MRi	1	0.0429	6.685	362.8728
	RC30DRe,RC30RRiMd,RC30NFR	3	0.1329	6.4887	362.3066
	RC30DRe,RC30MRi,RC30RRiMd,RC30NFR	4	0.1513	6.485	363.6903

Appendix E17: Stepwise regression models of hydrologic parameters selected for *Maccaffertium* (Family: Heptageniidae) in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	**BF15TD,BF15CD,BF15CDAD,BF30TD,BF30TDAD,BF30CDAD**	**6**	**0.3971**	**2.5628**	**266.585**
	BF15TD,BF15CD,BF15CDAD,BF30TD,BF30TDAD	5	0.3607	2.6114	266.987
	BF15CD,BF15CDAD,BF30TDAD,BF30CDAD	4	0.3283	2.6493	267.008
	BF15CD,BF15CDAD,BF30TDAD	3	0.2833	2.709	267.970
High flow pulse	**HFP30NOP**	1	0.019	3.108	280.156
	HFP15TD,HFP30NOP	2	0.0431	3.0994	281.144
	HFP15NOP,HFP15TD,HFP30TD	3	0.0489	3.1208	283.254
	HFP15CD,HFP15CDPD,HFP30TD,HFP30CDAD	4	0.0865	3.0895	283.609
	HFP15TDPD,HFP15CD,HFP30NOP,HFP30TDPD,HFP30TDAD	5	0.1028	3.0935	285.285
Small flood	SFP30TD,SFP30TDPD	2	0.0884	3.0252	278.527
	SFP30NOP	1	0.0297	3.091	279.563
	SFP30CD	1	0.0297	3.091	279.563
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.0889	3.0544	280.931
Large flood	**LFP30TDPD**	1	0.0897	2.9939	276.116
	LFP30CDPD	1	0.0897	2.9939	276.116
	LFP15NOP,LFP30NOP	2	0.0902	3.0222	278.422
	LFP15NOP,LFP15TD,LFP30NOP	3	0.0902	3.0523	280.856
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30CD	4	0.0902	3.0833	283.393
Rate of change	**RC30RReMd**	**1**	**0.1339**	**2.9202**	**273.426**
	RC30DRe,RC30RReMd	**2**	**0.1733**	**2.8809**	**273.249**
	RC30DRi,RC30DRe,RC30RReMd	3	0.1807	2.8965	275.198
	RC30DRi,RC30DRe,RC30MRe,RC30RReMd	4	0.1881	2.9126	277.243
	RC30DRi,RC30DRe,RC30MRi,RC30MRe,RC30RReMd	5	0.1905	2.9385	279.732

Appendix E18: Stepwise regression models of hydrologic parameters selected for *Tricorythodes* (Family: Leptohyphidae) in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Numb.	RSquare	RMSE	AICc
Base flow	BF30TD	1	0.0214	5.6436	344.584
	BF30TDAD,BF30CD	2	0.0219	5.697	346.8884
High flow pulse	HFP15NOP	1	0.016	5.6591	344.88
	HFP30NOP	1	0.016	5.6591	344.88
	HFP15CDAD,HFP30TDPD	2	0.0219	5.697	346.8884
	HFP15TD,HFP15CD,HFP30NOP	3	0.0219	5.7537	349.322
	HFP15TD,HFP15CD,HFP30TDAD	3	0.0219	5.7537	349.322
Small flood	**SFP15CDAD,SFP30TDAD**	**2**	**0.1776**	**5.224**	**337.5284**
	SFP30TDPD	1	0.0694	5.5034	341.8673
	SFP15TDAD,SFP15CDAD,SFP30TDPD	3	0.2555	5.0199	334.5888
	SFP15TDAD,SFP15CDAD,SFP30TDPD,SFP30TDAD	4	0.2628	5.0461	336.5963
	SFP15NOP,SFP15TDPD,SFP30TDAD,SFP30CD,SFP30CDAD	5	0.3663	4.7269	331.0726
	SFP15TD,SFP15TDPD,SFP30TDAD,SFP30CD,SFP30CDAD	5	0.3663	4.7269	331.0726
Rate of change	**RC30MRi,RC30RRiMd**	**2**	**0.2025**	**5.1444**	**335.8683**
	RC30RRiMd	1	0.0718	5.4963	341.7274
	RC30MRi,RC30MRe,RC30NFR	3	0.3126	4.8235	330.2769
	RC30MRi,RC30MRe,RC30RReMd,RC30NFR	4	0.3155	4.8621	332.5838
	RC30MRi,RC30MRe,RC30RRiMd,RC30RReMd,RC30NFR	5	0.3199	4.8968	334.8872

Appendix E19: Stepwise regression models of hydrologic parameters selected for *Tricorythodes* (Family: Leptohyphidae) in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	**BF15CD,BF30TD**	**2**	**0.5057**	**22.547**	**495.4601**
	BF15TDAD,BF15CD,BF15CDAD,BF30CDAD	4	0.5622	21.649	493.8813
	BF15TDAD,BF15CD,BF15CDAD,BF30CD,BF30CDAD	5	0.5777	21.4816	494.5769
	BF15TDAD,BF15CD,BF15CDAD	3	0.5201	22.4391	496.3065
	BF15CD	1	0.4519	23.5139	498.7075
High flow pulse	HFP30NOP	1	0.0527	30.9127	528.2534
	HFP30NOP,HFP30TDAD	2	0.0603	31.0894	530.1568
	HFP15NOP,HFP15TDPD,HFP30NOP	3	0.0675	31.2779	532.1739
	HFP15CDPD,HFP30NOP,HFP30TD,HFP30CD	4	0.0696	31.5595	534.5883
	HFP15TD,HFP15CD,HFP30NOP,HFP30TD,HFP30CD	5	0.0727	31.8332	537.0548
Small flood pulse	SFP30NOP	1	0.0198	31.4457	530.0998
	SFP15TD,SFP30CD	2	0.0199	31.7508	532.4302
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.0199	32.0663	534.8624
Large flood pulse	LFP30TDAD	1	0.0238	31.3809	529.877
	LFP15TD,LFP30TDAD	2	0.0238	31.6866	532.2116
	LFP15TDPD,LFP15CDAD,LFP30NOP	3	0.0238	32.0019	534.6452
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30TD	4	0.0238	32.3268	537.1825
Rate of Change	RC30RReMd	1	0.0423	31.0822	528.844
	RC30RReMd,RC30NFR	2	0.0648	31.014	529.8944
	RC30DRe,RC30RReMd,RC30NFR	3	0.0707	31.2241	531.988
	RC30DRi,RC30MRi,RC30RReMd,RC30NFR	4	0.0754	31.4612	534.2512

Appendix E20: Stepwise regression models of hydrologic parameters selected for *Caenis* (Family: Caenidae) in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30CDAD	1	0.0442	51.3422	583.0467
	BF30TDAD,BF30CD	2	0.0478	51.7461	585.1809
High flow pulse	HFP15CDPD	1	0.0478	51.2462	582.8447
	HFP30CDPD	1	0.0478	51.2462	582.8447
	HFP15TDAD,HFP30TDAD	2	0.0478	51.7461	585.1809
	HFP15CDAD,HFP30TDPD	2	0.0478	51.7461	585.1809
	HFP15TD,HFP15CD,HFP30NOP	3	0.0478	52.261	587.6146
Small flood	SFP30TD	1	0.0572	50.9926	582.309
	SFP15TDAD,SFP30TD	2	0.0588	51.4451	584.5508
	SFP15TDAD,SFP15CDAD,SFP30TD	3	0.0703	51.64	586.3235
	SFP15TDAD,SFP30NOP,SFP30TD,SFP30CDAD	4	0.074	52.0593	588.6432
Rate of change	RC30NFR	1	0.0387	51.4894	583.3559
	RC30RRiMd,RC30RReMd	2	0.0445	51.8347	585.3656
	RC30DRi,RC30RRiMd,RC30RReMd	3	0.0663	51.7494	586.5521
	RC30DRi,RC30RRiMd,RC30RReMd,RC30NFR	4	0.0681	52.2265	588.9895

Appendix E21: Stepwise regression models of hydrologic parameters selected for *Camelobaetidius* (Family: Baetidae) in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30CD	1	0.0134	24.1095	501.408
	BF30TDAD,BF30CD	2	0.0136	24.3416	503.731
High flow pulse	HFP15NOP	1	0.013	24.1138	501.428
	HFP30NOP	1	0.013	24.1138	501.428
	HFP15CDAD,HFP30TDPD	2	0.0136	24.3416	503.731
	HFP15TD,HFP15CD,HFP30NOP	3	0.0136	24.5838	506.164
Small flood	**SFP15TDPD**	**1**	**0.071**	**23.3942**	**498.155**
	SFP15NOP,SFP15TDPD	2	0.1355	22.7881	496.609
	SFP15TD,SFP15TDPD	2	0.1355	22.7881	496.609
	SFP15TDPD,SFP15TDAD,SFP15CD	3	0.1406	22.9471	498.724
	SFP30NOP,SFP30TDPD,SFP30TDAD,SFP30CDAD	4	0.1433	23.1441	501.093
Rate of change	**RC30MRi**	**1**	**0.1085**	**22.9176**	**495.933**
	RC30MRi,RC30RReMd	2	0.1181	23.016	497.683
	RC30DRe,RC30MRi,RC30RReMd	3	0.1226	23.1866	499.845
	RC30DRe,RC30MRi,RC30MRe,RC30RReMd	4	0.132	23.295	501.795

Appendix E22: Stepwise regression models of hydrologic parameters selected for *Neochoroterpes* (Family: Leptophlebiidae) in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30CDAD	1	0.0011	41.9348	561.187
	BF15TD,BF30TD	2	0.0012	42.3417	563.518
	BF15TD,BF30TDAD	2	0.0012	42.3417	563.518
High flow pulse	HFP15CDPD	1	0.0012	41.9326	561.182
	HFP30CDPD	1	0.0012	41.9326	561.182
	HFP15NOP,HFP15TD	2	0.0012	42.3417	563.518
	HFP15NOP,HFP15TDPD	2	0.0012	42.3417	563.518
	HFP15TD,HFP15CD,HFP30NOP	3	0.0012	42.763	565.952
	HFP15TD,HFP15CD,HFP30TDAD	3	0.0012	42.763	565.952
Small flood	SFP15CD	1	0.023	41.4722	559.989
	SFP15TDPD,SFP15TDAD	2	0.0488	41.3203	560.881
	SFP15TDPD,SFP15TDAD,SFP15CDAD	3	0.0574	41.5416	562.822
	SFP15NOP,SFP15TDPD,SFP15TDAD,SFP15CD	4	0.0594	41.9186	565.244
	SFP15TD,SFP15TDPD,SFP15TDAD,SFP15CD	4	0.0594	41.9186	565.244
	SFP15TDPD,SFP15TDAD,SFP15CD,SFP15CDPD	4	0.0594	41.9186	565.244
Rate of change	RC30MRi	1	0.0081	41.7874	560.807
	RC30RRiMd,RC30RReMd	2	0.0243	41.8497	562.256
	RC30DRi,RC30RRiMd,RC30RReMd	3	0.0269	42.2101	564.546
	RC30DRi,RC30RRiMd,RC30RReMd,RC30NFR	4	0.0299	42.5707	566.911

Appendix E23: Stepwise regression models of hydrologic parameters selected for *Procloeon* (Family: Baetidae) in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30CDAD	1	0.0225	4.5722	321.8466
	BF30TDAD,BF30CD	2	0.0291	4.6013	323.8205
High flow pulse	HFP15CDPD	1	0.0276	4.5603	321.5648
	HFP30CDPD	1	0.0276	4.5603	321.5648
	HFP15CDAD,HFP30TDPD	2	0.0291	4.6013	323.8205
	HFP15TD,HFP15CD,HFP30NOP	3	0.0291	4.6471	326.2542
	HFP15TD,HFP15CD,HFP30TDAD	3	0.0291	4.6471	326.2542
Small flood	SFP30NOP	1	0.0252	4.5659	321.6987
	SFP15CD,SFP30TDAD	2	0.0362	4.5844	323.4233
	SFP15TDPD,SFP30TD,SFP30TDAD	3	0.0432	4.6131	325.4603
	SFP15NOP,SFP15TDPD,SFP30NOP,SFP30TDPD	4	0.0434	4.6594	327.9849
	SFP15NOP,SFP15TDPD,SFP30TDPD,SFP30CDPD	4	0.0434	4.6594	327.9849
Rate of change	RC30DRi	1	0.0286	4.558	321.5104
	RC30MRi,RC30MRe	2	0.0309	4.5971	323.7203
	RC30DRi,RC30MRi,RC30MRe	3	0.035	4.633	325.9248
	RC30DRi,RC30MRi,RC30MRe,RC30RRiMd	4	0.0352	4.6793	328.4469

Appendix E24: Stepwise regression models of hydrologic parameters selected for *Acentrella* (Family: Baetidae) in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	**BF15TDAD,BF15CD**	**2**	**0.4699**	**115.246**	**671.658**
	BF15CD	1	0.434	117.933	672.86
	BF15TD,BF15TDAD,BF15CD	3	0.4709	116.282	673.989
	BF15TDAD,BF15CD,BF30CD,BF30CDAD	4	0.4727	117.259	676.339
	BF15TDAD,BF15CD,BF30TD,BF30CD,BF30CDAD	5	0.4745	118.280	678.81
High flow pulse	**HFP30TDAD**	**1**	**0.1173**	**147.280**	**696.859**
	HFP30TD,HFP30TDAD	2	0.13	147.635	698.407
	HFP15TDPD,HFP15CDPD,HFP30TDPD	3	0.1439	147.914	699.975
	HFP15TDPD,HFP15CDPD,HFP30TDPD,HFP30CDPD	4	0.1493	148.946	702.173
Small flood	SFP30TDAD	1	0.0418	153.443	701.287
	SFP15NOP,SFP30NOP	2	0.0423	154.906	703.599
	SFP15NOP,SFP30TD	2	0.0423	154.906	703.599
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.0423	156.447	706.033
Large flood	**LFP30NOP**	**1**	**0.0878**	**149.716**	**698.631**
	LFP30NOP,LFP30TD	2	0.0878	151.177	700.967
	LFP30NOP,LFP30TDPD	2	0.0878	151.177	700.967
	LFP15TDAD,LFP15CDPD,LFP30NOP	3	0.0878	152.681	703.401
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30TD	4	0.0878	154.231	705.938
Rate of change	**RC30MRi,RC30RReMd,RC30NFR**	**3**	**0.4822**	**115.037**	**672.826**
	RC30MRi,RC30MRe,RC30RReMd,RC30NFR	4	0.4996	114.233	673.516
	RC30MRi,RC30MRe,RC30RRiMd,RC30RReMd,RC30NF	5	0.5155	113.572	674.423
	RC30RReMd,RC30NFR	2	0.4212	120.426	676.407
	RC30RReMd	1	0.3404	127.315	681.127

Appendix E25: Stepwise regression models of hydrologic parameters selected for *Argia* (Family: Coenagrionidae) in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF15TD	1	0.0003	5.9139	349.6366
	BF15TDAD	1	0.0003	5.9139	349.6366
	BF15CD	1	0.0003	5.9139	349.6366
	BF30TDAD,BF30CD	2	0.0007	5.9704	351.9503
High flow pulse	HFP15CD	1	0.0005	5.9134	349.6281
	HFP30TD	1	0.0005	5.9134	349.6281
	HFP15CDAD,HFP30TDPD	2	0.0007	5.9704	351.9503
	HFP30TDPD,HFP30CDAD	2	0.0007	5.9704	351.9503
	HFP15TD,HFP15CD,HFP30NOP	3	0.0007	6.0298	354.384
	HFP15TD,HFP15CD,HFP30TDAD	3	0.0007	6.0298	354.384
Small flood	SFP30CD	1	0.0112	5.8816	349.0447
	SFP15TDPD,SFP15TDAD	2	0.0469	5.8307	349.3939
	SFP15CD,SFP15CDAD,SFP30TDAD	3	0.0566	5.8589	351.2802
	SFP30NOP,SFP30TDPD,SFP30TDAD,SFP30CDAD	4	0.0737	5.8643	352.8256
Rate of change	RC30RRiMd	1	0.0147	5.8714	348.8572
	RC30RRiMd,RC30RReMd	2	0.0789	5.7322	347.5544
	RC30MRe,RC30RRiMd,RC30RReMd	3	0.1014	5.718	348.6512
	RC30MRi,RC30MRe,RC30RRiMd,RC30RReMd	4	0.1201	5.7155	350.0492

Appendix E26: Stepwise regression models of hydrologic parameters selected for *Erpetogomphus* (Family: Gomphidae) in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30CD	1	0.0488	5.2039	335.8232
	BF15TD,BF30CD	2	0.0651	5.2094	337.2249
	BF15TDAD,BF30TDAD,BF30CD	3	0.1206	5.1026	336.3517
	BF15TDAD,BF30TDAD,BF30CD,BF30CDAD	4	0.1508	5.065	337.001
	BF15TD,BF15TDAD,BF30TDAD,BF30CD,BF30CDAD	5	0.1731	5.05	338.2146
High flow pulse	HFP15TDAD	1	0.0334	5.2458	336.6901
	HFP15TDPD,HFP15CDPD	2	0.0644	5.2114	337.2669
	HFP15NOP,HFP15TDPD,HFP15CD	3	0.0707	5.2455	339.335
	HFP15NOP,HFP15TDPD,HFP15TDAD,HFP15CD	4	0.0839	5.2608	341.096
	HFP15TDPD,HFP15CDPD,HFP30NOP,HFP30TD,HFP30TDPD	5	0.0921	5.2916	343.2612
Small flood	SFP15TDAD,SFP30NOP	2	0.1014	5.1072	335.0865
	SFP15TDAD,SFP30CD	2	0.1014	5.1072	335.0865
	SFP15TDPD	1	0.0439	5.2171	336.0968
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.1023	5.1554	337.4647
Large flood	LFP15TD	1	0.0047	5.3231	338.27
	LFP15CDPD,LFP15CDAD	2	0.0212	5.3303	339.7025
	LFP15NOP,LFP15TDPD,LFP15TDAD	3	0.0219	5.3814	342.0981
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30TDAD	4	0.022	5.4358	344.6297
Rate of change	RC30DRe	1	0.017	5.2902	337.5989
	RC30DRi,RC30NFR	2	0.0311	5.3034	339.1557
	RC30DRi,RC30RReMd,RC30NFR	3	0.0495	5.3048	340.5495
	RC30DRi,RC30MRe,RC30RReMd,RC30NFR	4	0.0622	5.3229	342.3647

Appendix E27: Stepwise regression models of hydrologic parameters selected for Oligochaeta in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Numb.	RSquare	RMSE	AICc
Base flow	BF15TD	1	0.0027	7.7806	379.2641
	BF15TDAD	1	0.0027	7.7806	379.2641
	BF15CD	1	0.0027	7.7806	379.2641
	BF15CDAD	1	0.0027	7.7806	379.2641
	BF30TDAD,BF30CD	2	0.0031	7.8552	381.582
High flow pulse	HFP15CD	1	0.0005	7.7892	379.3831
	HFP30TD	1	0.0005	7.7892	379.3831
	HFP15CDAD,HFP30TDPD	2	0.0031	7.8552	381.582
	HFP30TDPD,HFP30CDAD	2	0.0031	7.8552	381.582
	HFP15TD,HFP15CD,HFP30NOP	3	0.0031	7.9334	384.0157
	HFP15TD,HFP15CD,HFP30TDAD	3	0.0031	7.9334	384.0157
Small flood	**SFP30TDPD,SFP30CD,SFP30CDAD**	**3**	**0.1371**	**7.3809**	**376.2196**
	SFP30TDPD	1	0.0164	7.7271	378.5191
	SFP15TDPD,SFP15TDAD	2	0.1019	7.4555	375.9422
	SFP30NOP,SFP30TDAD,SFP30CDAD	3	0.1911	7.146	372.7273
	SFP15TDAD,SFP30TDAD,SFP30CDPD,SFP30CDAD	4	0.2233	7.0733	373.0696
Rate of change	**RC30MRi,RC30MRe,RC30RRiMd,RC30RReMd,RC30NFR**	**5**	**0.2861**	**6.852**	**371.1701**
	RC30RRiMd	1	0.0465	7.608	376.8409
	RC30MRi,RC30MRe	2	0.1451	7.2741	373.2819
	RC30MRi,RC30MRe,RC30NFR	3	0.238	6.9358	369.5028
	RC30MRi,RC30MRe,RC30RReMd,RC30NFR	4	0.269	6.8623	369.7991

Appendix E28: Stepwise regression models of hydrologic parameters selected for Oligochaeta in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF15CD	1	0.0647	8.1484	384.2525
	BF15CD,BF30TD	2	0.0721	8.1951	386.157
	BF15CDAD,BF30CD,BF30CDAD	3	0.0995	8.1537	386.9747
	BF15CDAD,BF30TD,BF30CD,BF30CDAD	4	0.1137	8.1713	388.6537
High flow pulse	HFP30TDAD	1	0.0472	8.224	385.2491
	HFP30TDAD,HFP30CDAD	2	0.0569	8.262	387.0355
	HFP30TDPD,HFP30TDAD,HFP30CDAD	3	0.0604	8.3287	389.2684
	HFP30TD,HFP30TDPD,HFP30CD,HFP30CDPD	4	0.0844	8.3051	390.4078
Small flood	SFP30NOP	1	0.021	8.3364	386.7162
	SFP30CD	1	0.021	8.3364	386.7162
	SFP30TD,SFP30TDPD	2	0.021	8.4177	389.0513
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.0211	8.5012	391.4812
Large flood	LFP15CD	1	0.0082	8.3907	387.4164
	LFP15NOP,LFP15CDPD	2	0.0321	8.3701	388.4395
	LFP15NOP,LFP15CDPD,LFP30TDPD	3	0.0366	8.4336	390.62
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30TD	4	0.0366	8.5193	393.1572
Rate of change	**RC30MRe,RC30RReMd,RC30NFR**	**3**	**0.2245**	**7.5664**	**378.9007**
	RC30MRi,RC30MRe,RC30RReMd,RC30NFR	4	0.2541	7.4963	379.3422
	RC30DRi,RC30MRi,RC30MRe,RC30RReMd,RC30NFR	5	0.2703	7.4912	380.8025
	RC30RReMd,RC30NFR	2	0.1067	8.0409	384.106
	RC30NFR	1	0.0491	8.2158	385.1422

Appendix E29: Stepwise regression models of hydrologic parameters selected for *Neoperla* (Family: Perlidae) in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	**BF30TDAD**	**1**	**0.1346**	**12.1434**	**427.3407**
	BF15CDAD,BF30CD	2	0.1599	12.0815	428.0763
	BF15TD,BF30TDAD,BF30CD	3	0.168	12.1429	429.9878
	BF15TD,BF30TD,BF30TDAD,BF30CD	4	0.18	12.1771	431.7381
High flow pulse	HFP15NOP	1	0.0439	12.7638	432.7212
	HFP15TDPD,HFP15CDPD	2	0.0608	12.7741	434.0964
	HFP15TDPD,HFP30TDAD,HFP30CDAD	3	0.0749	12.8042	435.7153
	HFP15TDAD,HFP15CDAD,HFP30TDAD,HFP30CDAD	4	0.1062	12.7135	436.3936
Small flood	SFP30NOP	1	0.0422	12.7752	432.8183
	SFP30CD	1	0.0422	12.7752	432.8183
	SFP15TDAD,SFP30NOP	2	0.0434	12.8921	435.0896
	SFP15TDAD,SFP30CD	2	0.0434	12.8921	435.0896
Large flood	LFP15CDPD	1	0.0304	12.8541	433.4827
	LFP15TDPD,LFP30TD	2	0.0315	12.9715	435.7529
	LFP15TDPD,LFP15CDAD,LFP30NOP	3	0.0328	13.0922	438.117
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30TDAD	4	0.0328	13.2251	440.6542
Rate of change	**RC30RReMd,RC30NFR**	**2**	**0.1676**	**12.0257**	**427.5765**
	RC30MRi,RC30MRe,RC30RReMd,RC30NFR	4	0.263	11.5441	425.9729
	RC30MRi,RC30RReMd,RC30NFR	3	0.2257	11.7144	426.1077
	RC30MRi,RC30MRe,RC30RRiMd,RC30RReMd,RC30NFR	5	0.2735	11.5804	427.846
	RC30RReMd	1	0.0974	12.4015	429.612

Appendix E30: Stepwise regression models of hydrologic parameters selected for *Cheumatopsyche* (Family: Hydropsychidae) in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30TD	1	0.0042	14.9114	449.5169
	BF30TDAD,BF30CD	2	0.0042	15.0568	451.8528
High flow pulse	HFP15NOP	1	0.0026	14.9234	449.6039
	HFP30NOP	1	0.0026	14.9234	449.6039
	HFP15CDAD,HFP30TDPD	2	0.0042	15.0568	451.8528
	HFP30TDPD,HFP30CDAD	2	0.0042	15.0568	451.8528
	HFP15TD,HFP15CD,HFP30NOP	3	0.0042	15.2066	454.2864
	HFP15TD,HFP15CD,HFP30TDAD	3	0.0042	15.2066	454.2864
Small flood	SFP15CD	1	0.0226	14.7728	448.5086
	SFP15NOP,SFP15TDAD	2	0.047	14.7299	449.482
	SFP15TD,SFP15TDAD	2	0.047	14.7299	449.482
	SFP15NOP,SFP15TDAD,SFP15CDAD	3	0.1	14.4564	448.8221
	SFP15TD,SFP15TDAD,SFP15CDAD	3	0.1	14.4564	448.8221
	SFP15NOP,SFP15TDAD,SFP15CDAD,SFP30TD	4	0.1033	14.5765	451.1623
	SFP15TD,SFP15TDAD,SFP15CDAD,SFP30TD	4	0.1033	14.5765	451.1623
Rate of change	RC30DRe	1	0.0557	14.5207	446.6492
	RC30DRi,RC30DRe	2	0.0611	14.6207	448.6787
	RC30DRi,RC30DRe,RC30RReMd	3	0.0832	14.5911	449.8241
	RC30DRi,RC30DRe,RC30MRi,RC30MRe	4	0.1064	14.5515	450.977
	RC30DRi,RC30DRe,RC30MRi,RC30MRe,RC30RReMd	5	0.1075	14.693	453.5559

Appendix E31: Stepwise regression models of hydrologic parameters selected for *Cheumatopsyche* (Family: Hydropsychidae) in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	**BF30CD**	**1**	**0.2871**	**40.396**	**557.1503**
	BF15TD,BF30CD	2	0.3107	40.1101	557.6711
	BF15TD,BF15CD,BF30CD	3	0.3439	39.5198	557.4339
	BF15TD,BF15CD,BF30CD,BF30CDAD	4	0.359	39.4587	558.7132
High flow pulse	**HFP30TDAD,HFP30CDPD**	**2**	**0.2216**	**42.6212**	**564.2291**
	HFP30NOP,HFP30TD,HFP30CDPD,HFP30CDAD	4	0.2907	41.5092	564.1845
	HFP15TDPD,HFP30TDAD,HFP30CDPD	3	0.2514	42.2142	564.5573
	HFP30CDPD	1	0.0626	46.3217	571.9333
Small flood	SFP15NOP	1	0.0561	46.481	572.3042
	SFP30TD,SFP30TDPD	2	0.0738	46.4929	573.6196
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.0741	46.9491	576.0384
Large flood	LFP30TDAD	1	0.0609	46.3631	572.0298
	LFP15CDPD,LFP30TDAD	2	0.0725	46.526	573.6964
	LFP15NOP,LFP15CDPD,LFP30TDAD	3	0.073	46.977	576.1026
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30TD	4	0.073	47.4539	578.6398
Rate of change	**RC30MRi,RC30NFR**	**2**	**0.2407**	**42.0971**	**562.893**
	RC30DRe,RC30MRi,RC30NFR	3	0.2887	41.1495	561.7984
	RC30DRe,RC30MRi,RC30MRe,RC30NFR	4	0.3018	41.1836	563.3342
	RC30NFR	1	0.1634	43.7597	565.7884

Appendix E32: Stepwise regression models of hydrologic parameters selected for *Chimara* (Family: Philopotomidae) in the Blanco River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	BF30CDAD	1	0.0104	8.9955	394.9333
	BF30TDAD,BF30CD	2	0.0118	9.0768	397.1932
High flow pulse	HFP15CDPD	1	0.0117	8.9895	394.8613
	HFP30CDPD	1	0.0117	8.9895	394.8613
	HFP15CDAD,HFP30TDPD	2	0.0118	9.0768	397.1932
	HFP30TDPD,HFP30CDAD	2	0.0118	9.0768	397.1932
	HFP15TD,HFP15CD,HFP30NOP	3	0.0118	9.1671	399.6268
	HFP15TD,HFP15CD,HFP30TDAD	3	0.0118	9.1671	399.6268
Small flood	**SFP30NOP,SFP30TDPD,SFP30TDAD**	**3**	**0.1675**	**8.4141**	**390.369**
	SFP30TDPD	1	0.0544	8.7933	392.4784
	SFP30TDPD,SFP30TDAD	2	0.0787	8.764	393.4056
	SFP15TDAD,SFP15CDAD,SFP30TD	3	0.2103	8.1947	387.5163
	SFP15NOP,SFP15TDAD,SFP15CD,SFP30TDAD	4	0.248	8.0778	387.41
	SFP15TD,SFP15TDAD,SFP15CD,SFP30TDAD	4	0.248	8.0778	387.41
Rate of change	**RC30DRe,RC30RReMd**	**2**	**0.1551**	**8.3929**	**388.733**
	RC30DRe	1	0.0645	8.7463	391.899
	RC30DRi,RC30DRe,RC30RReMd	3	0.2038	8.2284	387.9588
	RC30DRe,RC30RRiMd,RC30RReMd,RC30NFR	4	0.2262	8.1942	388.9556

Appendix E33: Stepwise regression models of hydrologic parameters selected for *Hydroptila* (Family: Hydroptilidae) in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	**BF30CD**	**1**	**0.114**	**6.8101**	**364.8745**
	BF15TDAD,BF30CD	2	0.1589	6.7003	364.4071
	BF15TD,BF15TDAD,BF30TDAD	3	0.2191	6.5202	362.8289
	BF15TD,BF15TDAD,BF30TD,BF30TDAD	4	0.2295	6.5424	364.6426
High flow pulse	**HFP15TDAD,HFP30CDPD**	**2**	**0.2374**	**6.3798**	**359.114**
	HFP30CDPD	**1**	**0.0987**	**6.8686**	**365.7999**
	HFP15CDAD,HFP30CD,HFP30CDPD	3	0.2534	6.3753	360.4019
	HFP15NOP,HFP15CDAD,HFP30CD,HFP30CDPD	4	0.2656	6.3874	362.0537
Small flood	SFP30NOP	1	0.0176	7.171	370.4521
	SFP30CD	1	0.0176	7.171	370.4521
	SFP30TD,SFP30TDPD	2	0.0184	7.2381	372.7463
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.0185	7.3098	375.1749
Large flood	LFP30TDAD	1	0.0217	7.1561	370.2275
	LFP30NOP,LFP30TD	2	0.0231	7.2208	372.4871
	LFP15CD,LFP15CDPD,LFP30NOP	3	0.0254	7.2841	374.7937
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30TD	4	0.0254	7.358	377.3309
Rate of change	**RC30NFR**	**1**	**0.1466**	**6.6835**	**362.8494**
	RC30MRi,RC30NFR	2	0.1856	6.5928	362.6603
	RC30DRe,RC30MRi,RC30NFR	3	0.2127	6.5469	363.2706
	RC30DRe,RC30MRi,RC30RRiMd,RC30NFR	4	0.2318	6.5324	364.4774

Appendix E34: Stepwise regression models of hydrologic parameters selected for *Nectopsyche* (Family: Leptoceridae) in the Colorado River; significant models are denoted with bold font.

Flow Qualifier	Model	Number	RSquare	RMSE	AICc
Base flow	**BF15CD**	**1**	**0.1642**	**3.7853**	**301.4477**
	BF15CD,BF30TD	2	0.1895	3.764	302.1264
	BF15TD,BF15CD,BF30TD	3	0.2054	3.7639	303.4893
	BF15TD,BF15CD,BF30TD,BF30CDAD	4	0.2092	3.793	305.7676
High flow pulse	HFP30TDAD	1	0.0374	4.0623	309.0775
	HFP15TDAD,HFP15CDAD	2	0.0638	4.0452	309.9098
	HFP15TDPD,HFP15CDPD,HFP30NOP	3	0.082	4.0458	311.2884
	HFP15TDPD,HFP15TDAD,HFP15CDPD,HFP30TD	4	0.0958	4.0559	313.004
Small flood	SFP30NOP	1	0.002	4.1363	311.026
	SFP30CD	1	0.002	4.1363	311.026
	SFP15TDPD,SFP15TDAD	2	0.014	4.1515	312.7109
	SFP15TDPD,SFP15TDAD,SFP30TDPD	3	0.0233	4.1729	314.6302
Large flood	LFP15TD	1	0.0157	4.108	310.2834
	LFP15TD,LFP15CDAD	2	0.0166	4.146	312.5676
	LFP15CDPD,LFP15CDAD,LFP30NOP	3	0.0177	4.1851	314.9439
	LFP15NOP,LFP15TDPD,LFP15TDAD,LFP30TDAD	4	0.0177	4.2276	317.4811
Rate of change	**RC30DRe**	**1**	**0.0889**	**3.9522**	**306.1099**
	RC30DRe,RC30MRe	2	0.124	3.913	306.3203
	RC30DRe,RC30MRe,RC30RReMd	**3**	**0.1993**	**3.7785**	**303.9063**
	RC30DRi,RC30DRe,RC30MRe,RC30RReMd	4	0.2347	3.7314	303.9987
	RC30DRi,RC30DRe,RC30MRi,RC30MRe,RC30RReMd	5	0.2369	3.7646	306.4902

APPENDIX F

Appendix F1: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Stenelmis* abundance in the Colorado River.

Hydrologic parameters	Source	DF	F Ratio	P-value	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Base flow	Model	4	6.05	**0.0005**	Intercept	51.35	6.46	7.95	**<.0001**	.
	Error	49			BF30CD	27.76	8.5	3.27	**0.002**	1.73
	C. Total	53			BF15TD	25.09	9.74	2.58	**0.01**	2.27
					BF15TDAD	-19.87	10.003	-1.99	**0.05**	2.40
					BF30TD	-35.33	14.09	-2.51	**0.02**	4.76
High flow pulse	Model	1	6.14	**0.02**	Intercept	51.35	7.25	7.08	**<.0001**	
	Error	52			HFP15NOP	-17.96	7.25	-2.48	**0.02**	
	C. Total	53								

Appendix F2: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against Chironomidae abundance in the Blanco River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|
Small flow	Model	1	4.04	**0.05**	Intercept	34.35	4.83	7.12	**<.0001**
	Error	52			SFP15CD	9.7	4.83	2.01	**0.05**
	C. Total	53							

Appendix F3: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against Chironomidae abundance in the Colorado River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Base flow	Model	1	24.12	**<.0001**	Intercept	63.11	11.93	5.29	**<.0001**	
	Error	52			BF30TDAD	-58.59	11.93	-4.91	**<.0001**	
	C. Total	53								
High flow pulse	Model	1	7.37	**0.009**	Intercept	63.11	13.51	4.67	**<.0001**	
	Error	52			HFP30TDPD	-36.67	13.51	-2.71	**0.01**	
	C. Total	53								
Rate of change	Model	3	14.61	**<.0001**	Intercept	63.11	10.74	5.88	**<.0001**	.
	Error	50				43.15	11.28	3.82	**0.0004**	1.1
	C. Total	53			RC30DRe	33.14	11.71	2.83	**0.007**	1.19
					RC30RReMd	-43.51	11.28	-3.86	**0.0003**	1.1

Appendix F4: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against Simuliidae abundance in the Colorado River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|
Base flow	Model	1	7.11	**0.01**	Intercept	91.65	23.30	3.93	**0.0002**
	Error	52			BF30CDAD	-62.14	23.30	-2.67	**0.01**
	C. Total	53							

Appendix F5: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Fallceon* abundance in the Colorado River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|
Base flow	Model	1	4.99	**0.03**	Intercept	7.17	1.81	3.96	**0.0002**
	Error	52			BF15CD	4.04	1.81	2.24	**0.03**
	C. Total	53							

Appendix F6: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Isonychia* abundance in the Colorado River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|
Base flow	Model	1	14.15	**0.0004**	Intercept	14.13	4.33	3.26	**0.002**
	Error	52			BF15CD	16.28	4.33	3.76	**0.0004**
	C. Total	53							

Appendix F7: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Thraulodes* abundance in the Colorado River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|
Base flow	Model	1	23.46	**<.0001**	Intercept	33.69	5.27	6.39	**<.0001**
	Error	52			BF15CD	25.53	5.27	4.84	**<.0001**
	C. Total	53							
High flow pulse	Model	1	7.06	**0.01**	Intercept	33.69	5.96	5.65	**<.0001**
	Error	52			HFP30TDAD	-15.83	5.96	-2.66	**0.01**
	C. Total	53							

Appendix F8: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Maccaffertium* abundance in the Blanco River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Rate of change	Model	2	3.13	**0.05**	Intercept	4.04	0.89	4.56	**<.0001**	.
	Error	51			RC30MRi	2.10	0.96	2.19	**0.03**	1.17
	C. Total	53			RC30RRiMd	-1.87	0.96	-1.95	0.06	1.17

Appendix F9: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Maccaffertium* abundance in the Colorado River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Base flow	Model	6	5.16	**0.0004**	Intercept	2.33	0.35	6.69	**<.0001**	.
	Error	47			BF15TD	-0.99	0.58	-1.7	0.1	2.79
	C. Total	53			BF15CD	2.34	0.57	4.09	**0.0002**	2.7
					BF15CDAD	-5.95	2.04	-2.92	**0.005**	34.22
					BF30TD	1.61	0.73	2.21	**0.03**	4.37
					BF30TDAD	6.64	2.23	2.98	**0.005**	40.91
					BF30CDAD	1.22	0.73	1.68	0.1	4.34
Large flood	Model	1	5.12	**0.03**	Intercept	2.33	0.41	5.73	<.0001	
	Error	52			LFP30TDPD	-0.92	0.41	-2.26	**0.03**	
	C. Total	53								
Rate of change	Model	2	5.35	**0.01**	Intercept	2.33	0.39	5.95	**<.0001**	
	Error	51			RC30DRe	-0.64	0.41	-1.56	0.13	
	C. Total	53			RC30RReMd	-1.3	0.41	-3.19	**0.002**	

Appendix F10: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Tricorythodes* abundance in the Blanco River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Small flood	Model	2	5.1943	**0.009**	Intercept	4.74	0.71	6.63	**<.0001**	.
	Error	51			SFP15CDAD	2.82	1.14	2.48	**0.02**	2.53
	C. Total	53			SFP30TDPD	-3.66	1.14	-3.22	**0.002**	2.53
Rate of change	Model	2	6.4745	**0.003**	Intercept	4.74	0.70	6.77	**<.0001**	.
	Error	51			RC30MRi	2.19	0.76	2.89	**0.01**	1.17
	C. Total	53			RC30RRiMd	-2.34	0.76	-3.08	**0.003**	1.17

Appendix F11: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Tricorythodes* abundance in the Colorado River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Base flow	Model	2	26.09	<.0001	Intercept	13.89	3.07	4.53	<.0001	.
	Error	51			BF15CD	27.47	4.13	6.65	<.0001	1.81
	C. Total	53			BF30TD	-9.74	4.13	-2.36	0.02	1.81

Appendix F12: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Camelobaetidius* abundance in the Blanco River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|
Small flood	Model	1	3.98	**0.05**	Intercept	14.167	3.18	4.45	**<.0001**
	Error	52			SFP15TDPD	-6.35	3.18	-1.99	**0.05**
	C. Total	53							
Rate of change	Model	1	6.33	**0.02**	Intercept	14.167	3.12	4.54	**<.0001**
	Error	52			RC30MRi	-7.85	3.12	-2.52	**0.015**
	C. Total	53							

Appendix F13: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Acentrella* abundance in the Blanco River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Base flow	Model	2	22.60	**<.0001**	Intercept	109.56	15.68	6.99	**<.0001**	.
	Error	51			BF15TDAD	-37.82	20.35	-1.86	0.07	1.68
	C. Total	53			BF15CD	77.24	20.35	3.79	**0.0001**	1.68
High flow pulse	Model	1	6.91	**0.01**	Intercept	109.56	20.04	5.47	**<.0001**	
	Error	52			HFP30TDAD	-52.67	20.04	-2.63	**0.01**	
	C. Total	53								
Large flood	Model	1	5.01	**0.03**	Intercept	109.56	20.37	5.38	**<.0001**	
	Error	52			LFP30NOP	-45.58	20.37	-2.24	**0.03**	
	C. Total	53								
Rate of change	Model	3	15.52	**<.0001**	Intercept	109.56	15.65	7	**<.0001**	.
	Error	50			RC30MRi	-39.14	16.13	-2.43	**0.02**	1.06
	C. Total	53			RC30RReMd	-99.19	16.06	-6.18	**<.0001**	1.05
					RC30NFR	54.13	16.51	3.28	**0.002**	1.11

Appendix F14: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against Oligochaeta abundance in the Blanco River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Rate of change	Model	3	4.83	**0.005**	Intercept	3.56	1.03	3.45	**0.001**	.
	Error	50			RC30MRe	4.02	1.46	2.76	**0.008**	2.01
	C. Total	53			RC30RReMd	-4.78	1.45	-3.29	**0.002**	1.99
					RC30NFR	3.87	1.20	3.22	**0.002**	1.36

Appendix F15: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Neoperla* abundance in the Colorado River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Rate of change	Model	2	5.14	**0.009**	Intercept	8.61	1.64	5.26	**<.0001**	.
	Error	51			RC30RReMd	-4.77	1.68	-2.84	**0.006**	1.05
	C. Total	53			RC30NFR	3.48	1.68	2.07	**0.04**	1.05

Appendix F16: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Cheumatopsyche* abundance in the Colorado River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Base flow	Model	1	20.94	**<.0001**	Intercept	42.07	5.50	7.65	**<.0001**	
	Error	52			BF30CD	25.16	5.50	4.58	**<.0001**	
	C. Total	53								
High flow pulse	Model	2	7.26	**0.002**	Intercept	42.07	5.800008	7.25	**<.0001**	.
	Error	51			HFP30TDAD	-61.458	19.04	-3.23	**0.002**	10.773
	C. Total	53			HFP30CDPD	70.28	19.04	3.69	**0.0005**	10.773
Rate of change	Model	2	8.08	**0.0009**	Intercept	42.07	5.73	7.34	**<.0001**	.
	Error	51			RC30MRi	-13.44	5.90	-2.28	**0.03**	1.06
	C. Total	53			RC30NFR	22.21	5.90	3.76	**0.0004**	1.06

Appendix F17: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Chimarra* abundance in the Blanco River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	T Ratio	Prob>|t|	VIF
Small flood pulse	Model	3	3.35	**0.03**	Intercept	5.04	1.15	4.4	**<.0001**	.
	Error	50			SFP30NOP	4.64	2.01	2.31	**0.03**	3.07
	C. Total	53			SFP30TDPD	20.73	7.36	2.82	**0.007**	41.31
					SFP30TDAD	-20.27	7.86	-2.58	**0.01**	47.06
Rate of change	Model	2	4.68	**0.01**	Intercept	5.04	1.14	4.41	**<.0001**	.
	Error	51			RC30DRe	3.94	1.35	2.92	**0.005**	1.4
	C. Total	53			RC30RReMd	3.16	1.35	2.34	**0.02**	1.4

Appendix F18: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Hydroptila* abundance in the Colorado River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	T Ratio	Prob>|t|	VIF
Base flow	Model	1	6.69	**0.01**	Intercept	3.33	0.93	3.6	**0.0007**	
	Error	52			BF30CD	2.40	0.93	2.59	**0.01**	
	C. Total	53								
High flow pulse	Model	2	7.94	**0.001**	Intercept	3.33	0.87	3.84	**0.0003**	.
	Error	51			HFP15TDAD	-2.91	0.96	-3.05	**0.004**	1.21
	C. Total	53			HFP30CDPD	3.45	0.96	3.61	**0.0007**	1.21
Rate of change	Model	1	8.94	**0.004**	Intercept	2.52	0.51	4.90	**<.0001**	.
	Error	52			RC30DRe	1.95	0.59	3.29	**0.002**	1.33
	C. Total	53			RC30MRe	-1.82	0.71	-2.56	**0.01**	1.91
					RC30RReMd	1.58	0.73	2.17	**0.04**	2.00

Appendix F19: Analysis of variance results and parameter estimates of the significant hydrologic parameters that were selected in the stepwise regression model against *Nectopsyche* abundance in the Colorado River.

Hydrologic parameters	Source	DF	F Ratio	Prob > F	Parameter Estimates	Estimate	Std Error	T Ratio	Prob>|t|	VIF
Base flow	Model	1	10.22	0.002	Intercept	2.52	0.52	4.89	**<.0001**	
	Error	52			BF15CD	1.65	0.52	3.20	**0.0024**	
	C. Total	53								
Rate of change	Model	3	4.15	**0.01**	Intercept	2.52	0.51	4.9	**<.0001**	.
	Error	50			RC30DRe	1.95	0.59	3.29	**0.002**	1.33
	C. Total	53			RC30MRe	-1.82	0.71002	-2.56	**0.01**	1.91
					RC30RReMd	1.58	0.727002	2.17	**0.04**	2.00

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