Small-bodied Fishes Monitoring in the San Juan River: 2016

Annual Report

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San Juan River Basin
Recovery Implementation Program

EXECUTIVE SUMMARY

In 2016, annual small-bodied fishes monitoring occurred from Bloomfield, NM (River Mile [RM] 196.1 to Mexican Hat, UT (RM 52.8). Ninety-eight sites were sampled river-wide, 43 in the primary channel, 32 in secondary channels, and 23 in zero velocity (i.e., backawaters and embayments) channels. A total of 6,513 fishes were captured river-wide representing 6 native species and 12 nonnative species. The number of fishes captured in 2016 was almost double the total combined number of captures in 2014 and 2015 (N: 3,827). Speckled Dace *Rhinichthys osculus* (N: 4,438, 68%) were the most common fish captured in 2016, followed by Channel Catfish *Ictalurus punctatus* (N: 716, 11%), Bluehead Sucker *Catostomus discobolus* (N: 363, 6%), and Flannelmouth Sucker *Catostomus latipinnis* (N: 362, 6%). The proportion of natives captured river-wide was high (0.80) and was greater than 0.60 in every channel type.

Wild post-larval age-0 Colorado Pikeminnow *Ptychocheilus lucius*, Razorback Sucker *Xyrauchen texanus*, and Roundtail Chub *Gila robusta* were captured in 2016, the first captures for these fishes since standardized small-bodied fishes monitoring began in 1998. Twenty-three wild post-larval age-0 Colorado Pikeminnows were captured within a small section of river from RM 108.4 to RM 57.8. These fish also had a high probability of presence in near- and zero-velocity mesohabitats and were never captured in moderate- or high-velocity mesohabitats. Nineteen age-1 Colorado Pikeminnow were also captured in 2016, and densities of age-1 Colorado Pikeminnow have remained relatively stable since 2012. A single wild age-0 Razorback Sucker was captured in a zero velocity channel at RM 57.8 and three wild age-0 Roundtail Chubs were captured in a zero velocity channel at RM 153.0. Captures of nonnative species were low river-wide but Channel Catfish *Ictalurus punctatus* was the second most commonly captured fish in 2016.

Although the number of fishes captured in 2016 was much higher than previous years, the densities of most common species have remained stable in Reaches 3 – 6 for the past 5 years. Densities of Speckled Dace and Channel Catfish were significantly higher in 2016 than the previous 4 in Reaches 3 – 6, although these increases in densities were dependent on channel type. Similar to previous years, few of the River Ecosystem Restoration Initiative (RERI) and Reference Secondary Channels were sampled because they were either dry or could not be located. The number of fish captured in RERI channels in 2016 (N: 117) was the highest recorded since sampling of these channels began in 2012. Furthermore, the majority (≥ 97%) of fishes captured in both RERI and Reference secondary channels were native species.

The exact mechanism for increased abundances in 2016 is difficult to determine, though the large spring runoff was likely a contributing factor and flow-ecology relationships in the San Juan River should continue to be investigated. However, the most important findings in 2016 were the capture of 23 wild age-0 Colorado Pikeminnows and one wild age-0 Razorback Sucker. Although accurate estimates are unknown, it is likely that 1,000s to 10,000s wild age-0 Colorado Pikeminnow were present in the system in 2016. As the captures of age-0 endangered fish become more common, the current augmentation programs for both endangered species must become more flexible to prevent potential deleterious interactions between hatchery-reared and wild fish. Furthermore, small-bodied fishes monitoring must also become more adaptive to increase captures of wild fish when they are present in the system, increasing our knowledge on their distribution and habitat use. Increased captures of wild age-0 fish will increase our knowledge on this important life stage and help to develop and refine management actions.

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INTRODUCTION

In 1991, a 7-year research period was initiated to gather baseline information on federally endangered Colorado Pikeminnow *Ptychocheilus lucius* and Razorback Sucker *Xyrauchen texanus* after both species were re-discovered and documented spawning in the San Juan River. In 1992, a Cooperative Agreement between the U.S. Fish and Wildlife Service, States of Colorado and New Mexico, the Jicarilla Apache Indian Tribe, the Southern Ute Indian Tribe, and the Ute Mountain Ute Indian Tribe was signed to form the San Juan River Basin Recovery Implementation Program (SJRIP). The Navajo Nation later signed the Cooperative Agreement and joined the SJRIP in 1996. The purpose of the SJRIP is to conserve populations of Colorado Pikeminnow and Razorback Sucker in the San Juan River Basin while water development proceeds in the basin in compliance with all federal, state, and tribal laws (SJRIP 2016). The research program was incorporated into the SJRIP when it was formed in 1992.

After the 7-year research period ended, the SJRIP initiated several management actions to aid in endangered species recovery including mechanical control of nonnative species, habitat restoration, population augmentation, and the implementation of flow recommendations. To assess the effects of these management actions on endangered fish recovery and the native fish community as a whole, a long-term monitoring program was initiated in 1998. The goals of this monitoring program were to: (1) track the status and trends of endangered and other fish populations in the San Juan River, (2) track changes in abiotic parameters (i.e., water quality, temperature, channel morphology, and habitat) important to the fish community, and (3) utilize collected data to help assess progress towards recovery of endangered fish species (Propst et al. 2006). The SJRIP Long-Range Plan specifies that monitoring and evaluation of fish in the San Juan River is a necessary element for assessing the progress of the recovery program for Colorado Pikeminnow and Razorback Sucker (Element 4; SJRIP 2016).

Task 4.1.2.2 of the SJRIP's Long-Range Plan specifies the need for juvenile and small-bodied fishes (SBF) monitoring to locate areas and habitats used for rearing and to determine if young fish are surviving and recruiting into adult populations (SJRIP 2016). Data collected during annual SBF monitoring can, and has been used to assess recovery of Colorado Pikeminnow and Razorback Sucker. In addition to assessing recovery of both endangered fish species, SBF data have also been used to evaluate the influences of SJRIP management actions on the river's fish community as a whole. These assessments have included evaluating the effects of flow regime management on SBF in secondary channels (Propst and Gido 2004; Franssen et al. 2007; Gido and Propost 2012; Gido et al. 2013), assessing the influences of habitat stability on the spatial and temporal trends in SBF communities in secondary channels (Gido et al. 1997), and determining the effects of habitat heterogeneity on the community structure of SBF (Franssen et al. 2015).

The goal of SBF monitoring is to quantitatively assess the effects of management actions on survival of post-larval early life stages of native and nonnative fishes and their recruitment into subsequent life stages and use this information to recommend appropriate modifications to recovery strategies for Colorado Pikeminnow and Razorback Sucker in the San Juan River (SJRIP 2012). The specific objectives for SBF monitoring are: (1) annually document occurrence and density of native and nonnative age-0/small-bodied fishes in the San Juan River; (2) document mesohabitat use by age-0 Colorado Pikeminnow, Razorback Sucker, and Roundtail Chub, as well as other native and nonnative fishes in the primary channel, secondary channels, and large backwaters; (3) obtain data that will aid in the evaluation of the responses of native and nonnative fishes to different flow regimes and other management actions; (4) track trends in native and nonnative species populations; and (5) characterize patterns of mesohabitat use by native and nonnative small-bodied fishes.

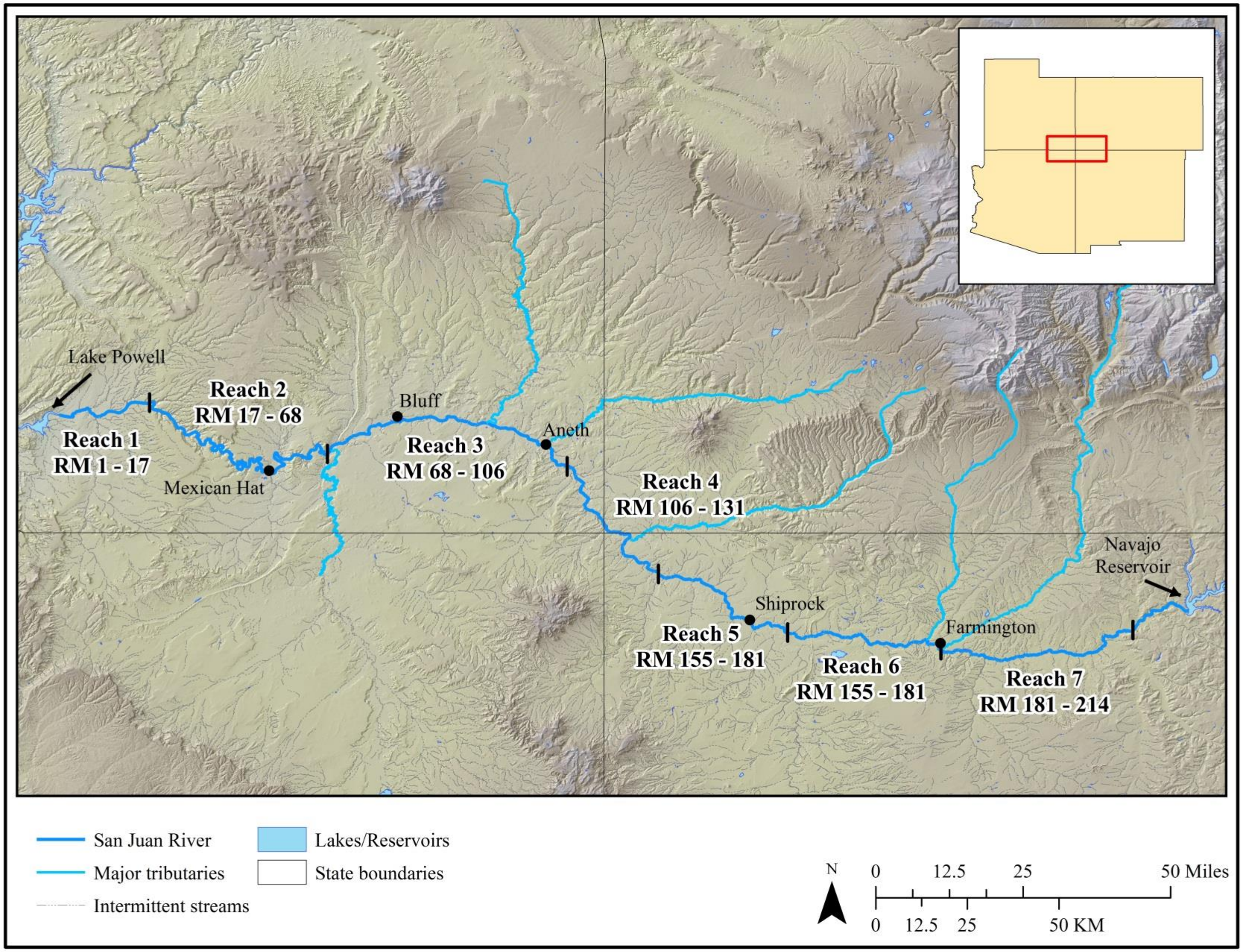


Figure 1. Map of the San Juan River indicating location of Geomorphic Reaches and river miles (RM). Map insert indicates the location of the San Juan River in the states of Colorado, New Mexico, and Utah.

Study Area

The San Juan River is a major tributary of the Colorado River and begins in the San Juan Mountains of southwestern Colorado. The river is heavily influenced by Navajo Dam, located at River Mile (RM) 224 in New Mexico, and by Lake Powell in Utah (Figure 1). Over the 224 river miles between Navajo Dam and Lake Powell, the San Juan River changes dramatically and has been classified into eight different geomorphic reaches based on several datasets analyzed by Bliesner and Lamarra (2000). The upper three Reaches, 8 (RM 224 - 213), 7 (RM 213 - 181), and 6 (RM 180 - 155) have been heavily influenced by anthropogenic modifications and the river in this area is predominately a single channel. The middle portion of the river, Reaches 5 (RM 151 – 131), 4 (RM 130 – 107), and 3 (RM 106 – 68) are braided with multiple side channels and a broad floodplain. The lower two Reaches, 2 (RM 67 – 17) and 1 (RM 16 – 0) are canyon bound, and Reach 1 is heavily influenced by Lake Powell.

Since small-bodied fishes monitoring began in 1998, sampling has annually occurred downstream of the confluence with the Animas River (RM 180.5), but some alterations to the spatial extent of monitoring have occurred over time (Figure 2). From 1999 to 2010, annual monitoring occurred from the Animas River confluence (RM 180.5) downstream to Clay Hills Crossing, UT (RM 2.9). Beginning in 2011, annual sampling downstream of Sand Island, UT (RM 76.4) ceased, and now occurs only once every five years. In 2012, monitoring was extended upstream of the Animas River confluence to Bloomfield, NM (RM 196.1), an additional 15.5 miles of river. Since 1999, only Reaches 3 – 6 have been sampled every year (Figure 2).

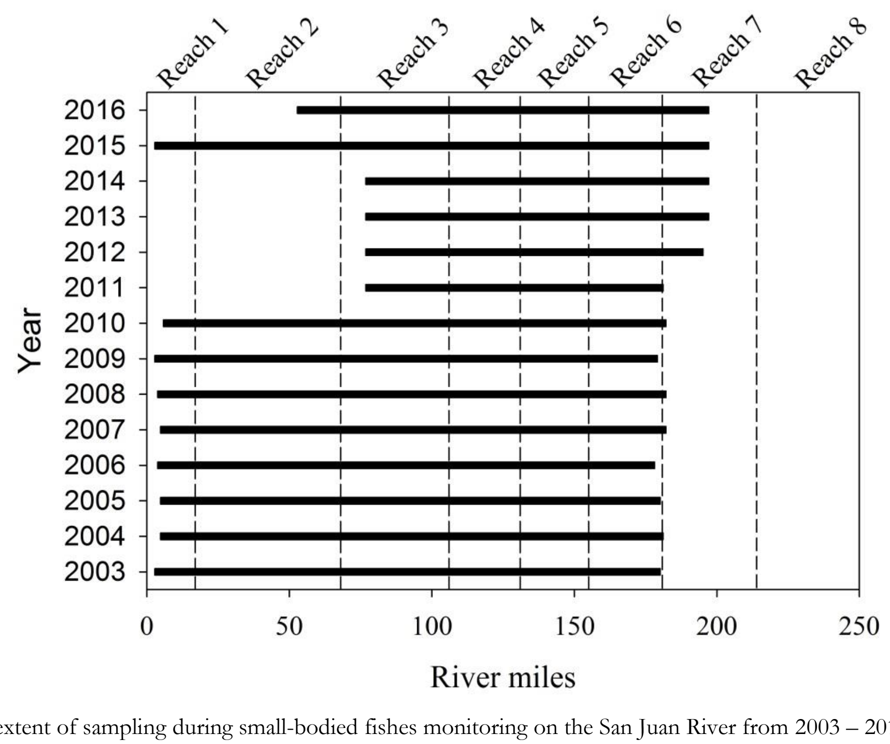


Figure 2. Spatial extent of sampling during small-bodied fishes monitoring on the San Juan River from 2003 – 2016. Note that river miles begin (River Mile 0) at the inflow to Lake Powel in Utah and end at Navajo Dam (River Mile 224) in New Mexico.

METHODS

Sampling protocol

Small-bodied fishes monitoring occurs annually during the fall, usually in conjunction with sub-adult and adult monitoring. During 2016, small-bodied monitoring from Shiprock, NM to Mexican Hat, UT occurred before sub-adult and adult monitoring to allow for that monitoring program to sample every river mile. The primary channel was sampled at designated 3-mile intervals, skipping the miles sampled by sub-adult and adult monitoring crews (SJRIP 2012). All secondary channels (less than 20% of total flow) and large (> 50 m²) zero velocity channels (i.e., backwaters and embayments) were sampled when encountered, irrespective of their occurrence outside a designated 3-mile interval. All primary channel sample sites were approximately 200 m long (measured along the shoreline). Lengths of secondary channel sample sites varied depending upon extent of surface water but were normally 100 – 200 m long.

At each sampling site, the river mile, geographic coordinates (UTM NAD83), and water quality parameters (dissolved oxygen, conductivity, and temperature) were recorded. All mesohabitats (e.g., riffle, run, pool) present within a site (except zero velocity channels) were sampled in rough proportion to their availability using a 3.0 x 1.8 m (3.0 mm heavy duty Delta untreated mesh) drag seine. Uncommon mesohabitats (e.g., debris pools and backwaters) were sampled in greater proportion to their availability than common mesohabitats. Seine hauls were made in at least five different mesohabitats at most sites; however, if habitat was homogeneous, as few as three seine hauls were made. At least two seine hauls, one across the mouth and one parallel to its long axis were made at each zero velocity channel site unless the mouth was too narrow in which case at least one seine haul, parallel to the zero velocity channel's long axis, was made. Types and descriptions of mesohabitats sampled during small-bodied fishes monitoring in the San Juan River are given in Table 1.

All captured fishes were identified to species and measured for total length (mm TL) and standard length (mm SL). All native fishes were released and nonnative fishes removed from the river. Fishes too small to easily be identified in the field were fixed in 10% formalin and returned to the laboratory. After collection of fish, the sampled width and length of each mesohabitat was measured to the nearest 0.1 m and recorded. The depth and dominant substrate at five generalized locations, and any cover (e.g., boulders, debris piles, large woody debris) associated with the mesohabitat were also recorded.

Retained specimens were identified and measured (TL and SL) in the laboratory to the nearest 0.1 mm. Personnel at the University of New Mexico Museum of Southwestern Biology (UNM-MSB), Division of Fishes, and personnel from American Southwest Ichthyological Researchers assisted in verification of fish identifications in the laboratory. All retained specimens were accessioned to the UNM-MSB, Division of Fishes.

Data Analysis

Due to changes in sampling protocol and the overall structure of the SBF dataset, editing of the data was required before any analyses could be conducted. Small-bodied fishes monitoring is designed to target post-larval small-bodied and juvenile fishes in the San Juan River, although larval and sub-adult/adult fishes are sometimes captured during sampling. Capture of both larval and sub-adult/adult fishes is likely biased as the capture efficiency of these size classes is low due to gear bias. To reduce the influence of gear bias and focus the analysis on the target size group, larval and sub-adult/adult (≥ 200 mm) fishes were removed from the dataset. A cutoff of 200 mm TL was used because it includes all ages of small-bodied fishes and is close to the average length of age-1 large bodied fishes for several species (Ryden 2000; Durst and Franssen 2014). Although sub-adult/adult fishes are not used in any data analyses, captures of any endangered species greater than 200 mm are reported. The size of larval fishes for each species was determined from larval identification guides which provided the approximate size (mm TL) at which a species reaches juvenile size (Snyder et al. 2016). Channel and mesohabitat type were also altered to reduce the number of categories for each variable. Backwater and embayment channel and mesohabitat types were grouped into a single category (i.e., zero velocity), because they were assumed to function similarly. All other mesohabitat types were standardized to match the classifications in Bliesner et al. (2009).

Table 1. Definitions of mesohabitats typically sampled during small-bodied fishes monitoring in the San Juan River. Definitions from Bliesner et al. 2009.

Mesohabitat	Definition
Backwater	Typically a body of water off-channel in an abandoned secondary mouth, behind a bar or in a bank indention, water depth from < 10 cm to > 1.5 m, no perceptible flow, substrate typically silt or sand and silt. Little or no mixing of backwater and channel water.
Pool	Area within channel where flow not perceptible or barely so; water depth usually ≥ 30 cm; substrate silt, sand, or silt over gravel, cobble, or rubble.
Eddy	Same as pool, except water flow is evident (but slow) and direction typically opposite that of channel or circular.
Shoal	Generally shallow (≤ 25 cm) areas with laminar flow (very slow to slow velocity: ≤ 5 cm/sec) over sand or cobble substrate.
Run	Typically moderate or rapid velocity water 10-30 cm/sec with little or no surface disturbance. Depths usually 10-74 cm but may exceed 75 cm. Substrate usually sand but may be silt in slow velocity runs and gravel or cobble in rapid velocity runs.
Riffle	Area within channel where gradient is moderate (5 cm/m), water velocity usually moderate to rapid (10 to 31 cm/sec), and water surface disturbed. Substrate usually cobble and rubble and portions of rocks may be exposed. Depths vary from < 5 to 50 cm, rarely greater.
Chute	Rapid velocity (≥ 30 cm/sec) portion of the channel (often near center) where gradient ≥ 10 cm/m. Channel profile often U- or V-shaped. Depth typically ≥ 30 cm. Substrate large cobble or rubble and often embedded.
Slackwater	Low velocity habitat usually along inside margin of river bends, shoreline invaginations, or immediately downstream of debris piles, bars, or other in-stream features, but deeper than shoals (> 25 cm).
Isolated pool	Small body of water in a depression, old backwater, or side channel, not connected to the channel as a result of receding flows.
Embayment	Open shoreline depression similar to a backwater but that faces upstream. Typically at the top end of abandoned secondary channels or bars.
Rapid	Deep, high gradient, high velocity areas often with standing waves.
Pocket water	Low velocity water similar to slack water, but in boulder fields. These usually occur in channel margins in the canyon reaches.
Plunge	The transition area below a riffle or chute where the channel deepens into a run with transition from high to low velocity.

Due to longitudinal differences in species distributions, life history, and the rarity of some species (e.g., Colorado Pikeminnow), capture rates for a specific species are highly variable between seine hauls. The resulting distribution of catch-per-unit-effort (CPUE, fish/100 m^2) data for a species has a substantial proportion of zeros and is often right skewed, for both a single year and the entire dataset (Figure 3). These "zero-inflated" datasets do not fit a normal distribution, making traditional statistical analysis using parametric techniques improbable. Furthermore, the zeros in the dataset can be either "true zeros" or "false zeros" (Martin et al. 2005). True zeros can occur because of an ecological process or because a species does not saturate its entire suitable habitat by chance. False zeros can occur when a species is not present when the sampling occurs or through sampling error. Not accounting for the extra zeros in the data can lead to failure to detect relationships and even incorrect inferences about statistical outcomes.

Traditional analysis of non-normally distributed CPUE data often utilized a logarithmic (CPUE + *x*) transformation of the data, with *x* being some constant (e.g., 0.001, 1). Although these transformations have been widely used, they do not always sufficiently normalize the data to warrant the use of parametric statistical analyses (Hubert and Fabrizio 2007). To account for the significant number of zeros and highly skewed data, CPUE for each species was analyzed using a Delta-GLM approach which combines two separate components: (1) a logistic model estimating the probability of presence ($CPUE_{0/1}$) fitted using a GLM with a binomial distribution and a logit link, and (2) a model for CPUE only when the species is present ($CPUE^{+}$) fitted using a GLM with a lognormal distribution (Stefánsson 1996; Fletcher et al. 2005; Acou et al. 2011; Vasconcelos et al. 2013). The expected density, $E(CPUE)$, is then obtained by (3) multiplying the response variables predicted by the binomial and lognormal models. This approach models the two aspects of the data (i.e., presence/absence and positive CPUE) separately, allowing for evaluation of how covariates influence the two separate processes. Furthermore, the approach is much simpler and easier to interpret than other methods such as mixture models (Fletcher et al. 2005).

The procedures which are required to model both portions of the Delta-GLM and combine them to calculate $E(CPUE)$ are as follows:

1. Logistic GLM to model presence/absence:

$$CPUE_{0/1} = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \varepsilon_{0/1}$$

Where $CPUE_{0/1}$ is a variable representing either the presence (i.e., 1) or absence (i.e., 0) of a species in each seine haul, βx's are explanatory variables (i.e., covariates) and their corresponding coefficient estimates, and $\varepsilon_{0/1}$ are the residuals of the GLM which are assumed to be binomially distributed.

2. Lognormal model for positive CPUE:

$$\ln(CPUE^{+}) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \varepsilon^{+}$$

where $CPUE^{+}$ is the density of a seine haul when the species was present, βx's are explanatory variables (i.e., covariates) and their corresponding coefficient estimates, and ε^{+} are the residuals which are assumed to be normally distributed with a mean of zero and a variance of σ_{ε}^{2}.

3. Combining models 1 and 2:

$$E(CPUE) = CPUE_{0/1} \times e^{\ln(CPUE^{+})} \times e^{\frac{\hat{\sigma}^2(\ln(CPUE_i^{+}))}{2}}$$

where $E(CPUE)$ is the expected density of a species for each seine haul, when the species was present,

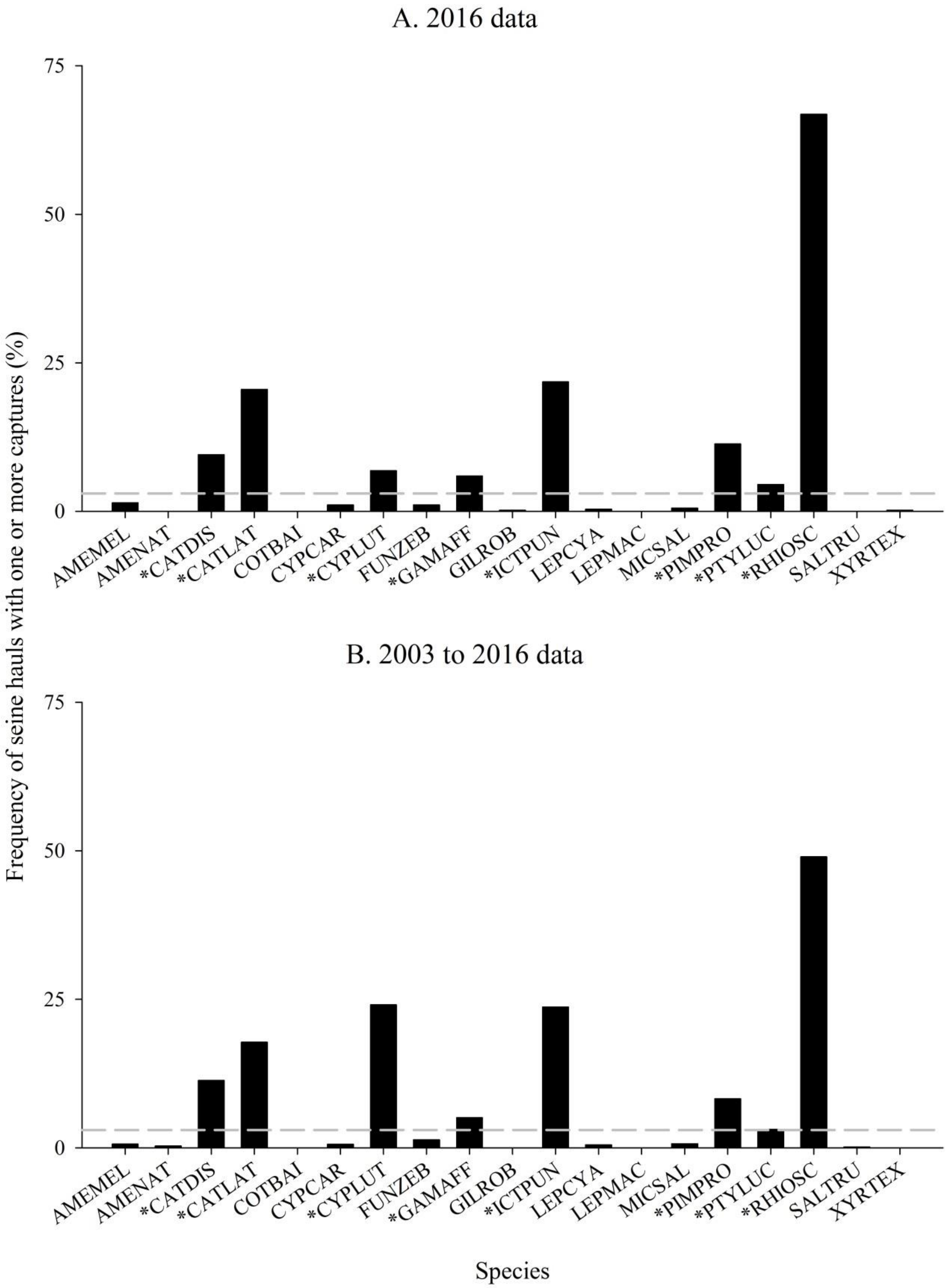


Figure 3. Frequency (%) of seine hauls with a capture (i.e., positives) by species for (A) 2016 data and (B) 2003 to 2016 data. Species (see Table A1 for common and scientific name) with an asterisk (*) had more than 3% of seine hauls with a capture. The grey dashed line indicates 3%.

$CPUE_{0/1}$ is the probability of presence at each seine haul estimated from the logistic model, $\ln(CPUE^{+})$ is the estimated density of a seine haul when the species was present estimated from the lognormal model, and $\sigma(\ln(CPUE_{i}^{+})$ is a correction factor to reduce bias in the log-transformed data as suggested by Sprugel (1983).

A global model containing all possible explanatory variables was built for both the logistic and positive lognormal model. The global model contained year (sampYear), geomorphic reach (Reach), channel type (ChannelType), mesohabitat type (Mesohabitat), discharge at time of sampling (sampDis), and the interactions between year and geomorphic reach (sampYear*Reach), year and channel type (sampYear*ChannelType), and geomorphic reach and channel type (Reach*ChannelType). The dredge function in the MuMin package (Bartoń 2016) for R was then used to model all possible combinations of explanatory variables with sampYear and Reach being fixed in all models. The negative log-likelihood from both models were combined and used to calculate Akaike's Information Criterion with a correction for finite sample sizes (AIC_c). The combined model with the lowest AIC_c was used to model the final $CPUE_{0/1}$ and $CPUE^{+}$ models for each species. Residual plots were examined to ensure that the final $CPUE^{+}$ model met the assumptions of a normal distribution and homogeneity.

The $CPUE_{0/1}$, $CPUE^{+}$, and Delta-GLM models were assessed for fit and predictive capability. The Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC) was used to test the predictive accuracy for the binomial model (Peterson et al. 2008). For the $CPUE^{+}$ and Delta-GLM models, a linear regression between observed (x-axis) and predicted (y-axis) CPUE was used to test predictive ability. The coefficient of determination (R^2) of this relationship shows the proportion of the linear variation in predicted values explained by the variation in observed values, the intercept describes bias, and the slope describes consistency.

Although the Delta-GLM procedure accounts for the influence of zeros in the dataset, an attempt to reduce the number of zeros (i.e., seine hauls with 0 captures) in the dataset was attempted. All species were examined to determine the number of zero (i.e., no captures) seine hauls for all available seine hauls. Only species which had at least 3% of all seine hauls from 2003 – 2016 with one or more captures (Figure 3) were analyzed using the above method. The Chute habitat type was removed from analysis because almost no fish were captured in this habitat type (< 1.0% seine hauls with a capture). The number of zeros per reach was also examined for each species. Any reach which had < 3.0% seine hauls with a capture were exclude from analysis for that species. Extreme $CPUE^{+}$ values for each species were also removed by removing the top 5th percentile of the $CPUE^{+}$ data.

The Kruskal-Wallis ANOVA for Ranks was used to assess differences in density since 2003 for each species and channel type (i.e., primary, secondary, and zero velocity). Only densities from Reaches 3 – 6 were used for assessing changes in density because only these four reaches have been monitored consistently since 2003. If the Kruskal-Wallis ANOVA for Ranks indicated a statistically significant ($P < 0.10$) difference between years, a post-hoc Dunn's test was used to determine specific differences. The 2016 density data was used as a control for the post-hoc Dunn's test to determine if the density in any other year was statistically different ($P < 0.10$). A Holm's correction was used to adjust the p-values for multiple comparisons. An α of 0.10 was used to determine statistically significant differences in density due to the natural variability often observed in age-0 fish populations (Brown and Guy 2007). All statistical analyses were performed using R 3.2.1 (R Core Team 2015) and utilizing the MASS (Venables and Ripley 2002), plyr (Wickham 2011), pROC (Robin et al. 2011), PMCMR (Pohlert et al. 2014), and MuMIn (Barton 2016) packages.

Table 2. Metrics which describe discharge (Q, cfs) of the San Juan River at Four Corners, CO (USGS gage 09371010) during the Spring (March 30th - June 30th) and Summer (July 1st - September 30th), 2003 - 2016.

Metric	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2003 - 2015 Mean
Spring (March 30th - June 30th)															
March Mean	690	1016	1285	583	1278	4799	970	1009	794	918	555	604	954	1013	1189
April Mean	581	2010	3082	861	1318	4111	1211	1389	791	1280	606	806	608	969	1435
May Mean	1707	2485	7694	1974	5787	5185	4170	1963	1247	2433	1223	1507	1375	2840	2981
June Mean	1418	1754	6382	2721	3174	7779	3184	1712	4739	860	655	655	4225	6246	3020
Spring Mean	1101	1820	4609	1530	2900	5460	2387	1517	1878	1378	762	1246	1780	2753	2182
Spring CV[1]	0.87	0.50	0.70	0.94	0.72	0.42	0.77	0.58	1.13	0.80	0.49	0.79	0.88	0.88	1
Days Q > 3,000	11	16	77	18	49	108	38	11	20	10	0	11	26	42	30
Days Q > 5,000	0	1	50	7	21	58	17	0	12	6	0	0	5	30	14
Days Q > 8,000	0	0	18	0	2	25	0	0	7	0	0	0	0	5	4
Summer (July 1st - September 30th)															
July Mean	584	586	1468	1031	1101	1583	852	985	1500	908	641	747	1626	1583	1047
August Mean	664	440	940	1266	1614	818	576	1356	681	679	1172	749	1448	1213	954
Sept Mean	1610	1100	762	1059	1287	883	543	970	896	767	2421	903	773	715	1075
Summer Mean	946	683	1060	1119	1334	1097	658	1105	1027	785	785	798	1288	1175	976
Summer CV[1]	1.61	0.74	0.53	0.48	0.56	0.52	0.31	0.58	0.51	0.34	1.95	0.71	0.60	0.95	1
Days Q > 1,000	16	12	43	42	54	42	5	36	34	17	37	17	44	25	31
Days Q < 1,000	75	80	49	50	38	50	87	56	58	75	55	75	47	66	61
Days Q < 750	64	73	40	24	11	32	72	24	43	54	40	58	36	42	44
Days Q < 500	40	35	9	0	0	6	18	0	7	2	13	28	0	1	12

[1]Coefficient of variation

Both abiotic and biotic factors are assumed to influence the densities of small-bodied and juvenile fishes in the San Juan River (Propst and Gido 2004; Franssen et al. 2007; Gido and Propst 2012). Mean daily discharge at Four Corners, CO (USGS gage 09371010) was used to calculate several discharge metrics for both the spring (March 1st to June 30th) and summer (July 1st to September 30th) (Table 2). Density of nonnative competitors and nonnative predators were also calculated for each year and geomorphic reach. Density of nonnative competitors was calculated as the total combined density (total fish/total area sampled x 100; fish/100 m^2) of Red Shiner, Fathead Minnow, and Western Mosquitofish captured during SBF monitoring. Nonnative predator density was calculated as the CPUE (fish/hour) of Channel Catfish > 300 mm from annual adult fall monitoring. The median density for each native and nonnative species as calculated from the Delta-GLM was then plotted against each discharge and nonnative competitor and predator metric to assess any potential relationships. Median density of nonnative species was also plotted against all discharge metrics to assess any potential relationships. Comparisons between species density and all discharge and nonnative fish metrics were only conducted for Reaches 3 – 5 for easy comparison to previous studies (Gido and Propst 2012; Propst and Gido 2004).

Due to limited data for the River Ecosystems Recovery Initiative (RERI) and Reference Secondary Channels, detailed statistical analyses were not conducted for these sites. However, information on the number of channels sampled, and the number of fishes for endangered, native, and nonnative species captured is given for each year of sampling. The simple inclusion of these data allows for the comparison of differences in catches from year to year and the influence of discharge on the number of channels which could be sampled.

RESULTS

2016 Discharge Summary

Discharge during the spring (March 1 – June 30) in 2016 at Four Corners, CO averaged 2,753 cfs, almost 600 cfs higher than the 2003 – 2015 mean of 2,182 cfs (Table 3, Figure 4). This was the highest average spring discharge since 2008 and higher than 10 of the previous 13 years. The number of days during the spring with discharge greater than 3,000 cfs and 5,000 cfs was also higher in 2016 than 2003 – 2015 averages. Summer (July 1 – September 30) discharge at Four Corners, CO averaged 1,175 cfs in 2016, slightly higher than the mean of 976 cfs from 2003 – 2015. The higher summer average was likely inflated by a large spike which occurred on August 6, 2016 (Figure 4). Number of days less than 500 cfs during the summer was low (N: 1), although the number of days less than 1,000 cfs in 2016 (N: 66) was similar to the previous 13 year average of 61.

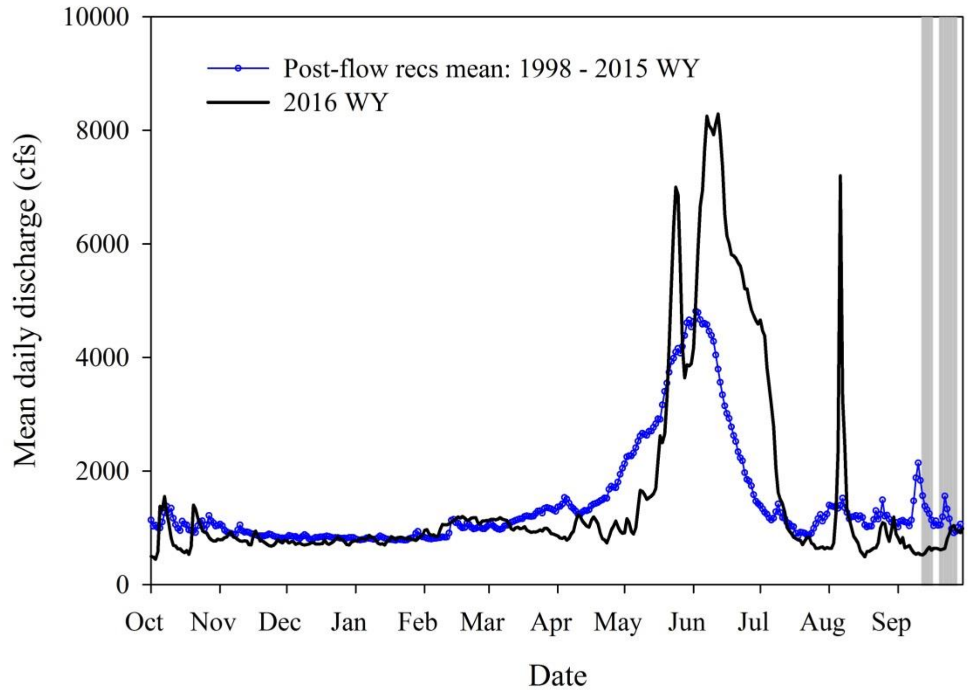


Figure 4. Comparison of San Juan River discharge (cfs) at Four Corners, CO during the 2016 water year (WY) and the mean daily discharge during the post-flow recommendations (post-flow recs) period (1998 – 2015 WY). The grey horizontal bars indicate when small-bodied fishes sampling occurred in 2016.

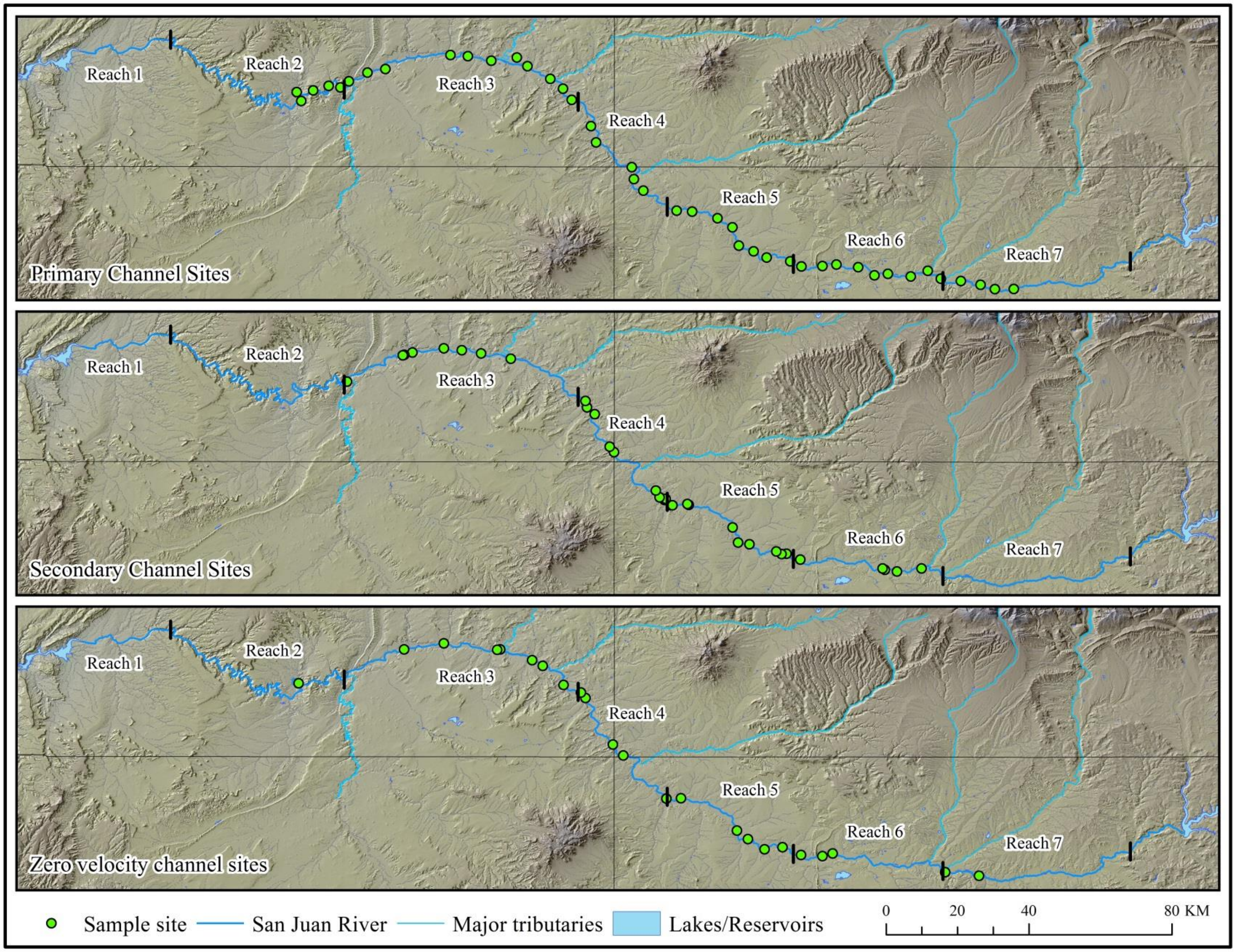


Figure 5. The location of primary channel (top), secondary channel (middle), and zero-velocity channel (bottom) sampling sites during 2016 small-bodied fishes monitoring on the San Juan River. Note that sampling occurred only from River Mile 196.1 (just upstream of the top of Reach 6) to River Mile 52.8 (middle of Reach 2).

River-wide Fish Summary

In 2016, SBF monitoring occurred from 12 – 16 and 20 – 27 September and sampled RM 196.1 (Bloomfield, NM; Reach 7) to RM 52.8 (Mexican Hat, UT; Reach 2) (Figure 2). Sampling occurred at 43 primary channel sites (8,588 m^2), 32 secondary channel sites (5,271 m^2), and 23 zero velocity channel sites (1,984 m^2) (Figure 5). Discharge during sampling averaged 732 cfs and ranged from 521 – 1040 cfs (Figure 4). The frequency of sampled mesohabitats varied between primary and secondary channel types, although runs were the most common mesohabitat sampled in both (Figure 6). Slackwater, riffles, and shoals were the next most common mesohabitats sampled in the primary channel. In secondary channels, pools, slackwaters, and riffles were the most commonly sampled mesohabitats following runs. Plunges were the least common sampled mesohabitat types in both the primary channel and secondary channels.

A total of 6,513 fishes were captured river-wide, 5,212 (80%) of which were native (Table 3). Speckled Dace *Rhinichthys osculus* (N: 4,438, 68%) were the most commonly captured fish species followed by Channel Catfish *Ictalurus punctatus* (N: 716, 11%), Bluhead Sucker *Catostomus discobolus* (N: 363, 6%), and Flannelmouth Sucker *Catostomus latipinnis* (N: 362, 6%). Total density of fishes (fish/100 m^2) river-wide was higher in 2016 than 2014 and 2015 in the primary channel and secondary channels (Figure 7). Total fish density (fish/100 m^2) in zero velocity channels was similar to 2014 and 2015 and lower than most previous years. Total density in zero velocity channels has much higher annual variability compared to density in the primary channel and secondary channels. The proportion of native fishes remained high (> 0.60) in all three channel types (Figure 7). This continues a trend observed since 2003 with the proportion of native species increasing across all three channel types. No Mottled Sculpin *Cottus bairdi* were captured in 2016, but three age-0 (mean 33 mm TL; range 31 – 36 mm TL) Roundtail Chub *Gila robusta* were captured from a single large backwater at RM 153.0.

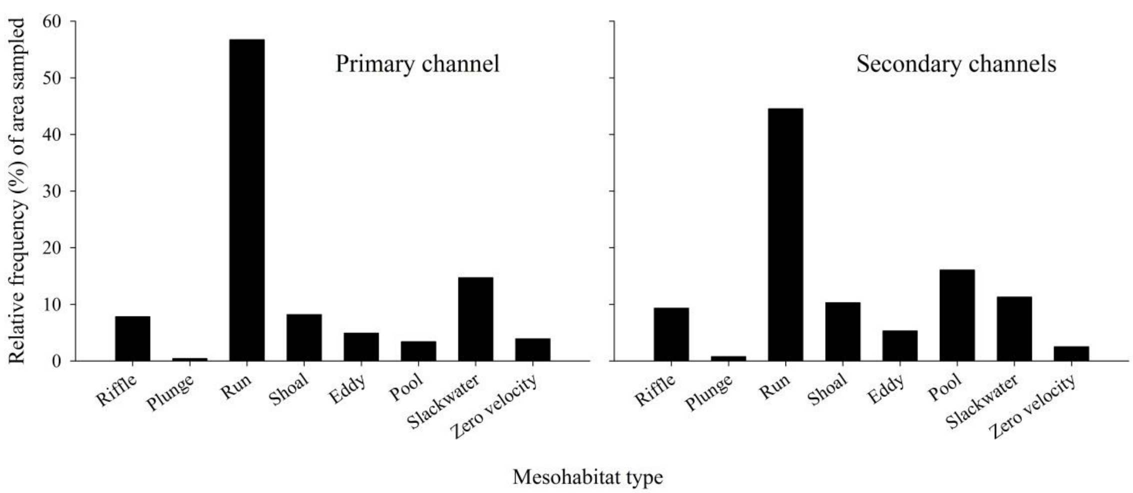


Figure 6. The relative frequency (%) of area, by mesohabitat type, sampled in the primary channel (left) and secondary channels (right) during 2016 small-bodied fishes monitoring on the San Juan River.

Table 3. Number of fish captured by species and channel type during small-bodied fishes monitoring on the San Juan River in 2016. Note that this includes only fish used in calculations of density except for age-2+ Colorado Pikeminnow and Razorback Sucker.

Species	Primary channel	Secondary channels	Large backwaters	Total
Bluehead Sucker	77	254	32	363
Flannelmouth Sucker	193	88	81	362
Roundtail Chub	0	0	3	3
Colorado Pikeminnow				
Age-0	4	8	11	23
Age-1	8	8	3	19
Age-2+	0	1	0	1
Speckled Dace	2733	1459	246	4438
Razorback Sucker				
Age-0	0	0	1	1
Age-1	0	0	0	0
Age-2+	0	1	1	2
Total natives	3015	1819	378	5212
Black Bullhead	2	5	3	10
White Sucker	1	1	2	4
Common Carp	0	6	1	7
Red Shiner	32	18	31	81
Plains Killifish	2	2	3	7
Western Mosquitofish	31	133	26	190
Channel Catfish	456	192	68	716
Green Sunfish	0	1	1	2
Largemouth Bass	1	0	2	3
Fathead Minnow	133	68	51	252
White Crappie	1	0	0	1
Total nonnatives	659	426	188	1273
Total fish (% native)	3689 (82.1)	2254 (81.0)	570 (66.8)	6513 (80.4)

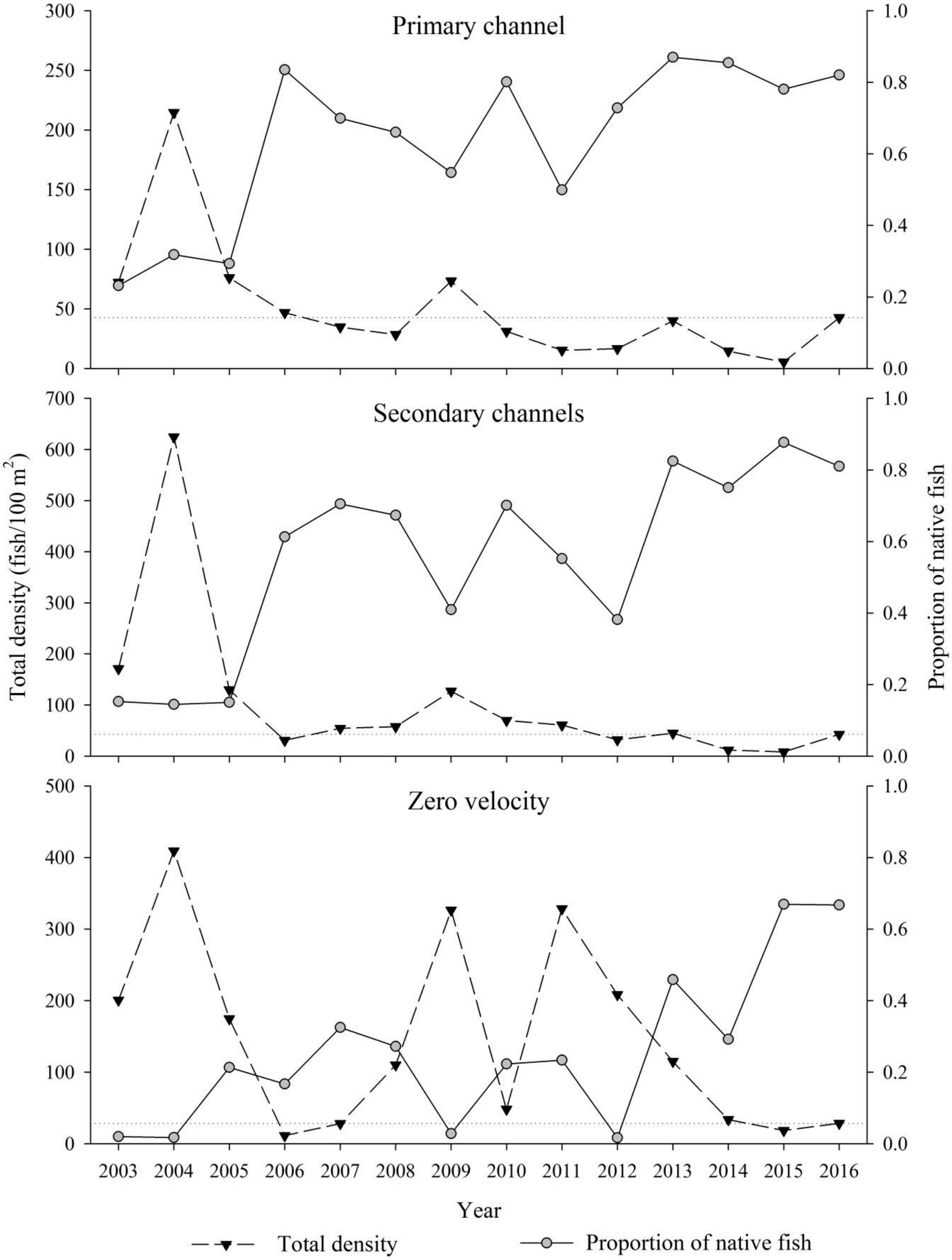


Figure 7. The total density (fish/100 m^2) of all fishes and proportion of native fishes captured in the primary channel (top), secondary channels (middle), and zero velocity channels (bottom) during small-bodied fishes monitoring on the San Juan River from 2003 – 2016. Note that dotted grey lines indicate the 2016 total density (fish/100 m^2) for that channel type.

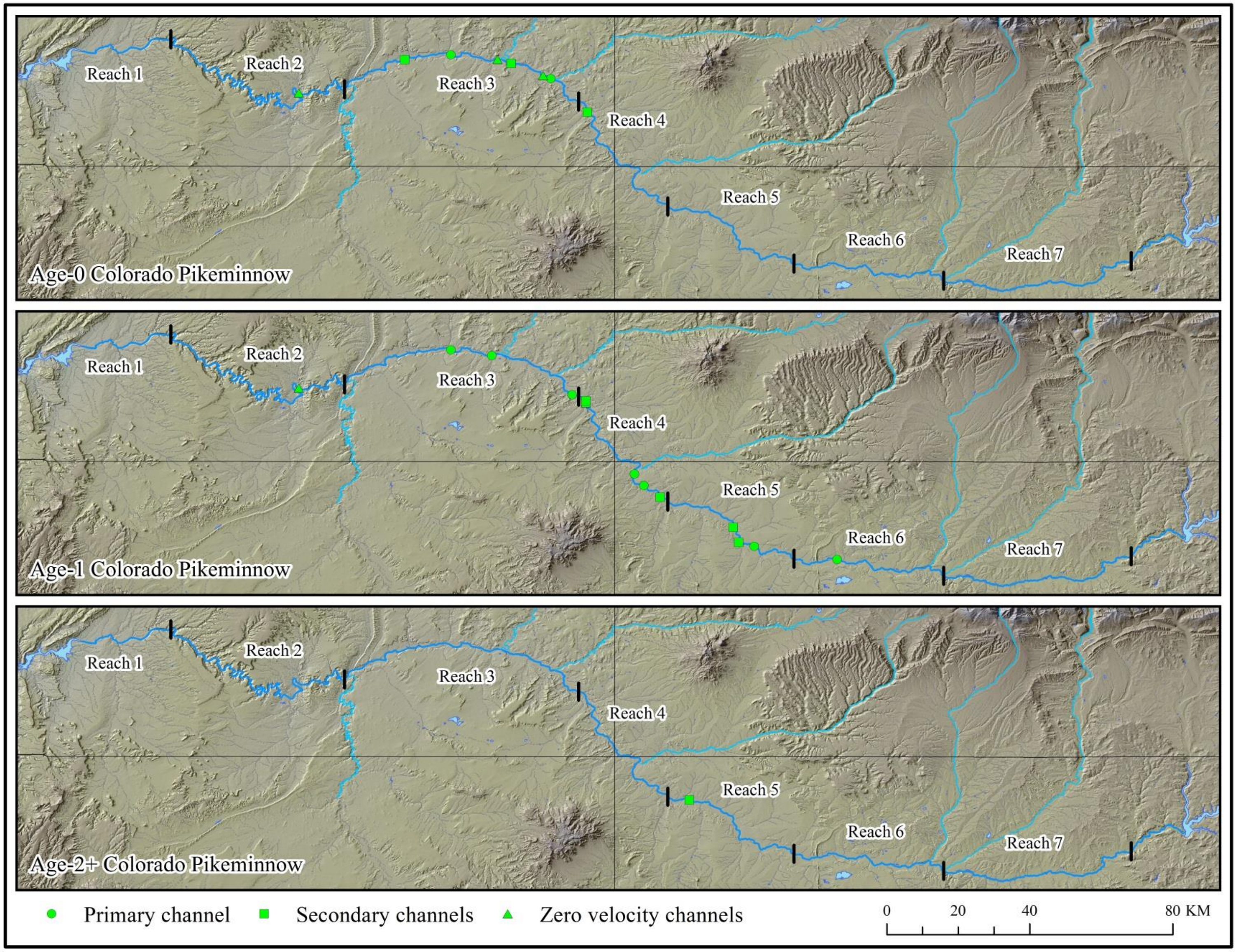
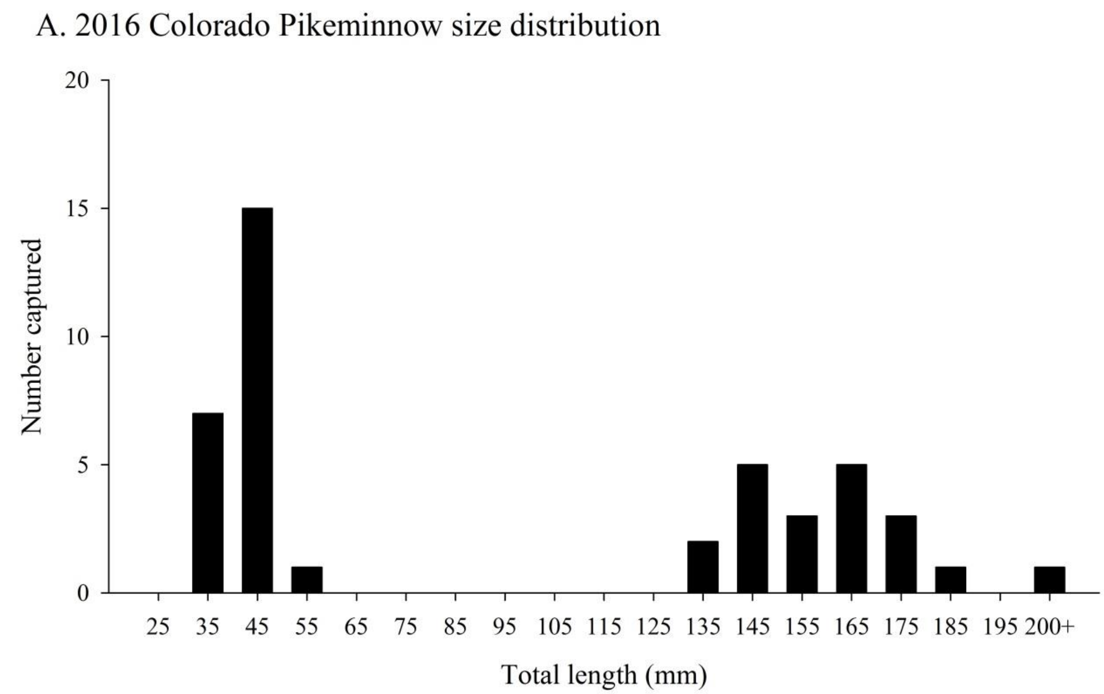


Figure 8. Location of age-0, age-1, and age-2+ Colorado Pikeminnow captured, by channel type, during small-bodied fishes monitoring on the San Juan River in 2016. Note that sampling occurred only from River Mile 196.1 (just upstream of the top of Reach 6) to River Mile 52.8 (middle of Reach 2).



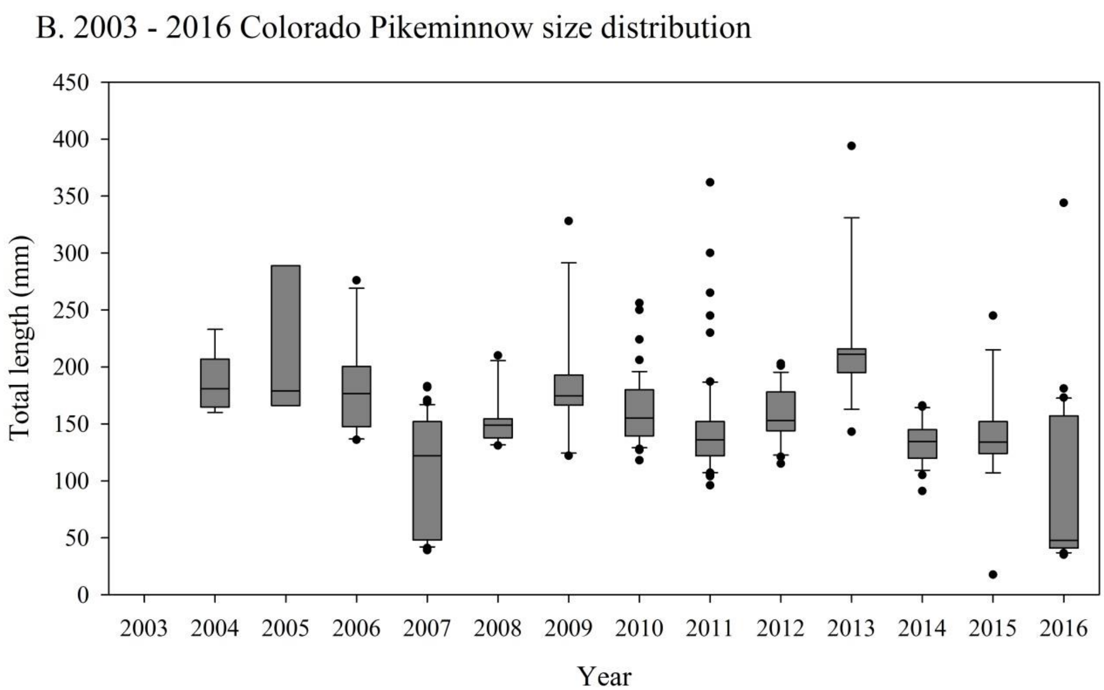


Figure 9. Size distribution (total length, mm) of Colorado Pikeminnow captured during small-bodied fishes monitoring on the San Juan River in (A) 2016 and (B) 2003 – 2016. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box farthest from zero indicates the 75th percentile, and whiskers are the 10th and 90th percentiles, and circles are outliers.

Endangered Fishes

Colorado Pikeminnow.— Forty-three Colorado Pikeminnows were captured in 2016, 23 of which were wild age-0 (< 90 mm TL), 19 were age-1 (90 ≥ mm TL ≤ 199), and 1 was age-2+ (344 mm TL). All age-1+ fish which were captured were assumed to be the result of population augmentation efforts, as 2016 was the first year that wild post-larval age-0 Colorado Pikeminnow have been captured during any monitoring effort on the San Juan River since standardized monitoring began in 1998. Captures occurred in Geomorphic Reaches 2 – 6 and occurred in all channel types (Figure 8). The size distribution of captured Colorado Pikeminnow ranged from 32 – 344 mm TL (Figure 9A). In comparison to previous years, the median size of fish captured in 2016 was much lower than all other years except 2007 (Figure 9B). The decrease in median size of captured fish can be attributed to the capture of age-0 in 2016.

The 23 age-0 Colorado Pikeminnows were captured in primary channel, secondary channel, and zero velocity channel sites but only between RM 108.4 and 57.8 (Figure 8). Age-0 fish averaged 42 mm TL and ranged 35 – 51 mm TL. Due to the lack of data, only captures from 2016 and Geomorphic Reaches 2 – 4 were included when analyzing age-0 Colorado Pikeminnow density, therefore sampYear was not fixed in either the $\boldsymbol{CPUE_{0/1}}$ or $\boldsymbol{CPUE^{+}}$ models. The top Delta-GLM model for age-0 Colorado Pikeminnow included $\boldsymbol{CPUE_{0/1}}$(Reach + Mesohabitat)$\boldsymbol{CPUE^{+}}$(Reach) based on the lowest AIC_c and weight (Table 4). Although the $\boldsymbol{CPUE_{0/1}}$ had a high AUC (0.93) and the $\boldsymbol{CPUE^{+}}$ had a moderate fit ($y = 0.53x + 5.09$, R^2: 0.42) between observed and predicted density values, the Delta-GLM had a poor fit ($y = 0.04x + 1.62$, R^2: 0.04) with predicted densities being under predicted at high observed densities (Table 5).

Probability of presence for age-0 Colorado Pikeminnow varied significantly between reaches (X^2: 50.7, $P < 0.01$), channel types (X^2: 50.2, $P < 0.01$), and mesohabitat types (X^2: 212.9, $P < 0.01$) (Figure 10). Fish were less likely to be present in the primary channel and Geomorphic Reach 4, although the low probability of presence in Reach 4 is likely due to captures occurring at only one site in this reach which was located at the downstream end of the reach. Age-0 Colorado Pikeminnow were only captured in pool, slackwater, and zero-velocity mesohabitat types, with the probability of presence highest in pools followed by zero-velocity mesohabitat types. Median density of age-0 Colorado Pikeminnow for Reaches 2 – 4 was 2.1 fish/100 m² (range: 0.1 – 3.9 fish/100 m², N: 12) in 2016. Median density in the primary channel was 2.1 fish/100 m² (N: 3), 2.3 fish/100 m² (range: 0.1 – 2.4 fish/100 m², N: 4) in secondary channels, and 0.8 fish/100 m² (range: 0.8 – 3.9 fish/100 m², N: 5) in zero velocity channel types.

Table 4. Explanatory variables included in the top five Delta-GLM models used to predict density of age-0 Colorado Pikeminnow.

Model	Logistic model	Lognormal model	ΔAICc	w_i
1	$CPUE_{0/1}$(Reach + Mesohabitat)	$CPUE^{+}$(Reach)	0	0.18
2	$CPUE_{0/1}$(Reach + ChannelType + Mesohabitat)	$CPUE^{+}$(Reach)	1.77	0.08
3	$CPUE_{0/1}$(Reach + Mesohabitat)	$CPUE^{+}$(Reach + sampDis)	2.03	0.07
4	$CPUE_{0/1}$(Reach + Mesohabitat + sampDis)	$CPUE^{+}$(Reach)	2.20	0.06
5	$CPUE_{0/1}$(Reach + Mesohabitat)	$CPUE^{+}$(Reach + Mesohabitat)	2.32	0.06

Table 5. Results and validation for the top CPUE0/1, CPUE+, and Delta-GLM models used to predict the density of age-0 Colorado Pikeminnow, age-1 Colorado Pikeminnow, Bluehead Suckers, Flannelmouth Suckers, Speckled Dace, Channel Catfish, Fathead Minnows, Red Shiners, and Western Mosquitofish captured during small-bodied fishes sampling in the San Juan River from 2003 - 2016. Shown is the residual deviance in percent (Res. Dev. %), residual degrees of freedom (Res. df), area under the curve (AUC), and linear regression fits (coefficient of determination R^2, intercept, and slope) between predicted and observed densities.

	$CPUE_{0/1}$			$CPUE^+$					Delta-GLM		
Species	Res. Dev. (%)	Res. df	AUC	Res. Dev. (%)	Res. df	R^2	Int.	Slope	R^2	Int.	Slope
Age-0 Colorado Pikeminnows	35.8	260	0.93	34.8	9	0.42	5.09	0.53	0.04	1.62	0.04
Age-1 Colorado Pikeminnows	11.2	6617	0.77	28	172	0.21	4.3	0.21	0.03	0.31	0.01
Bluehead Suckers	25.2	6101	0.85	21.1	733	0.12	11.68	0.14	0.1	3.52	0.08
Flannelmouth Suckers	16.2	6127	0.77	18.9	1179	0.15	9.62	0.15	0.15	2.85	0.15
Speckled Dace	23.5	7176	0.81	24.9	3314	0.14	28.57	0.19	0.14	19.02	0.19
Channel Catfish	19.5	5740	0.79	11.5	1621	0.06	13.2	0.07	0.05	5.84	0.05
Fathead Minnows	31.3	6102	0.88	30.4	524	0.24	26.03	0.26	0.24	8.24	0.23
Red Shiners	31.7	6954	0.86	32	1633	0.21	46.62	0.21	0.21	27.19	0.19
Western Mosquitfish	26.4	6128	0.87	21.8	307	0.14	22.62	0.16	0.13	4.65	0.09

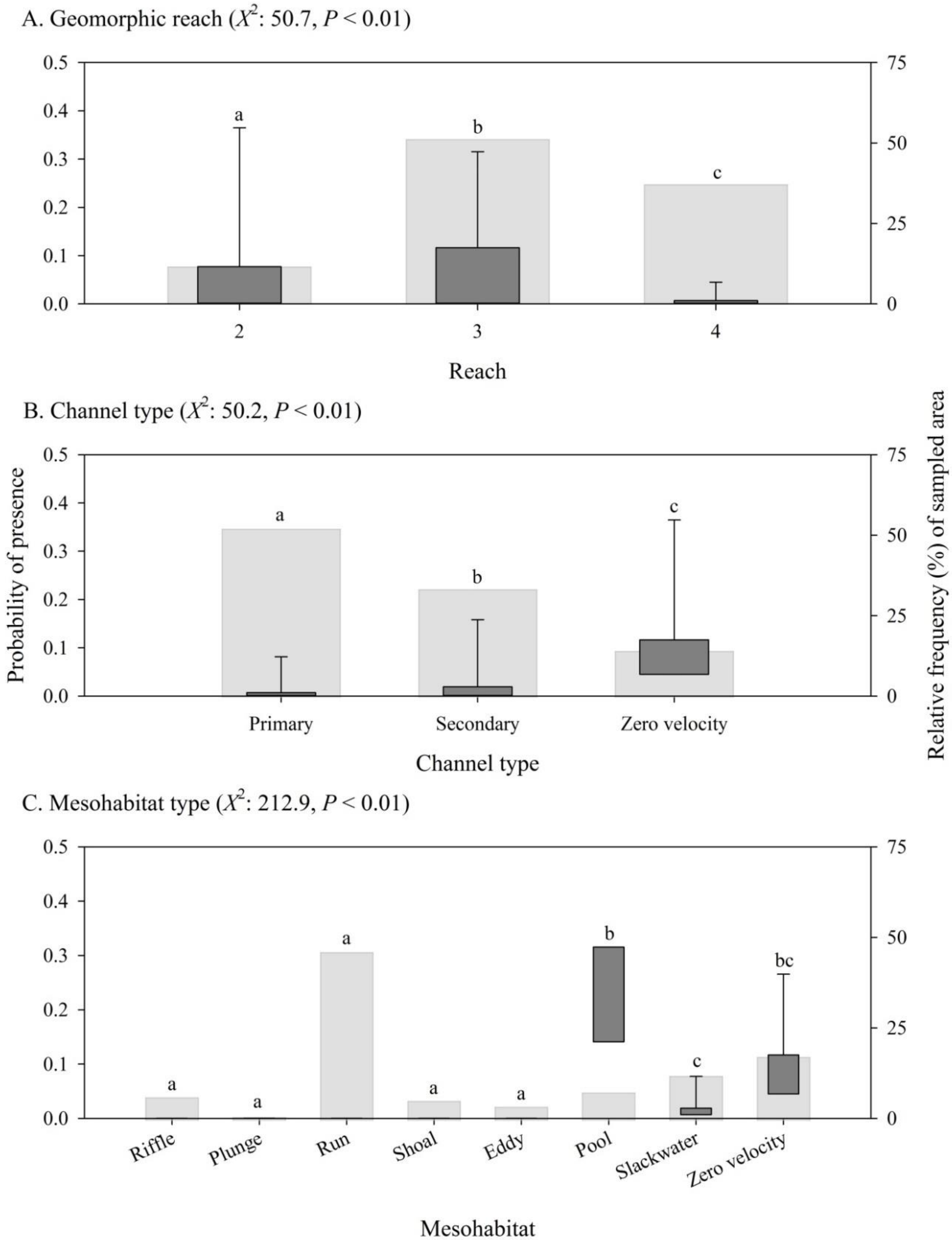


Figure 10. Probability of presence of age-0 Colorado Pikeminnow and relative frequency (%) of area sampled by (A) Geomorphic Reach, (B) channel type, and (C) mesohabitat type with results of Kruskal-Wallis ANOVA for Ranks. Letters indicate groupings based on the Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

Nineteen age-1 Colorado Pikeminnows were captured across primary channel (N = 8), secondary channel (N = 8), and zero velocity (N = 3) sampling sites between RM 162.0 and 57.8 (Figure 8). Age-1 fish averaged 156 mm TL (range: 132 – 181 mm TL), similar to the size distribution of previous years if 2016 age-0 fish were removed from the distribution (Figure 9). All seine hauls from Reach 7 and the year 2003 were removed for analysis of age-1 Colorado Pikeminnow density because both this Geomorphic Reach and year lacked captures. The top Delta-GLM model included $CPUE_{0/1}$(Year + Reach + Mesohabitat + sampDis) $CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis) based on the lowest AIC_c and highest AIC_c weight (Table 6). The $CPUE_{0/1}$ had a fair fit (AUC: 0.77) but $CPUE^{+}$ (y = 4.30 + 0.21x, R^2: 0.21) and the Delta-GLM (y = 0.31 + 0.01x, R^2: 0.03) both had poor fits between observed and predicted density, with density being underestimated at high densities in both models (Table 5).

The probability of presence for age-1 Colorado Pikeminnow varied significantly among reaches (X^2: 2,210.7, $P < 0.01$), with Reach 5 having the highest probability of presence (Figure 11A). A general decreasing trend in probability of presence is observed from Reach 4 down to Reach 1. Secondary and zero velocity channels had similar probabilities of presence, with both being greater than the primary channel. This is an interesting finding given that significantly more habitat is sampled in the primary channel compared to the combined amount of habitat sampled in secondary and zero velocity channels (Figure 11B). Probability of presence also varied significantly between mesohabitats (X^2: 950.9, $P <0.01$). Although several mesohabitats had similar probabilities of presence, riffle and slackwater mesohabitats had significantly lower probability of presence than other types (Figure 11C).

Median density of Colorado Pikeminnow in Reaches 3 – 6 in 2016 was 0.1 fish/100 m^2 (range: 0.0 – 0.3 fish/100 m^2, N: 8) in the primary channel, 0.4 fish/100 m^2 (range: 0.2 – 0.6 fish/100 m^2, N: 4) in secondary channels, and 0.1 fish/100 m^2 (range: 0.0 – 0.1 fish/100 m^2, N: 2) in zero velocity channels. Densities in these reaches have high annual variability, and few years were significantly different from 2016 across all three channel types (Figure 12). Only densities in the primary channel showed significant differences with densities in 2010 and 2011 being significantly higher than 2016. Although only a small portion of Reach 2 was sampled, two age-1 Colorado Pikeminnow were captured in a single seine haul. The density of age-1 Colorado Pikeminnow in Reach 2 was 0.03 fish/100 m^2 (N: 1). No age-1 Colorado Pikeminnow were captured in Reach 7 in 2016, and none have been captured in this reach since SBF monitoring began in this reach in 2012.

Table 6. Explanatory variables included in the top five Delta-GLM models used to predict density of age-1 Colorado Pikeminnows.

Model	Logistic model	Lognormal model	ΔAICc	w_i
1	$CPUE_{0/1}$(Year + Reach + Mesohabitat + sampDis)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	0.00	0.44
2	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	1.51	0.21
3	$CPUE_{0/1}$(Year + Reach + Mesohabitat + sampDis)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat)	2.56	0.12
4	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat)	4.07	0.06
5	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Reach*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	5.16	0.03

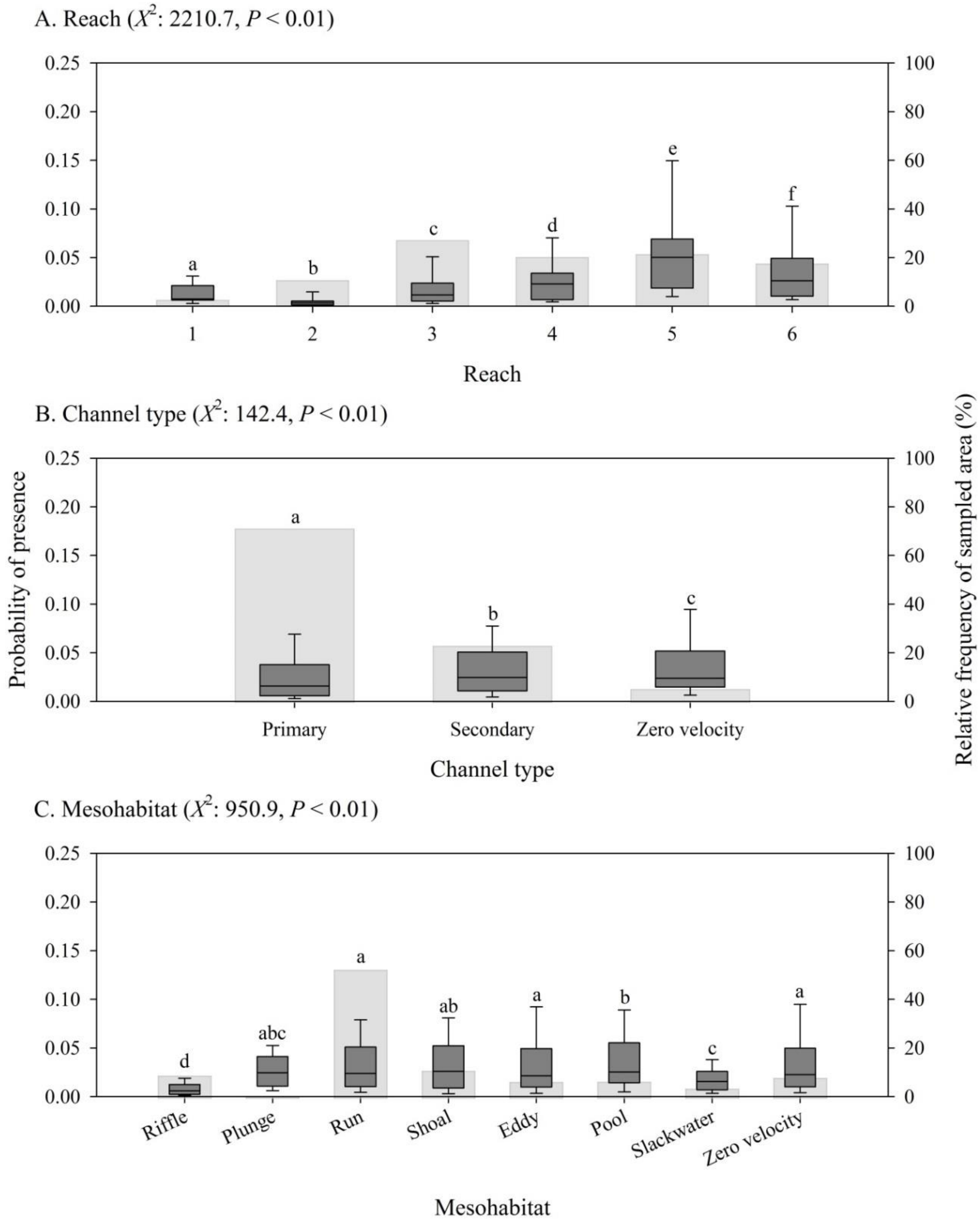


Figure 11. Probability of presence of age-1 Colorado Pikeminnow and relative frequency (%) of area sampled by (A) Geomorphic Reach, (B) channel type, and (C) mesohabitat type with results of Kruskal-Wallis ANOVA for Ranks. Letters indicate groupings based on the Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

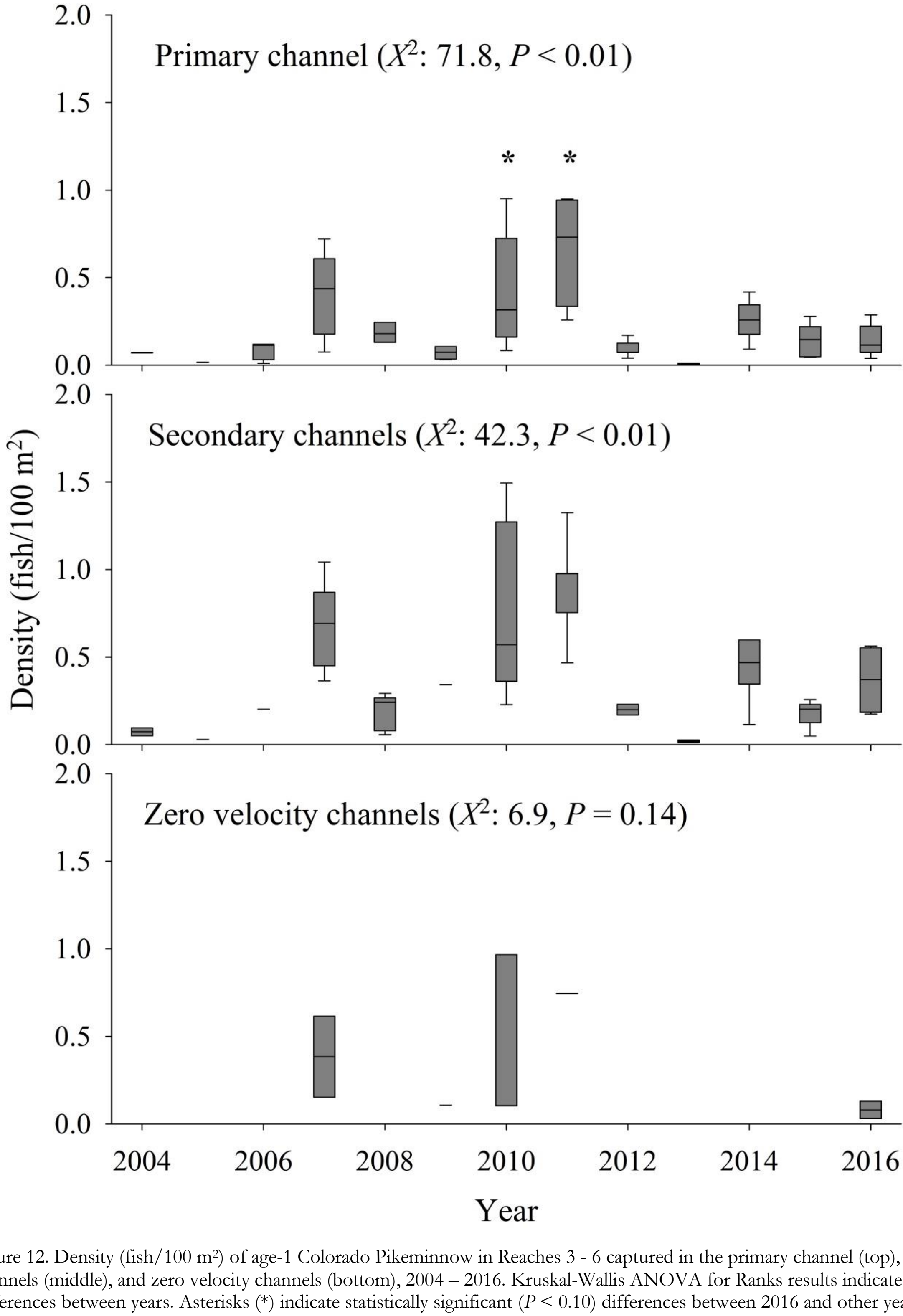


Figure 12. Density (fish/100 m^2) of age-1 Colorado Pikeminnow in Reaches 3 - 6 captured in the primary channel (top), secondary channels (middle), and zero velocity channels (bottom), 2004 – 2016. Kruskal-Wallis ANOVA for Ranks results indicate significant differences between years. Asterisks (*) indicate statistically significant (P < 0.10) differences between 2016 and other years based on Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

Razorback Sucker.— Three Razorback Suckers were captured in 2016. One age-0 fish (123 mm TL; Figure 13), which was presumed to be wild, was captured in a zero velocity channel located at the confluence of Lime Creek, UT (RM 57.8) (Figures 14). This would be the first wild age-0 Razorback Sucker ever captured during SBF monitoring and one of the very few ever captured in the San Juan River since the SJRIP began in 1992. The two remaining fish were adults (> 350 mm), both of which had been previously PIT tagged. Due to lack of age-0 and age-1 Razorback Sucker captures, no further analyses were conducted.

Figure 13. Picture of the age-0 Razorback Sucker (123 mm total length) captured in a zero velocity channel located at the confluence of Lime Creek, UT (River Mile 57.8).

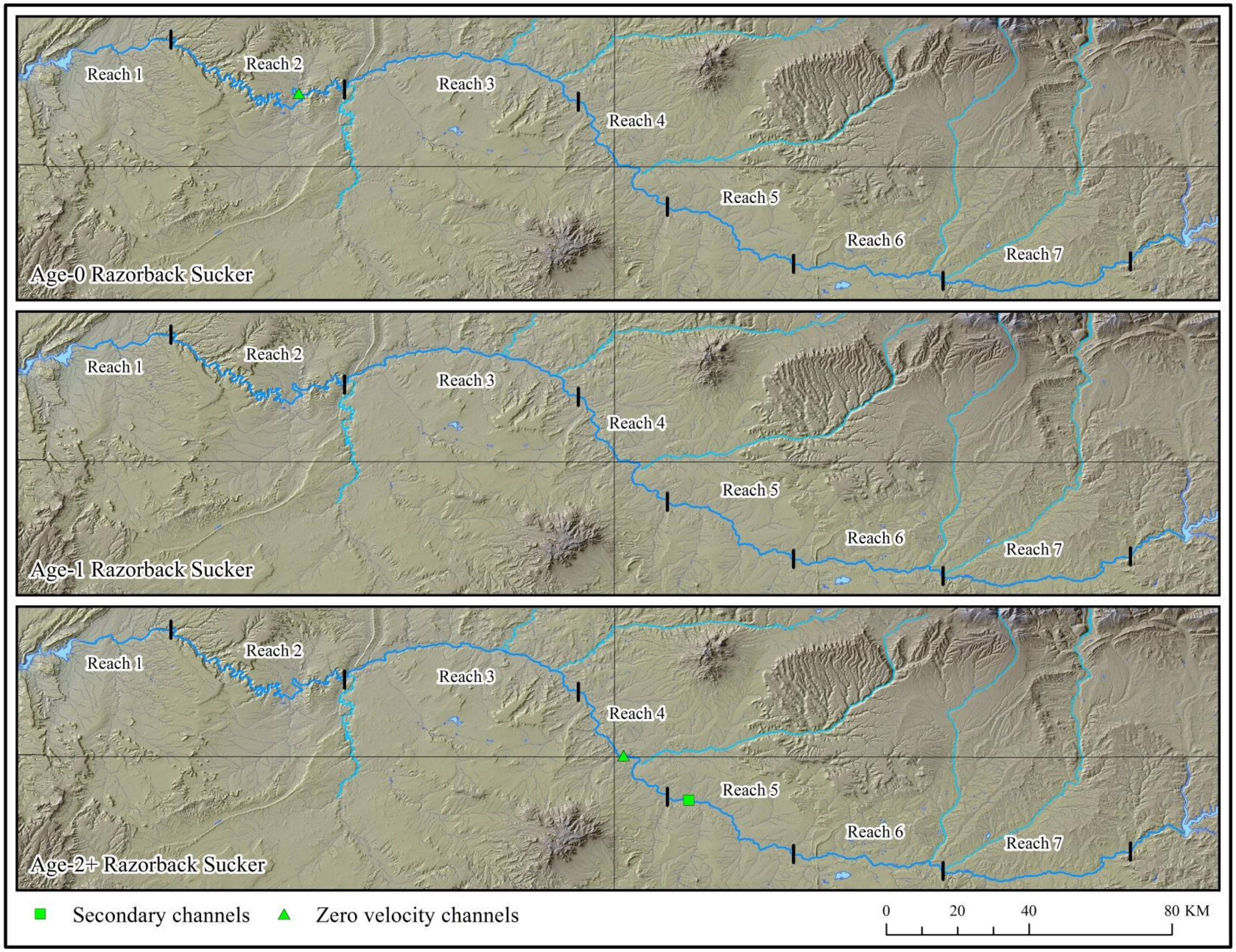


Figure 14. Location of age-0, age-1, and age-2+ Razorback Sucker captured, by channel type, during small-bodied fishes monitoring in 2016. Note that sampling occurred from River Mile 196.1 (just upstream of the top of Reach 6) to River Mile 52.8 (middle of Reach 2).

Common Native Fishes

Bluehead Sucker.— During 2016 SBF monitoring, 363 Bluehead Suckers were captured. Mean length of captured fish was 45 mm TL and ranged from 24 – 110 mm TL (Figure 15). The greatest number of captures occurred in secondary channels (N: 254), followed by the primary channel (N: 77) and zero velocity channels (N: 32). The majority of Bluehead Suckers were captured in Reach 6 (N: 290), with fewer captures occurring in Reach 7 (N: 16), Reach 5 (N = 45), and Reach 4 (N: 12). No Bluehead Suckers were captured in either Reach 3 or Reach 2.

Only 11% of seine hauls from 2003 – 2016 resulted in the capture of at least one Bluehead Sucker (Figure 3). Reaches 1 and 2 were excluded from analysis because each had less than 3% of seine hauls with a capture. The top Delta-GLM model included $CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach + Year*ChannelType) $CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis) based on the lowest AIC_c score and highest AIC_c weight (Table 7). The $CPUE_{0/1}$ model had a moderately high fit (AUC: 0.85) but fits for the $CPUE^{+}$ ($y = 0.14x + 11.68$, R^2:0.12) and the Delta-GLM ($y = 0.1x + 3.52$, R^2: 0.08) models were both poor, with densities often being under estimated (Table 5).

Significant differences for the probability of presence of Bluehead Suckers were observed across reaches (X^2: 3,208.7, $P < 0.01$), channel types (X^2: 12.4, $P < 0.01$), and mesohabitats (X^2: 90.5, $P < 0.01$) (Figure 16). The species was much more likely to be present in Reaches 6 and 7, with a decreasing chance of occurrence from Reach 5 to Reach 3. Bluehead Suckers were more likely to be present in zero velocity channels compared to both secondary channels and the primary channel, but the probability of occurrence was greater in secondary channels than the primary channel. Probability of presence was similar between several mesohabitat types, but the species was more likely to occur in zero velocity and shoal types, followed by runs and riffles (Figure 16C).

Median density of Bluehead Suckers in Reaches 3 - 6 in 2016 were 3.2 fish/100 m^2 (range: 0.3 – 4.0 fish/100 m^2, N: 21) in the primary channel, 6.0 fish/100 m^2 (range: 0.6 – 4.3 fish/100 m^2, N: 20) in secondary channels, and 1.7 fish/100 m^2 (range: 1.0 – 9.4 fish/100 m^2, N: 5) in zero velocity channels. Densities in 2016 were not significantly different from any years in secondary channels and zero velocity channels but were significantly lower than densities in 2004 and 2006 in the primary channel (Figure 17). Lack of significant differences between 2016 densities and previous years indicates a relatively stable population of juvenile Bluehead Suckers in Reaches 3 – 6 since 2003. Bluehead Suckers were also captured in the primary channel and zero velocity channels of Reach 7 in 2016, but no secondary channels were sampled in this reach (Figure 17). Median density in the primary channel was 3.1 fish/100 m^2 (range: 2.2 – 10.8 fish/100 m^2, N: 5) and 8.9 fish/100 m^2 (N: 2) in zero velocity channels in Reach 7. Trends in density for Reach 7 were not analyzed due to an overall lack of data for this reach.

Table 7. Explanatory variables included in the top five Delta-GLM models used to predict density of Bluehead Suckers.

Model	Logistic model	Lognormal model	ΔAICc	w_i
1	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	0	0.46
2	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat)	1.08	0.27
3	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	3.26	0.09
4	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat)	4.34	0.05
5	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Reach*ChannelType)	5.21	0.03

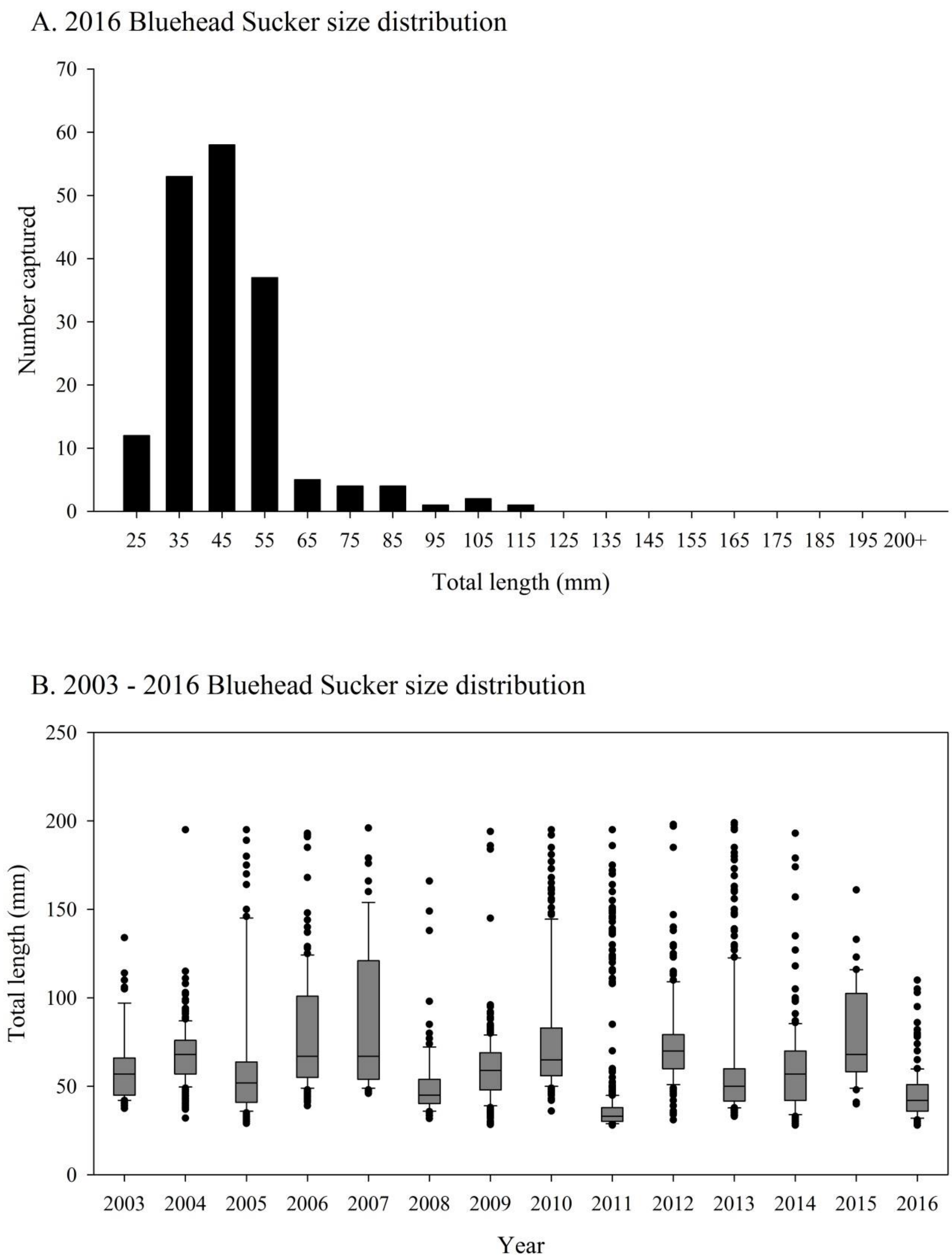


Figure 15. Size (total length, mm) distribution of Bluehead Sucker captured during small-bodied fishes monitoring in (A) 2016 and (B) 2003 – 2016. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles, and circles are outliers.

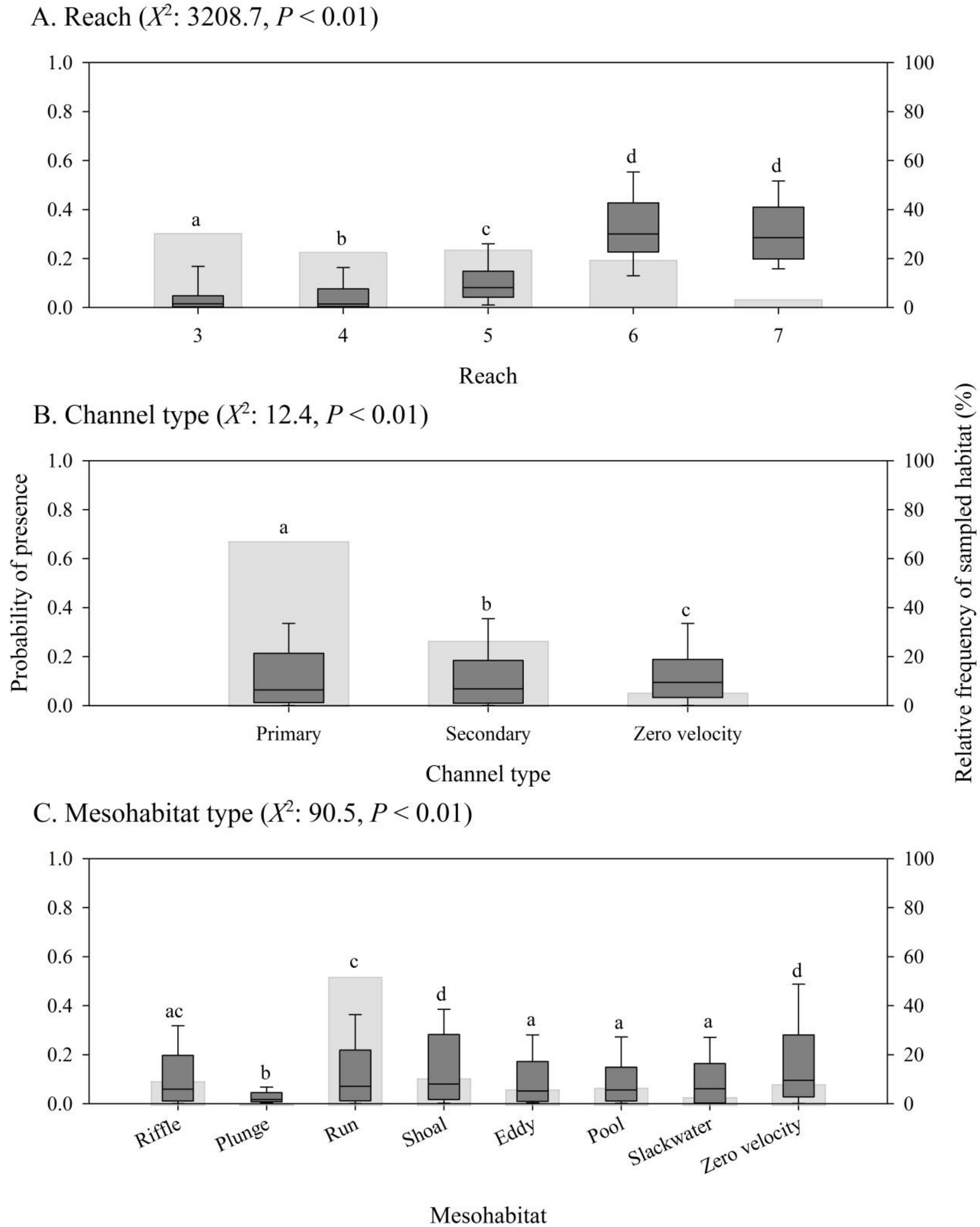


Figure 16. Probability of presence of Bluehead Sucker and relative frequency (%) of area sampled by (A) Geomorphic Reach, (B) channel type, and (C) mesohabitat type with results of Kruskal-Wallis ANOVA for Ranks. Letters indicate groupings based on the Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

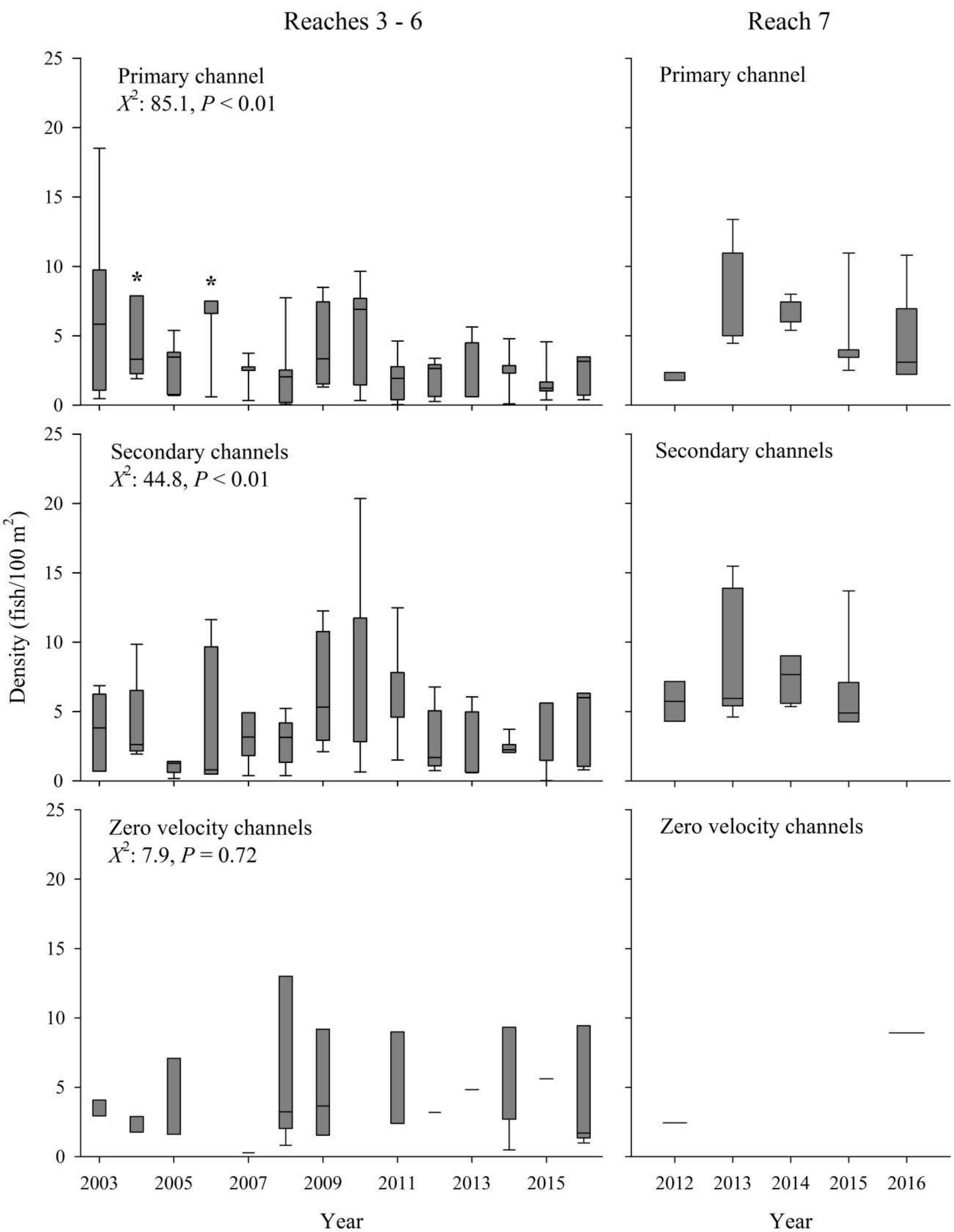


Figure 17. Density (fish/100 m²) of Bluehead Sucker captured during small-bodied fishes monitoring in the primary channel (top), secondary channels (middle), and zero velocity channels (bottom) in Reaches 3 – 6 from 2003 – 2016 (left) and Reach 7 from 2012 - 2016 (right). Kruskal-Wallis ANOVA for Ranks results indicate significant differences between years. Asterisks (*) indicate statistically significant (P < 0.10) differences between 2016 and other years based on Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

Flannelmouth Sucker.— Three-hundred and seventy-two Flannelmouth Suckers were captured in 2016, the fourth most commonly captured species. The greatest number of captures occurred in the primary channel (N: 193), followed by secondary channels (N: 88) and zero velocity channels (N: 79). Reach 5 (N: 169) and Reach 6 (N: 100) had the greatest number of captures. Almost no captures occurred in Reach 2 (N: 2) or Reach 7 (N: 3). Captured fish averaged 68 mm TL in 2016, but the variation in size of captured fish was large (range: 26 – 482 mm TL; Figure 18A). The median size and range of fish captured in 2016 was similar to previous years (Figure 18B).

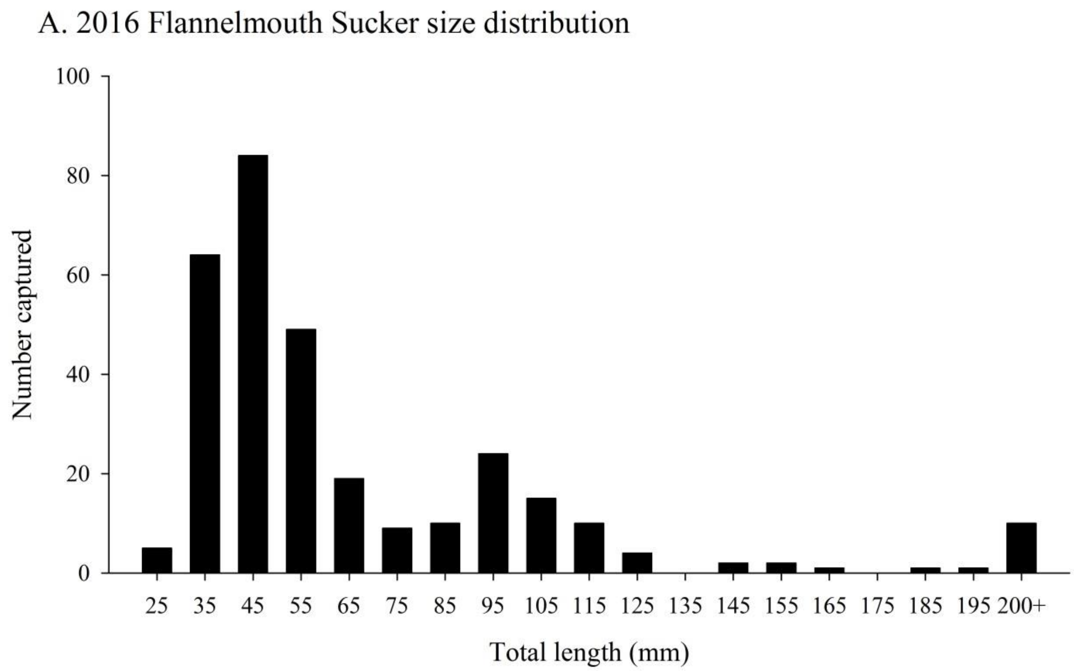
Captures of Flannelmouth Sucker occurred in 17.8% of all seine hauls since 2003 (Figure 3), but Reaches 1 and 2 were not included in density analyses because captures of Flannelmouth Sucker occurred in less than 3% of the seine hauls in these two Reaches. The top Delta-GLM model included $CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach)$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis) based on the lowest AIC_c and top AIC_c weight (Table 8). The next top three models were within 1 ΔAIC_c and accounted for 50% of the AIC_c weight. The top four models seemed to differ in the inclusion of discharge at time of sampling (sampDis), which was included only in the $CPUE_{0/1}$ model. The $CPUE_{0/1}$ had a decent model fit (AUC: 0.77) but the predictive ability of the $CPUE^{+}$ ($y = 0.15x + 9.92$, R^2: 0.15) and Delta-GLM ($y = 0.15x + 2.85$, R^2: 0.15) models were both low, with density generally being under predicted, especially at higher densities (Table 5).

Probability of presence for Flannelmouth Suckers differed significantly between reaches (X^2: 2,238.9, $P < 0.01$) with Reach 6 having the highest probability of presence and Reach 4 having the lowest (Figure 19A). Channel types had statistically significant differences in probability of occurrence (X^2: 36.1, $P < 0.01$) with probabilities higher in zero velocity and secondary channels in comparison to the primary channel. Probability of presence also differed between mesohabitat types (X^2: 564.5, $P < 0.01$) but several did have similar ranges of probabilities (Figure 19B). Riffles had the lowest probability of presence, with zero-velocity, pools, runs, and shoals all having similar probabilities of occurrence.

The median density of Flannelmouth Suckers in the primary channel of Reaches 3 – 6 was 2.2 fish/100 m^2 (range: 0.5 – 8.7 fish/100 m^2, N: 50) in 2016. The 2016 density in the primary channel was similar to the previous two years but significantly lower than 2003, 2004, 2009, 2010, and 2013 densities (Figure 20). This pattern was also observed in secondary channels and zero velocity channels with the density in secondary channels (median: 3.2 fish/100 m^2, range: 0.7 – 8.1 fish/100 m^2, N: 40) and zero velocity channels (median: 2.6 fish/100 m^2, range: 1.7 – 6.7 fish/100 m^2, N: 20) in Reaches 3 – 6 in 2016 not being significantly higher than any previous year. Density in zero velocity channels of Reaches 3 – 6 have high annual variation, though higher densities in comparison to 2016 do occur in 2009, 2010, and 2013 (Figure 20). Flannelmouth Suckers were captured in Reach 7 in 2016, but only in three seine hauls. Median density in the primary channel of Reach 7 was 1.2 fish/100 m^2 (range: 0.9 – 1.6 fish/100 m^2, N: 2) and 1.8 fish/100 m^2 (N: 1) in zero velocity channels. No secondary channels were sampled in Reach 7 in 2016. Lack of data, low capture rates, and lack of some channel types through time makes it difficult to discern trends in density of Flannelmouth Suckers over time in Reach 7 (Figure 20).

Table 8. Explanatory variables included in the top five Delta-GLM models used to predict density of Flannelmouth Suckers.

Model	Logistic model	Lognormal model	ΔAICc	w_i
1	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat)	0	0.20
2	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	0.19	0.19
3	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat)	0.48	0.16
4	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	0.67	0.15
5	$CPUE_{0/1}$(Year + Reach + Mesohabitat + sampDis + Year*Reach)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat)	2.45	0.06



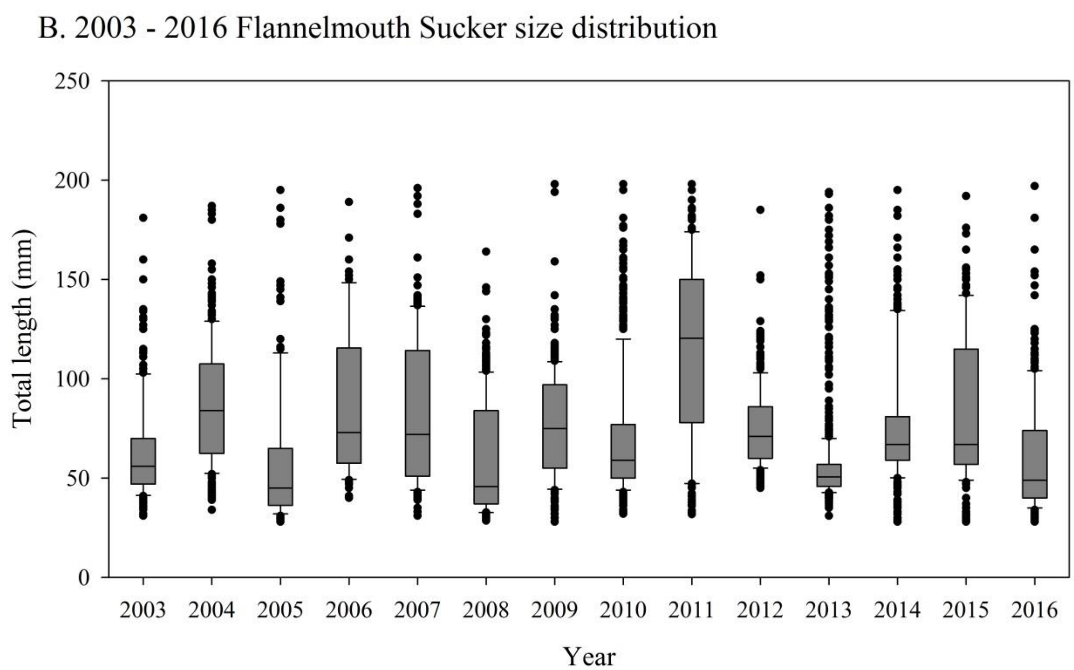


Figure 18. Size (total length, mm) distribution of Flannelmouth Sucker captured during small-bodied fishes monitoring in (A) 2016 and (B) 2003 – 2016. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles, and circles are outliers.

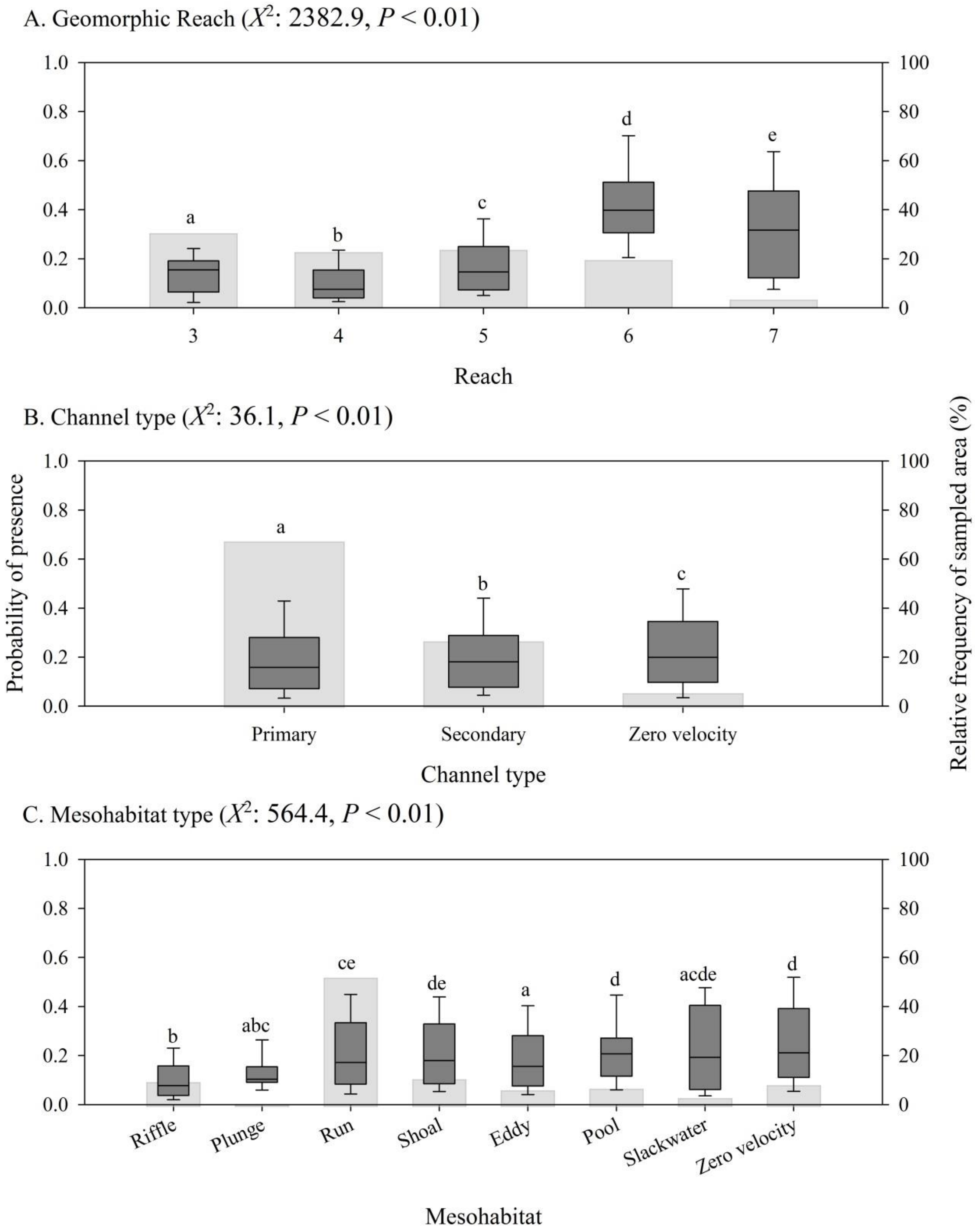


Figure 19. Probability of presence of Flannelmouth Sucker and relative frequency (%) of area sampled by (A) Geomorphic Reach, (B) channel type, and (C) mesohabitat type with results of Kruskal-Wallis ANOVA for Ranks. Letters indicate groupings based on the Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

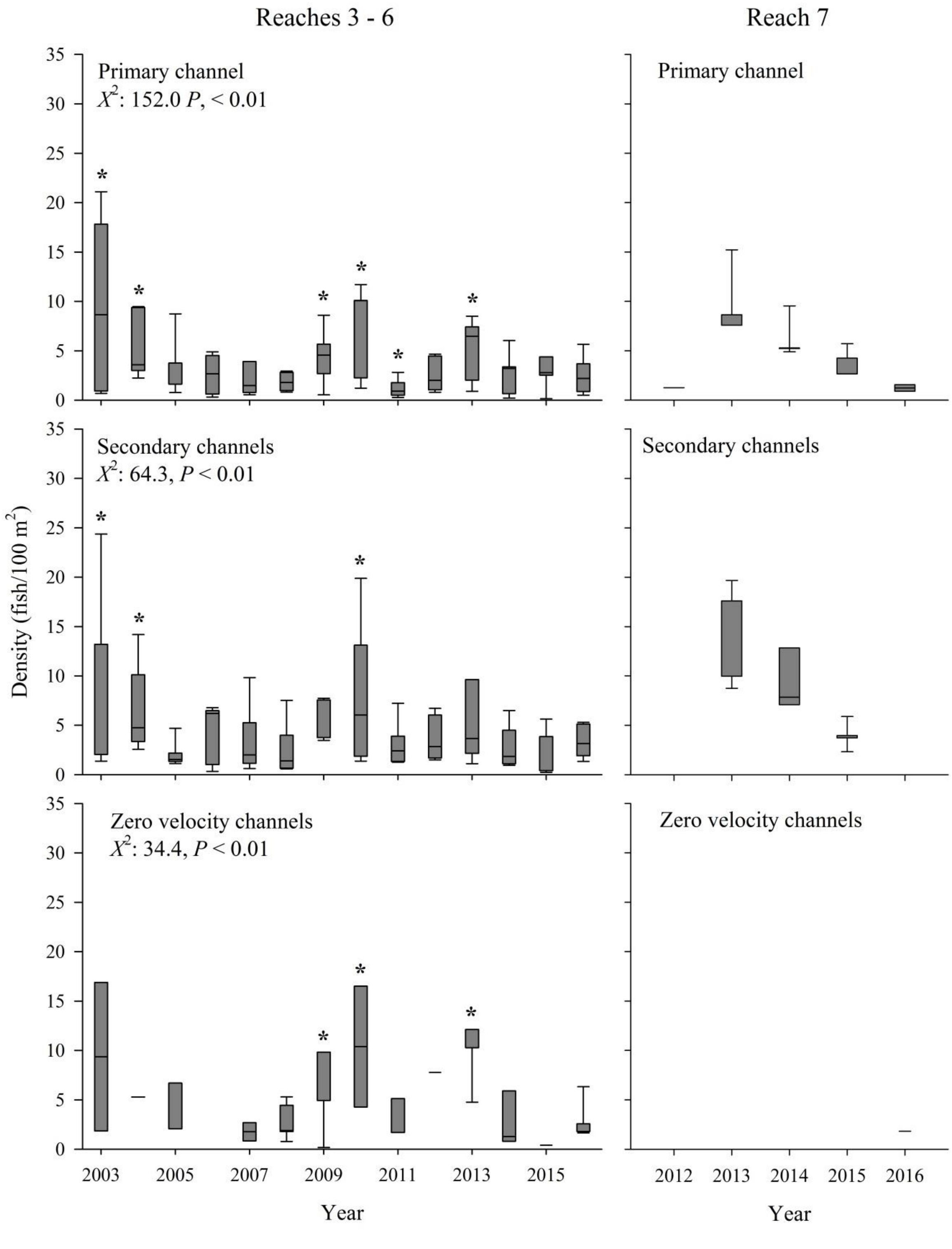


Figure 20. Density (fish/100 m²) of Flannelmouth Sucker captured during small-bodied fishes monitoring in the primary channel (top), secondary channels (middle), and zero velocity channels (bottom) in Reaches 3 – 6 from 2003 – 2016 (left) and Reach 7 from 2012 - 2016 (right). Kruskal-Wallis ANOVA for Ranks results indicate significant differences between years. Asterisks (*) indicate statistically significant ($P < 0.10$) differences between 2016 and other years based on Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

Speckled Dace.— Speckled Dace were the most commonly captured fish species during 2016 SBF monitoring with 4,438 captures. The majority of captures occurred in the primary channel (N: 2,733) followed by secondary channels (N: 1,459) with very few captures occurring in zero velocity channels (N: 246). Captures by Geomorphic Reach were greatest in Reach 6 (N: 2,273) and Reach 5 (N: 1,223) with the lowest number of captures occurring in Reach 7 (N: 83) and Reach 2 (N: 10). Captured Speckled Dace averaged 36 mm TL and ranged from 15 mm TL to 104 mm TL.

Speckled Dace was the most commonly captured fish species during SBF monitoring from 2003 – 2016 with 49% of all seine hauls during that period having at least one capture (Figure 3). No Reaches were removed during the analysis since all had at least 3% of seine hauls with a capture. The top Delta-GLM model included $CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach + Year*ChannelType) $CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach) based on AIC_c and AIC_c weight (Table 9). The top Delta-GLM model had 80% of the AIC_c weight with the top four models having 99% of the total AIC_c weight. The $CPUE_{0/1}$ model had a moderate fit (AUC: 0.81), but the $CPUE^{+}$ ($y = 0.19x + 28.57$, R^2: 0.14) and Delta-GLM ($y = 0.19x + 19.02$, R^2: 0.14) models both had poor fits between observed and predicted densities with low densities being over predicted and high densities being under predicted (Table 5).

Probability of presence for Speckled Dace decreased going downstream with higher probabilities in Reaches 6 and 7 and the lowest in Reaches 1 and 2 (Figure 21A). Unlike other native species, Speckled Dace had a lower probability of occurrence in zero velocity channels. Median probability of presence (0.49) was similar in both the primary and secondary channels but the overall range was much narrower in secondary channels (Figure 21B). All mesohabitats had high to moderate probability of presence for Speckled Dace but probabilities were highest in riffle, eddy, and plunge mesohabitats (Figure 21C). Runs, pools, and zero velocity mesohabitats had the lowest probabilities of occurrence.

In 2016, median density of Speckled Dace in Reaches 3 – 6 was 25.3 fish/100 m^2 (range: 7.4 – 138.2 fish/100 m^2, N: 185) in the primary channel, 17.5 fish/100 m^2 (range: 7.3 – 145.5 fish/100 m^2, N: 135) in secondary channels, and 14.4 fish/100 m^2 (range: 5.7 – 45.6 fish/100 m^2, N: 29) in zero velocity channels. Densities of Speckled Dace were significantly higher in the primary channel and secondary channels in 2016 than the previous 4 - 5 years (Figure 22). Densities were much similar to years before 2009 in these two channels. Densities in zero velocities channel in 2016 were significantly higher than 2014 and 2015 (Figure 22), but densities of Speckled Dace are generally low and have high annual variation in zero velocity channels in comparison to other channel types. In Reach 7, median density of Speckled Dace was 8.4 fish/100 m^2 (range: 8.0 – 43.5 fish/100 m^2, N: 11) in the primary channel and 5.4 fish/100 m^2 (N: 3) in zero velocity channels. No secondary channels in Reach 7 were sampled in 2016 so no densities could be calculated. Although changes in densities in Reach 7 were not evaluated, densities of Speckled Dace in the primary channel appear to be the lowest observed since sampling began in 2012. Changes in densities in zero velocity channels are difficult to discern due to the low number of samples from Reach 7.

Table 9. Explanatory variables included in the top five Delta-GLM models used to predict density of Speckled Dace.

Model	Logistic model	Lognormal model	ΔAICc	w_i
1	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach)	0	0.80
2	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + Mesohabitat + sampDis + Year*Reach)	3.11	0.17
3	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach)	7.97	0.01
4	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach + Reach*ChannelType)	9.42	0.01
5	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + Mesohabitat + sampDis + Year*Reach)	11.08	0.00

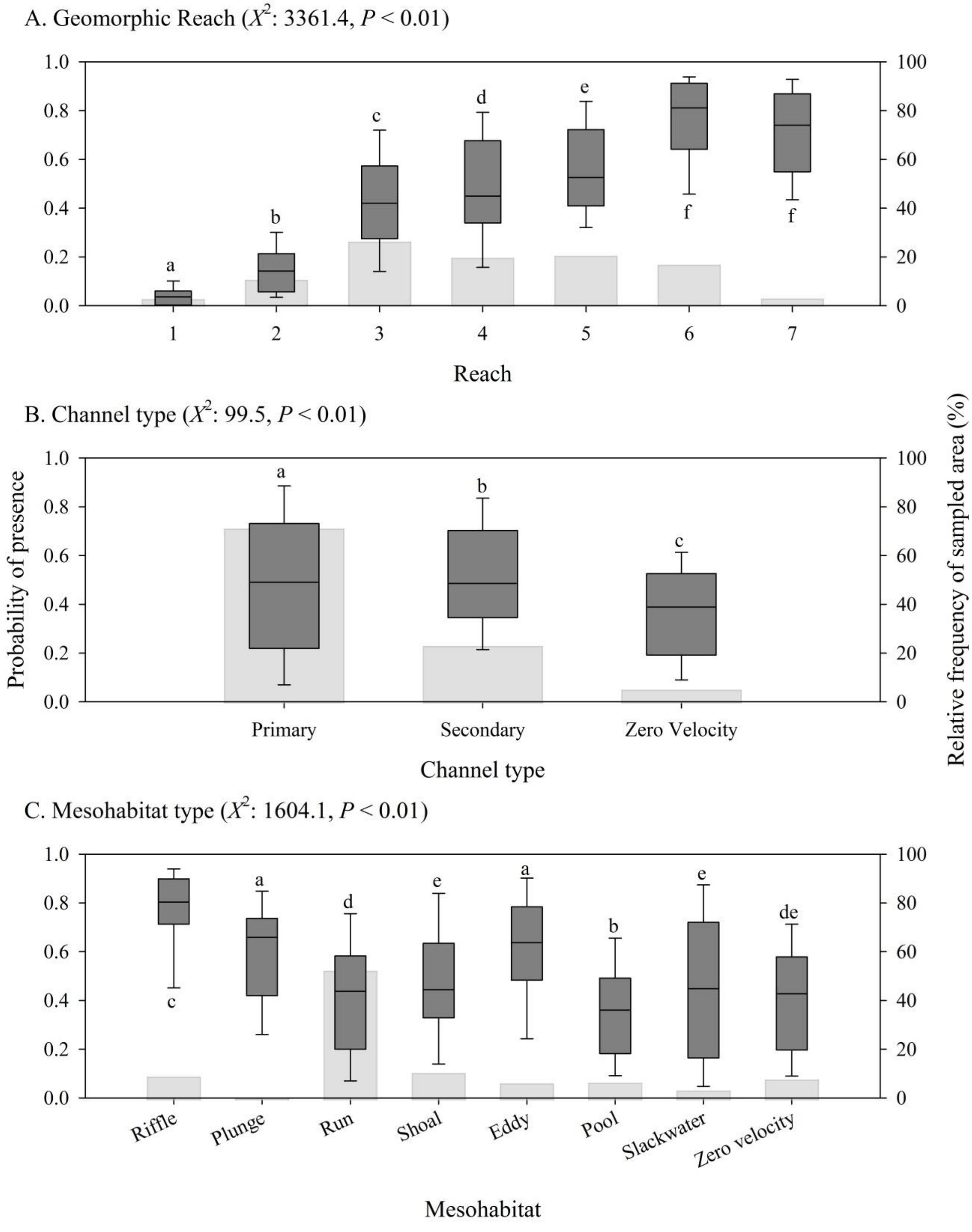


Figure 21. Probability of presence of Speckled Dace and relative frequency (%) of area sampled by (A) Geomorphic Reach, (B) channel type, and (C) mesohabitat type with results of Kruskal-Wallis ANOVA for Ranks. Letters indicate groupings based on the Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

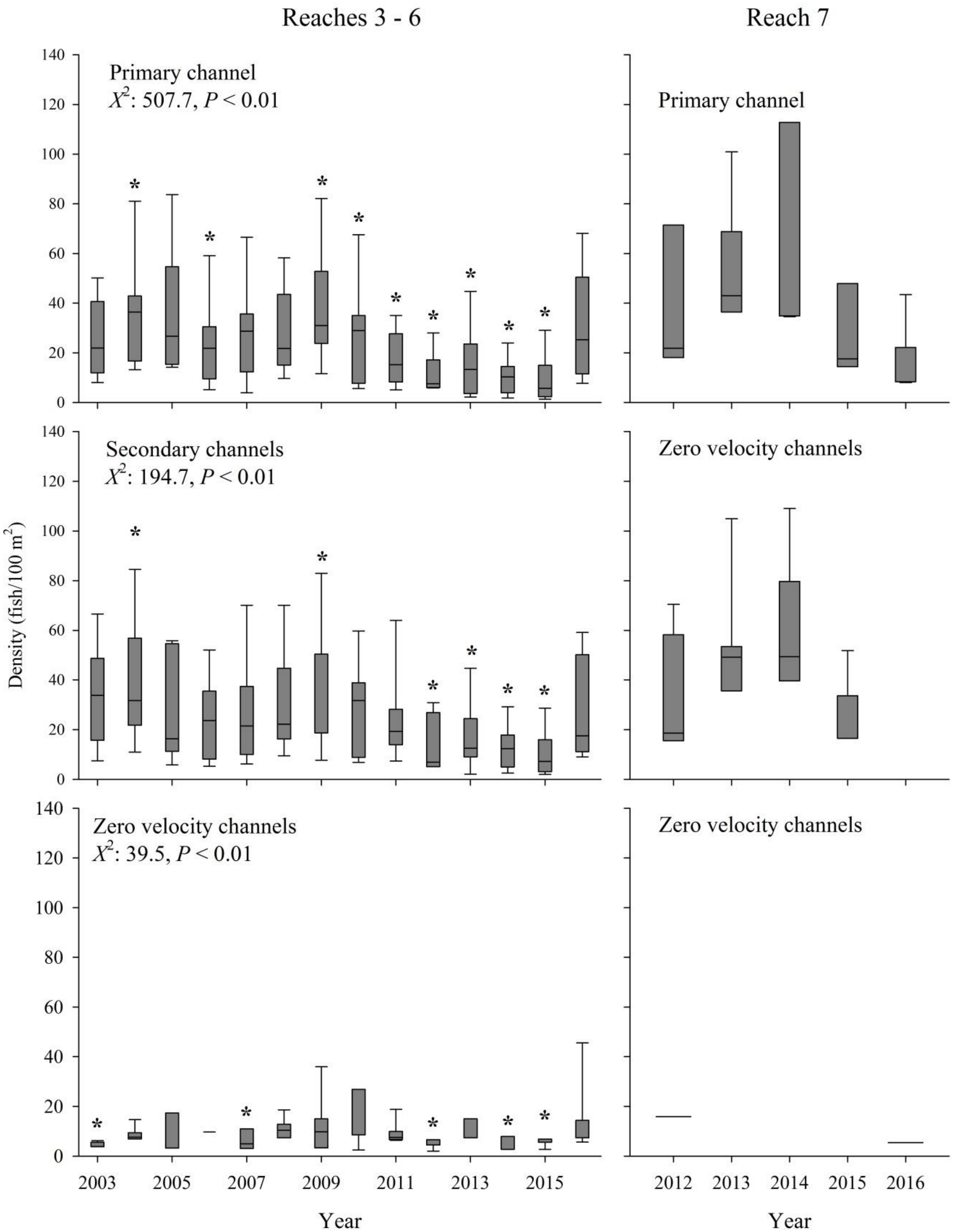


Figure 22. Density (fish/100 m^2) of Speckled Dace captured during small-bodied fishes monitoring in the primary channel (top), secondary channels (middle), and zero velocity channels (bottom) in Reaches 3 – 6 from 2003 – 2016 (left) and Reach 7 from 2012 - 2016 (right). Kruskal-Wallis ANOVA for Ranks results indicate significant differences between years. Asterisks (*) indicate statistically significant (P < 0.10) differences between 2016 and other years based on Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

Common Nonnative Species

Channel Catfish.— In 2016, 716 Channel Catfish were captured during SBF monitoring, the second most common fish species captured. Captured fish averaged 55 mm TL and ranged from 30 – 420 mm TL (Figure 23). The highest number of captures occurred in the primary channel (N: 456), followed by secondary channels (N: 192) and zero velocity channels (N: 68). No Channel Catfish were captured in Reaches 5 – 6, with the highest number of captures occurring in Reach 3 (N: 473).

Channel Catfish were the third most commonly captured fish from 2003 – 2016 with 24% of all seine hauls having at least one capture. To reduce the number of zeros in the data set for the Channel Catfish density analysis, Reaches 6 and 7 were removed because less than 1% of all seine hauls in these reaches resulted in at least one capture. The final Delta-GLM model with the best support included $CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType + Reach*ChannelType)$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis). The top Delta-GLM did not have a high AIC_c weight (0.35) and one model was within ΔAICc of 2 (Table 10). The $CPUE_{0/1}$ model had a moderate fit (AUC: 0.79) but both the $CPUE^{+}$ (y = 0.07x + 13.2, R^2: 0.06) and Delta-GLM (y = 0.05x + 5.84, R^2: 0.05) models showed a very poor ability to predict density with high densities being under predicted (Table 5).

Probability of presence for Channel Catfish showed different patterns in comparison to most other species in the San Juan River (Figure 24). There was an increasing trend in the probability of presence from upstream to downstream, with Reach 1 having the highest probability of occurrence and Reach 5 having the lowest. Channel Catfish were also more likely to be present in the primary channel compared to secondary channels and zero velocity channels (Figure 24B). Significant differences in the probability of presence between mesohabitat types (X^2: 508.0, $P < 0.01$) were also observed but several mesohabitats did overlap (Figure 24C). Channel Catfish were more likely to be present in shoals, and less likely to be present in riffles. The species also had a higher probability of occurring in runs, eddies, and plunges.

Density of Channel Catfish was highest in the primary channel in 2016 (median: 9.4 fish/100 m^2, range: 1.0 – 11.9 fish/100 m^2, N: 36), followed by secondary channels (median: 7.1 fish/100 m^2, range: 1.3 – 8.9 fish/100 m^2, N: 36) and zero velocity channels (median: 6.2 fish/100 m^2, 1.9 – 6.2 fish/100 m^2, N: 12). Density in the primary channel was significantly higher than the densities from 2012 – 2015, but was similar to most years from 2003 - 2011 (Figure 25A). Density in secondary channels was only significantly higher than densities in 2005, 2009, and 2015, and similar to most other years. Channel Catfish are rarely captured in zero velocity channels and densities in 2016 were similar to most other years (Figure 25C). Overall, the density of Channel Catfish in the San Juan River in 2016 appears to be significantly greater than most recent years even though no captures occurred in Reaches 5 – 7.

Table 10. Explanatory variables included in the top five Delta-GLM models used to predict density of Channel Catfish.

Model	Logistic model	Lognormal model	ΔAICc	w_i
1	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType + Reach*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	0	0.35
2	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType + Reach*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach)	1.18	0.19
3	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType + Reach*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Reach*ChannelType)	2.65	0.09
4	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType + Reach*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach + Reach*ChannelType)	4.78	0.03
5	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType + Reach*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach)	6.70	0.01

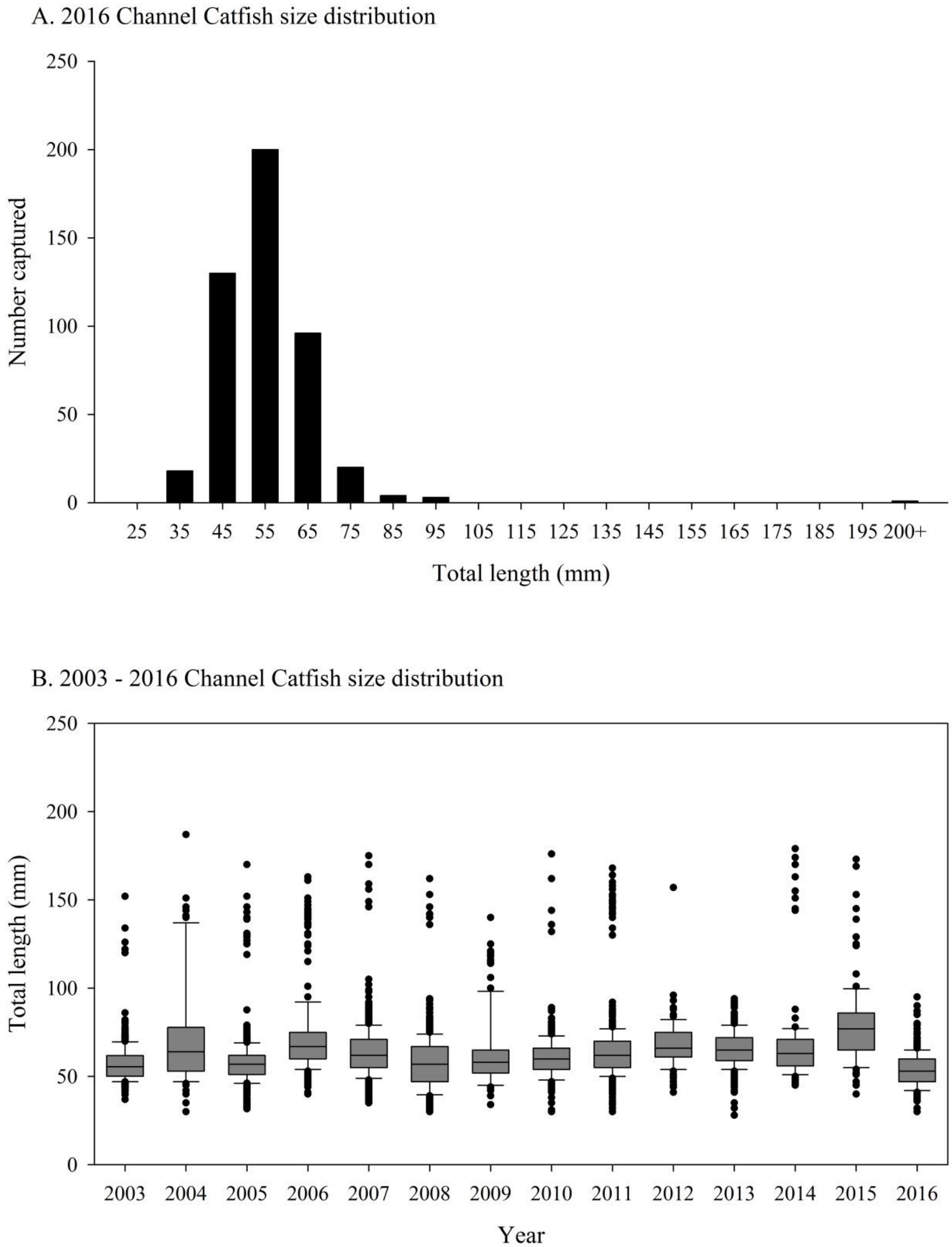


Figure 23. Size (total length, mm) distribution of Channel Catfish captured during small-bodied fishes monitoring in (A) 2016 and (B) 2003 – 2016. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles, and circles are outliers.

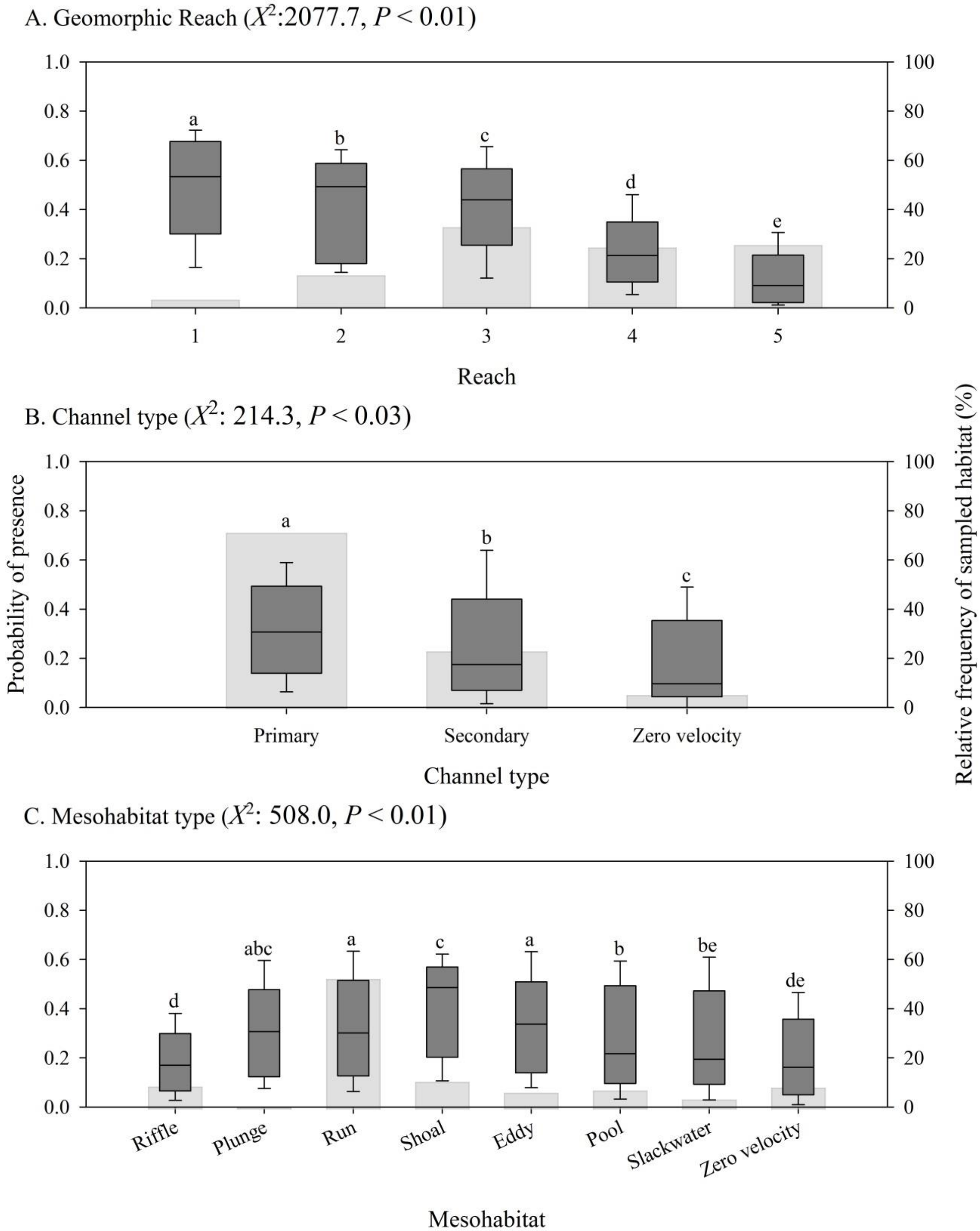


Figure 24. Probability of presence of Channel Catfish and relative frequency (%) of area sampled by (A) Geomorphic Reach, (B) channel type, and (C) mesohabitat type with results of Kruskal-Wallis ANOVA for Ranks. Letters indicate groupings based on the Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

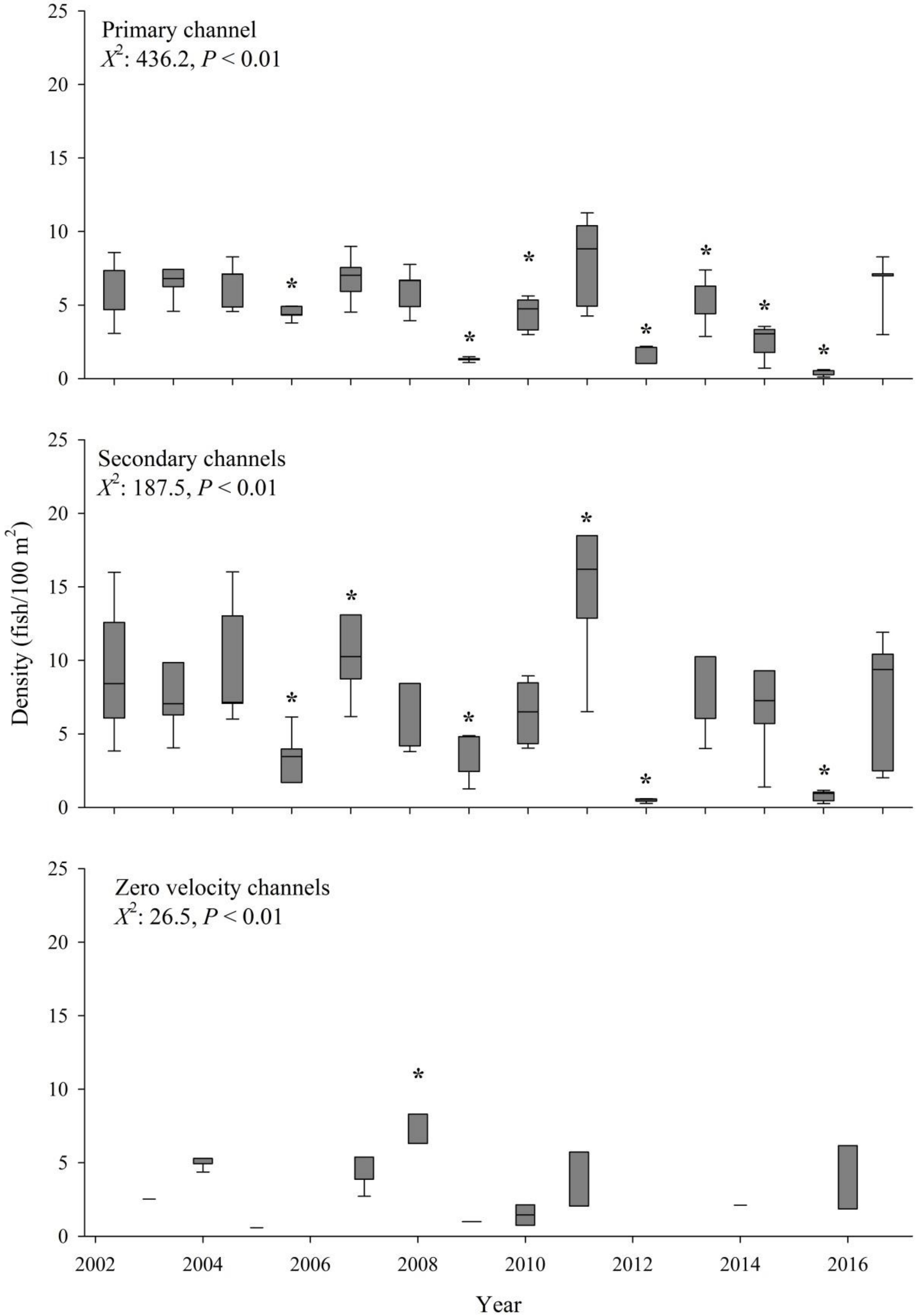


Figure 25. Density (fish/100 m²) of Channel Catfish captured during small-bodied fishes monitoring in the primary channel (top), secondary channels (middle), and zero velocity channels (bottom) in Reaches 3 – 5 from 2003 – 2016. Kruskal-Wallis ANOVA for Ranks results indicate significant differences between years. Asterisks (*) indicate statistically significant (P < 0.10) differences between 2016 and other years based on Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

Fathead Minnow.— A total of 252 Fathead Minnows *Pimephales promelas* were captured in 2016, the fifth most common species captured during SBF monitoring. The majority of captures occurred in the primary channel (N: 133), followed by secondary channels (N: 68) and zero velocity channels (N: 51). Captures varied between reaches with the highest number of captures occurring in Reach 5 (N: 117) and Reach 7 (N: 63). The fewest number of captures occurred in Reach 4 (N: 9). Captured Fathead Minnows averaged 36 mm TL and ranged between 21 – 62 mm TL.

From 2003 – 2016, Fathead Minnows were the sixth most common species captured with 8% of all seine hauls having at least one capture. Only capture data from Reaches 3 – 7 were used for the Delta-GLM analysis because Reaches 1 and 2 both had less than 3% of all seine hauls with at least one capture. The top supported Delta-Model only had 35% of the AIC_c weight and included $CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType) $CPUE^+$(Year + Reach + ChannelType + Mesohabitat + sampDis) but the top 5 models did account for 92% of the AIC_c weight (Table 11). The $CPUE_{0/1}$ did have good support (AUC: 0.88), but similar to other species, the $CPUE^+$ ($y = 0.26x + 26.03$, R^2: 0.24) and Delta-GLM ($y = 0.23x + 8.24$, R^2: 0.24) models had low ability to predict density (Table 5).

Fathead Minnows were much more likely to be present in Reaches 6 and 7, with a decreasing probability from Reach 5 to Reach 3 (Figure 26A). The species was much more likely to be present in zero velocity channels (Figure 26B). Fathead Minnows were also less likely to be present in secondary channels and very unlikely to occur in the primary channel. Zero velocity mesohabitats had a significantly higher probability of presence for Fathead Minnows in comparison to any other type of mesohabitat (Figure 26C). The species was least likely to be present in riffle mesohabitats in comparison to any others. Overall, the species appears to have a higher likelihood of being present in zero velocity or low velocity (i.e., pools, slackwaters, eddies) mesohabitats than other mesohabitats (i.e., riffles, runs, shoals).

Median density of Fathead Minnows in zero velocity channels was 5.7 fish/100 m^2 (range: 1.6 – 9.3 fish/100 m^2, N: 9), 2.3 fish/100 m^2 (range: 0.5 – 15.7 fish/100m^2, N: 19) in the primary channel and 2.3 fish/100 m^2 (range: 0.2 – 20.7 fish/100 m^2, N: 23) in secondary channels of Reaches 3 – 6 in 2016 (Figure 27). Density of Fathead Minnows has shown little variation in any channel type since 2006, with 2016 not being significantly different than any year before 2006. Densities in every year before 2006 were significantly higher in secondary and zero velocity channels and in 2004 in the primary channel (Figure 27). In Reach 7, median densities of Fathead Minnows in zero velocity channels were 40.8 fish/100 m^2 (N: 2) and 12.3 fish/100 m^2 in the primary channel (range: 5.3 – 53.0 fish/100 m^2, N: 10). No secondary channels were sampled in Reach 7 in 2016. Assessing trends through time in Reach 7 is difficult due to the short time frame the reach has been sampled (5 years) and also because only the primary channel has been sampled every year (Figure 27).

Table 11. Explanatory variables included in the top five Delta-GLM models used to predict density of Fathead Minnows.

Model	Logistic model	Lognormal model	ΔAICc	w_i
1	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	0	0.39
2	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Reach*ChannelType)	0.90	0.25
3	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	1.91	0.15
4	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach + Year*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Reach*ChannelType)	2.81	0.10
5	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType + Reach*ChannelType)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	5.32	0.03

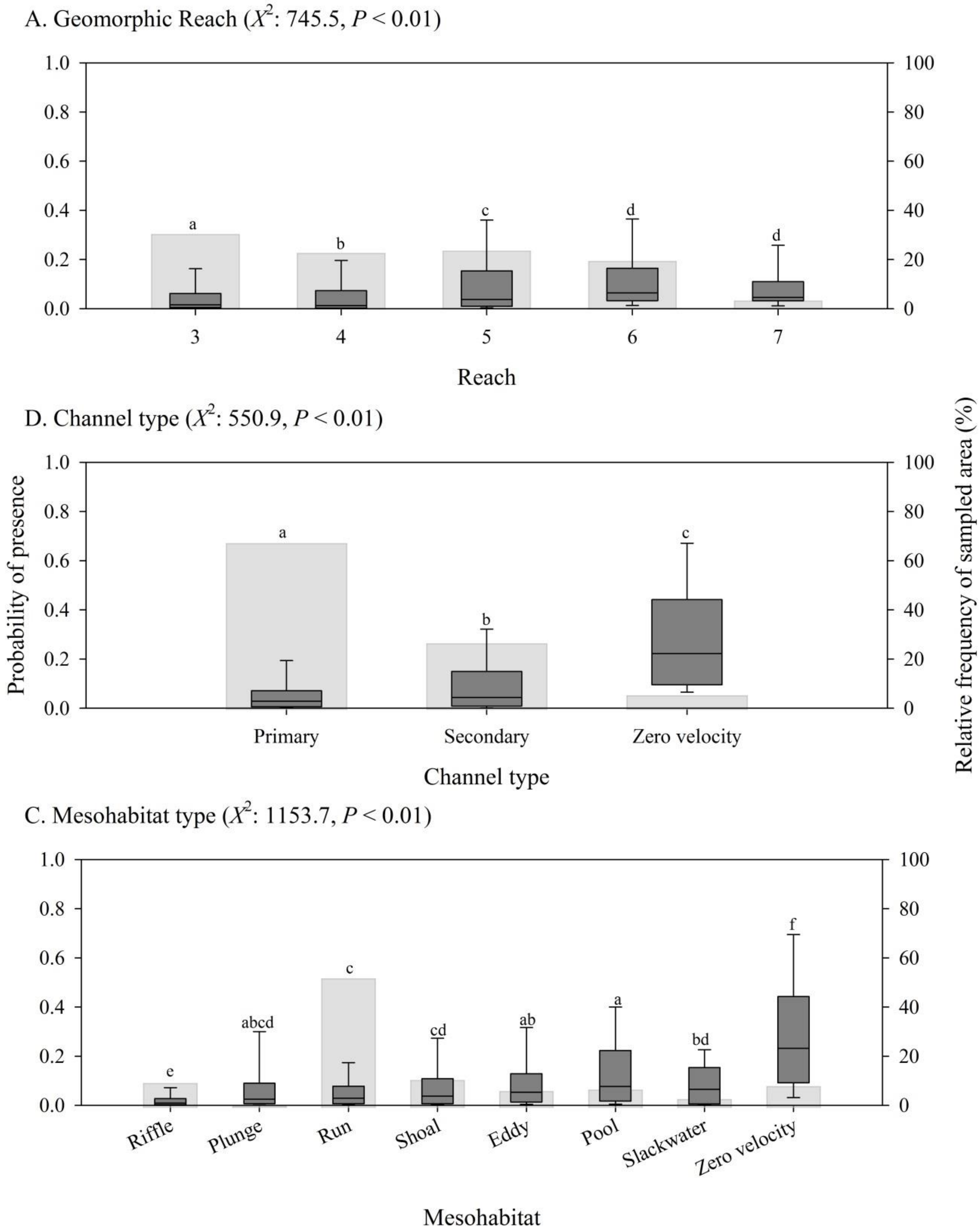


Figure 26. Probability of presence of Fathead Minnows and relative frequency (%) of area sampled by (A) Geomorphic Reach, (B) channel type, and (C) mesohabitat type with results of Kruskal-Wallis ANOVA for Ranks. Letters indicate groupings based on the Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

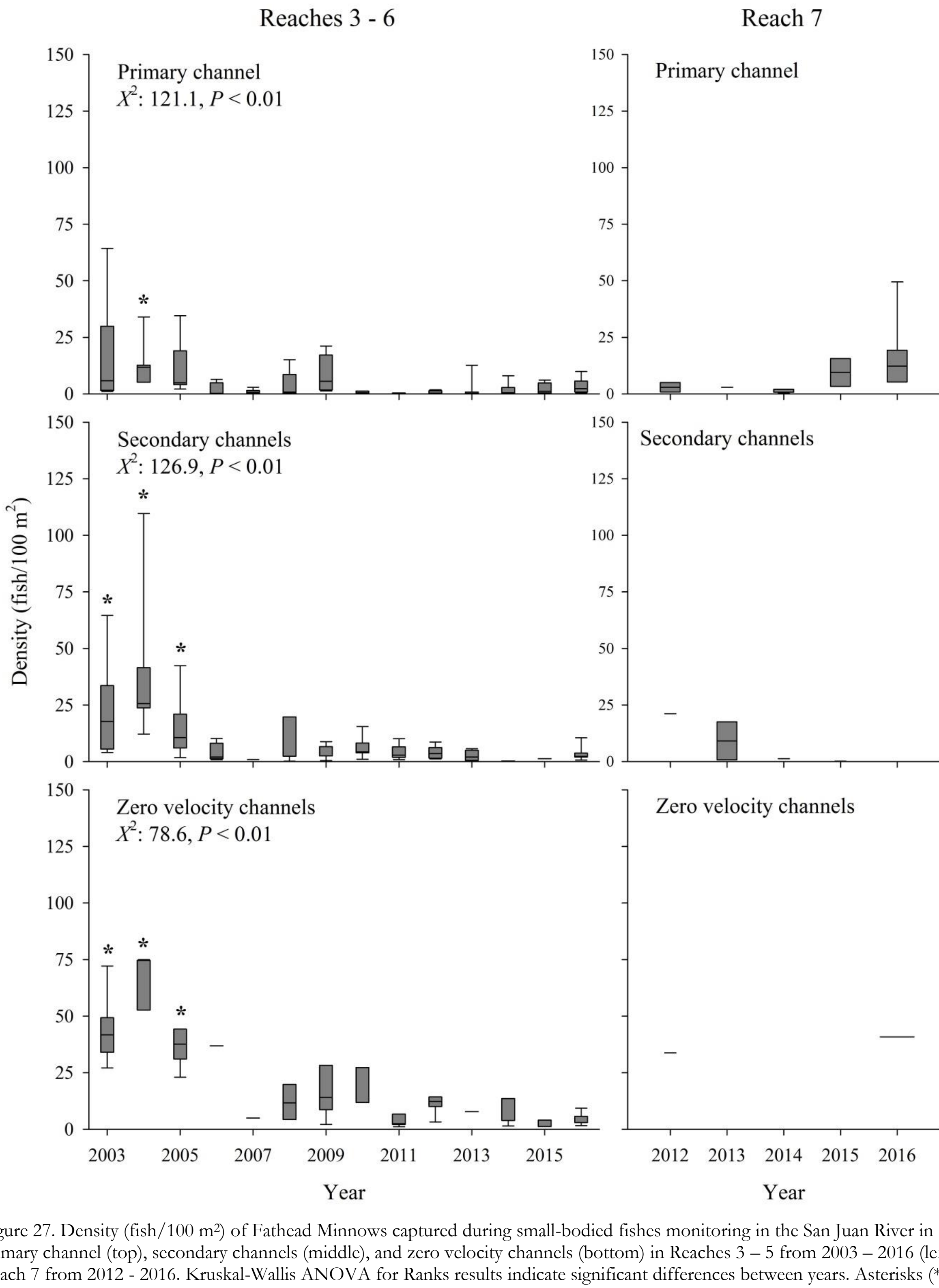


Figure 27. Density (fish/100 m^2) of Fathead Minnows captured during small-bodied fishes monitoring in the San Juan River in the primary channel (top), secondary channels (middle), and zero velocity channels (bottom) in Reaches 3 – 5 from 2003 – 2016 (left) and Reach 7 from 2012 - 2016. Kruskal-Wallis ANOVA for Ranks results indicate significant differences between years. Asterisks (*) indicate statistically significant (P < 0.10) differences between 2016 and other years based on Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

Red Shiner.— Eighty-one Red Shiners *Cyprinella lutrensis* were captured during 2016, the seventh most common species captured during SBF monitoring. Thirty-two fish were captured in the primary channel, 18 in secondary channels, and 31 in zero velocity channels. The greatest number of captures occurred in Reach 3 (N: 40) followed by Reach 5 (N: 17) and Reach 4 (N: 13). Eight fish were captured in Reach 7, 3 in Reach 6, and 0 in Reach 2. Captured Red Shiner averaged 34 mm TL and ranged between 18 and 58 mm TL.

From 2003 – 2016, Red Shiners were the second most commonly captured species during SBF monitoring with 24.0% of all seine hauls having at least one capture (Figure 3). Only Reach 7 captures were removed from the data set for analysis because all other reaches had over 3% of all seine hauls with at least one capture. The top two Delta-GLM models accounted for 99% of the AIC_c weight with the top model, which included $CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach) $CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat), receiving 72% of the AIC_c weight (Table 12). The $CPUE_{0/1}$ model had a moderate fit (AUC: 0.86) but both the $CPUE^{+}$ ($y = 0.21x + 46.62$, R^2: 0.21) and the Delta-GLM ($y = 0.19x + 27.19$, R^2: 0.21) models under predicted high densities (Table 5).

Red Shiners were more likely to occur in Reaches 3 and 4 in comparison to any other reach (Figure 28A). Probability of presence was lowest in Reach 6, with Reaches 1, 2, and 5 having similar probabilities of presence. Probability of presence varied significantly between channel types (X^2: 146.5, $P < 0.01$) with the species more likely to occur in zero velocity channel types, followed by secondary channels, and least likely to be present in the primary channel (Figures 28B). Not surprisingly, Red Shiners were more likely to be present in zero velocity mesohabitats in comparison to any other type (Figure 28C). The species was less likely to occur in riffles and slackwaters, with largely similar probabilities of presence across plunges, runs, shoals, eddies, and pools.

Median densities of Red Shiners were generally low across all channel types in 2016, but were 1.1 fish/100 m^2 (range: 0.2 – 3.0 fish/100 m^2, N: 16) in the primary channel, 0.6 fish/100 m^2 (range: 0.2 – 2.1 fish/100 m^2, N: 10) in secondary channels, and 2.3 fish/100 m^2 (range: 0.9 – 2.8 fish/100 m^2, n =8) in zero velocity channels. Densities of Red Shiner in 2016 continue to be at significantly lower densities across all channel types in comparison to most years before 2012 (Figure 29). These low densities are even more surprising when compared to the highs which occurred from 2003 – 2005. There appears to be three major periods in density of Red Shiners since 2003, with highs occurring from 2003 – 2005, a drop but level period from 2006 – 2012, and a second drop and lowest densities occurring from 2013 - 2016 (Figure 29).

Table 12. Explanatory variables included in the top five Delta-GLM models used to predict density of Red Shiners.

Model	Logistic model	Lognormal model	ΔAICc	w_i
1	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat)	0	0.72
2	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis)	1.93	0.27
3	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + Reach*ChannelType)	10.74	0.00
4	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach)	$CPUE^{+}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Reach*ChannelType)	12.65	0.00
5	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach)	$CPUE^{+}$(Year + Reach + Mesohabitat)	14.00	0.00

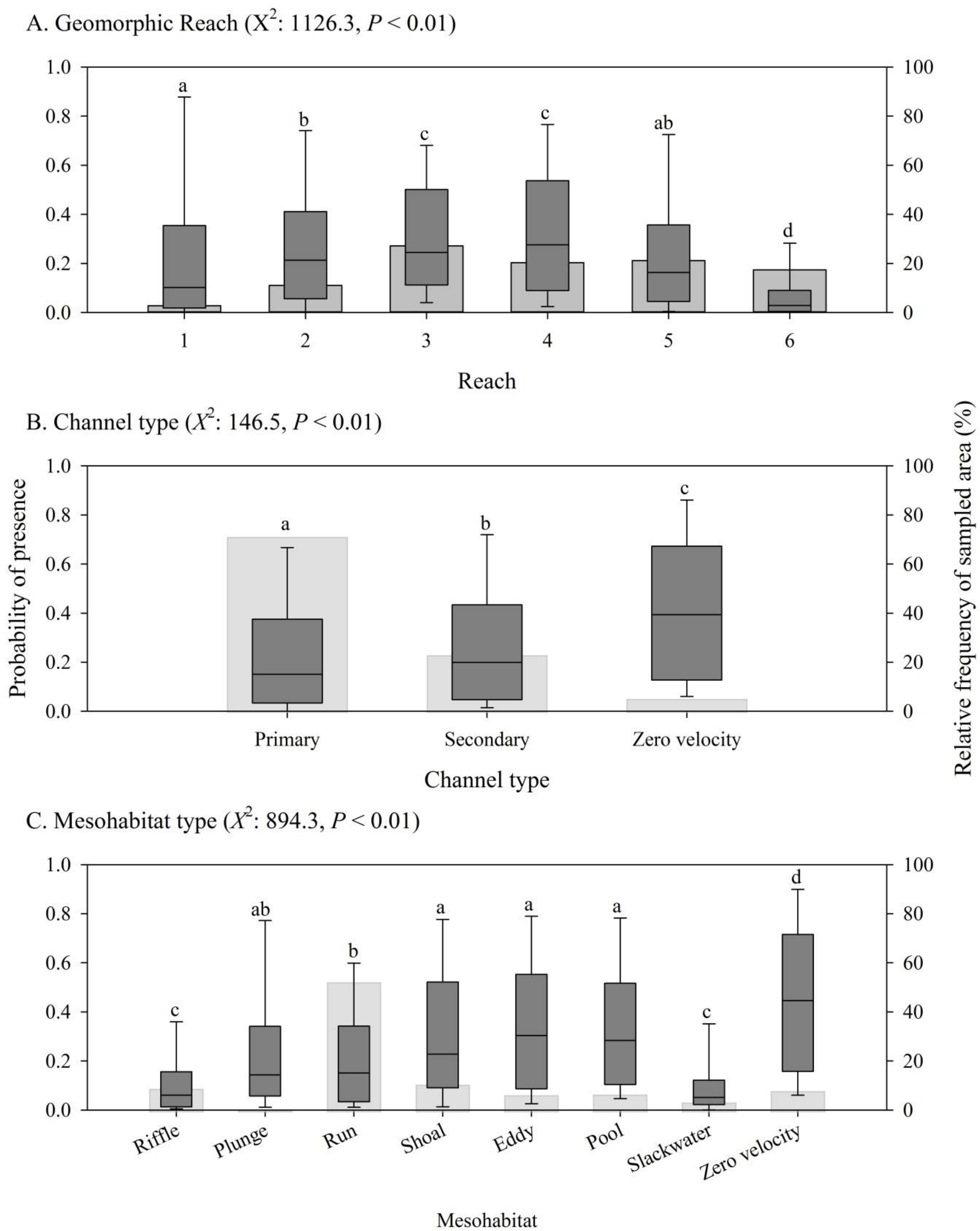


Figure 28. Probability of presence of Red Shiners and relative frequency (%) of area sampled by (A) Geomorphic Reach, (B) channel type, and (C) mesohabitat type with results of Kruskal-Wallis ANOVA for Ranks. Letters indicate groupings based on the Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

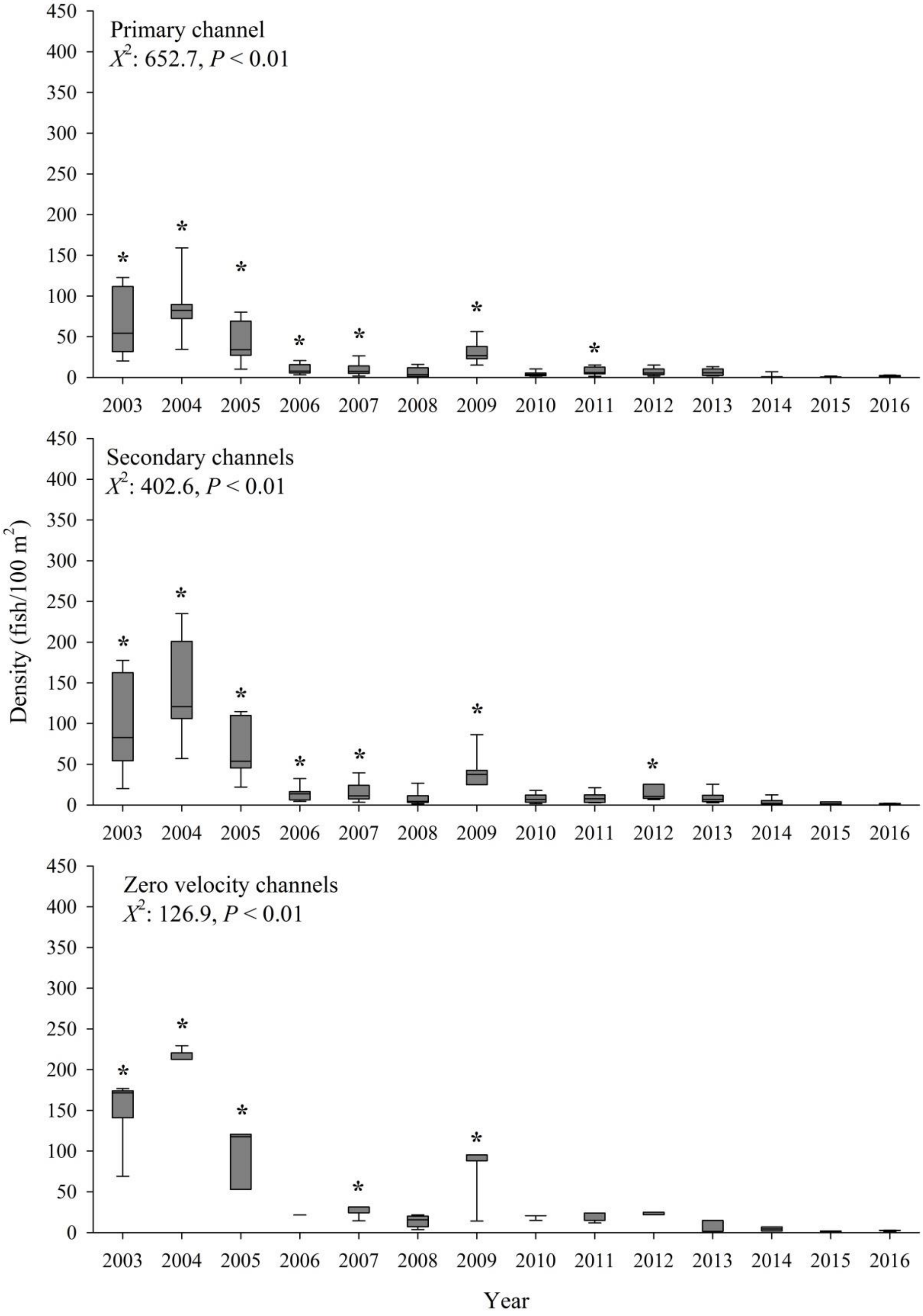


Figure 29. Density (fish/100 m^2) of Red Shiners captured during small-bodied fishes monitoring in the San Juan River in the primary channel (top), secondary channels (middle), and zero velocity channels (bottom) in Reaches 3 – 5 from 2003 – 2016. Kruskal-Wallis ANOVA for Ranks results indicate significant differences between years. Asterisks (*) indicate statistically significant ($P < 0.10$) differences between 2016 and other years based on Dunn's pos-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

Western Mosquitofish.— In 2016, 190 Western Mosquitofish *Gambusia affinis* were captured, the sixth most common species captured. More fish were captured in secondary channels (N: 133) than the primary channel (N: 31) and zero velocity channels (N: 23) combined. Large variations in captures between Reaches were observed with the greatest number occurring in Reach 5 (N: 94) and Reach 3 (N: 75). Many fewer captures occurred in Reach 4 (N: 6), Reach 6 (N: 12), and Reach 7 (N: 3). Captured Western Mosquito fish averaged 31 mm TL and ranged between 13 mm and 55 mm TL.

Western Mosquitofish was the seventh most common species captured from 2003 – 2016 with only 5.0% of all seine hauls having at least one capture. Only Reaches 3 – 7 had over 3% of all seine hauls with at least 1 capture, so Reaches 1 and 2 were not used in the Delta-GLM analysis. The top Delta-GLM model, $CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach) $CPUE^{+}$(Year + Reach + Mesohabitat + sampDis), received only 24% of the AIC_c weight and the top five models only accounted for 63% of the total AIC_c weight (Table 13). Both the $CPUE^{+}$ (y = 0.16x + 22.62, R^2: 0.14) and Delta-GLM (y = 0.09x + 4.65, R^2: 0.13) models under predicted densities, especially at higher densities, but the $CPUE_{0/1}$ model did have good support (AUC: 0.87) (Table 5).

Western Mosquitofish were unlikely to be present across all channel types but were more likely to occur in Reaches 5 and 6 and least likely in Reaches 3 and 7 (Figure 30A). Occurrence of Western Mosquitofish was much more likely in zero velocity channels in comparison to either secondary channels or the primary channel, although the probability of occurrence in secondary channels was higher than the primary channel (Figure 30B). The species had much higher probabilities of presence in zero velocity and pool mesohabitats than any other mesohabitat type (Figure 30C). The species was less likely to occur in riffles, shoals, and runs. The disparities between probability of presence for mesohabitats indicates that Western Mosquitofish have a high affinity for zero or low velocity mesohabitats (Figure 30).

In 2016, median densities of Western Mosquitofish in Reaches 3 – 6 were 5.7 fish/100 m^2 (range: 1.8 – 6.5 fish/100 m^2, N: 4) in zero velocity channels, 3.8 fish/100 m^2 (range: 0.2 – 7.3 fish/100 m^2, N: 12) in the primary channel, and 1.4 fish/100 m^2 (range: 0.3 – 10.0 fish/100 m^2, N: 16) in secondary channels. Density of Western Mosquitofish has been highly variable since 2003 across all channel types in Reaches 3 – 6 (Figure 31). Only 2016 densities in secondary channels and zero velocity channels differed from any previous years, with 2016 densities being lower. Western Mosquitofish were captured in only one seine haul in Reach 7 at a primary channel site (density: 0.4 fish/100 m^2, N: 1). Densities of Western Mosquitofish have generally been low in Reach 7 in most years, with the majority of years having almost no captures in any channel type (Figure 31).

Table 13. Explantory variables included in the top five Delta-GLM models used to predict density of Western Mosquitofish.

Model	Logistic model	Lognormal model	ΔAICc	w_i
1	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach)	$CPUE^+$(Year + Reach + Mesohabitat + sampDis)	0	0.24
2	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach + Year*ChannelType)	$CPUE^+$(Year + Reach + Mesohabitat + sampDis)	0.95	0.15
3	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach)	$CPUE^+$(Year + Reach + ChannelType + Mesohabitat + sampDis)	1.95	0.09
4	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + sampDis + Year*Reach)	$CPUE^+$(Year + Reach + Mesohabitat + sampDis)	1.99	0.09
5	$CPUE_{0/1}$(Year + Reach + ChannelType + Mesohabitat + Year*Reach)	$CPUE^+$(Year + Reach + Mesohabitat)	2.64	0.06

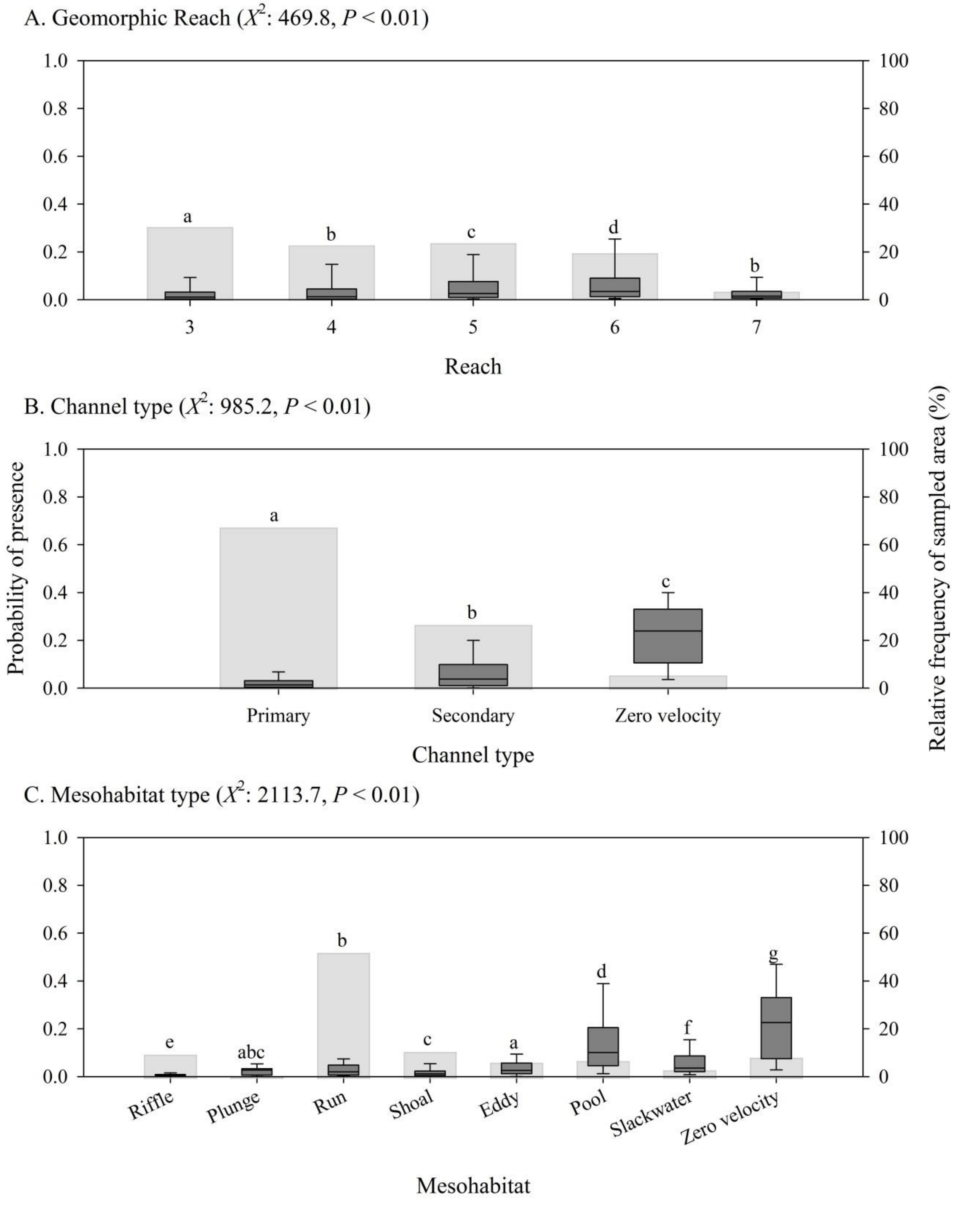


Figure 30. Probability of presence of Western Mosquitofish and relative frequency (%) of area sampled by (A) Geomorphic Reach, (B) channel type, and (C) mesohabitat type with results of Kruskal-Wallis ANOVA for Ranks. Letters indicate groupings based on the Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

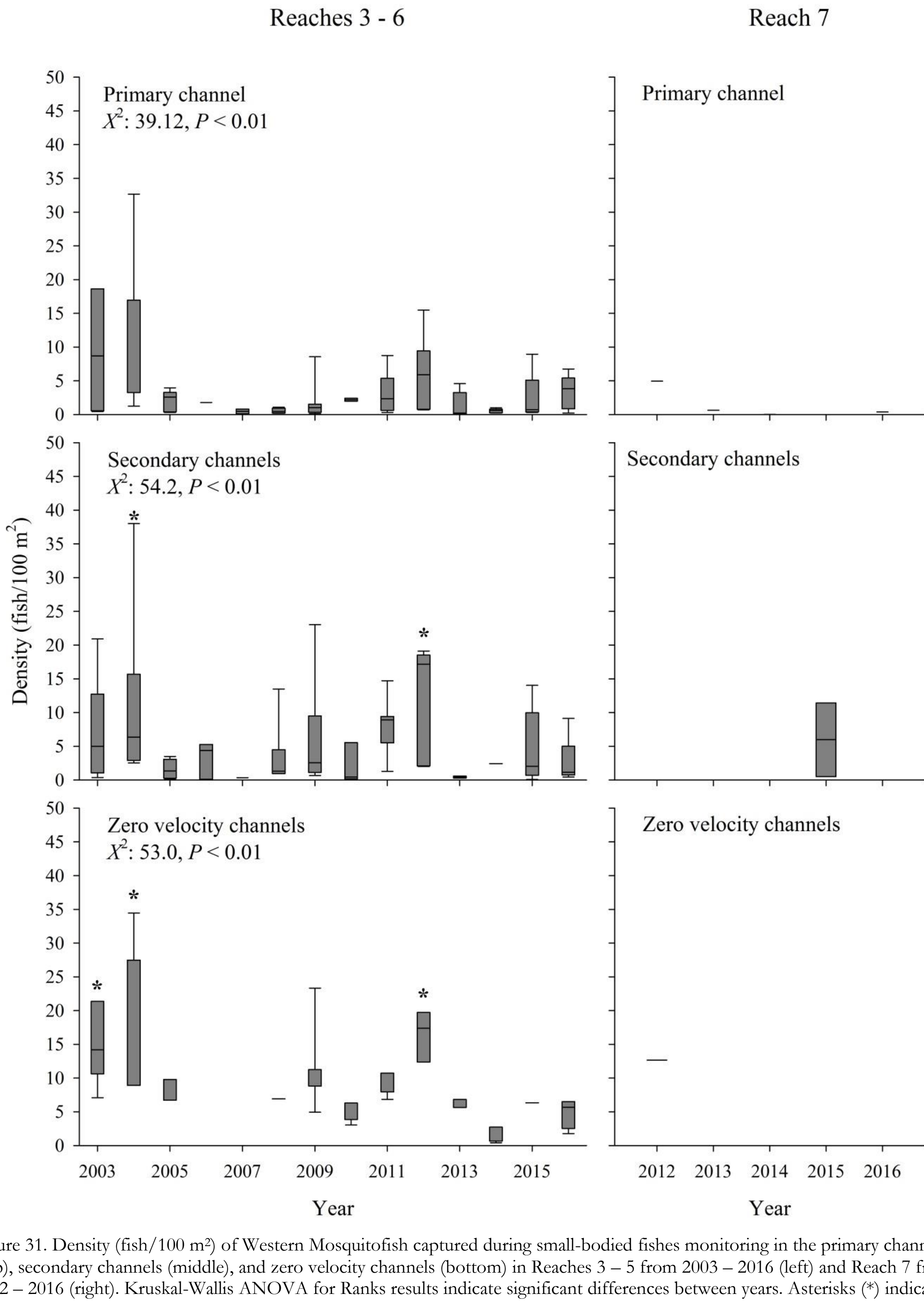


Figure 31. Density (fish/100 m^2) of Western Mosquitofish captured during small-bodied fishes monitoring in the primary channel (top), secondary channels (middle), and zero velocity channels (bottom) in Reaches 3 – 5 from 2003 – 2016 (left) and Reach 7 from 2012 – 2016 (right). Kruskal-Wallis ANOVA for Ranks results indicate significant differences between years. Asterisks (*) indicate statistically significant ($P < 0.10$) differences between 2016 and other years based on Dunn's post-hoc tests. Note that for box plots the boundary of the box closest to zero indicates the 25th percentile, the black line within the box is the median, the boundary of the box furthest from zero indicates the 75th percentile, whiskers are the 10th and 90th percentiles.

Uncommon Nonnative Species

A total of 35 uncommon nonnative fishes comprising eight different species were captured river-wide during 2016 monitoring (Table 14). Of the eight species captured, Black Bullhead *Ameiurus melas* (N: 10) was the most common followed by Plains Killifish *Fundulus zebrinus* (N: 7) and Common Carp *Cyprinus carpio* (N: 7). The majority of uncommon nonnative captures occurred in Reaches 3, 4, and 5. A single White Crappie *Pomoxis annularis* was captured in Reach 7, the first capture of this species during SBF monitoring since 2003. Four White Suckers *Catostomus commersoni* were also captured, 1 in Reach 2, 2 in Reach 3, and 1 in Reach 4. The seven Common Carp captured in 2016 were the most captured during SBF monitoring since 2009.

Table 14. Number of uncommon nonnative fishes captured, by Geomorphic Reach, during 2016 San Juan River small-bodied fishes monitoring.

Species	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Total
Black Bullhead		3	6		1		10
White Sucker	1	2	1				4
Common Carp		2	1	3	1		7
Plains Killifish		3	2			2	7
Green Sunfish			1		1		2
Largemouth Bass				2		1	3
White Crappie						1	1
Totals	1	10	11	5	3	4	34

Influence of Flow and Nonnatives on Fish Density

To assess the influence of abiotic and biotic influences on the density of native species, median density (fish/100 m^2) for each species and Reaches 3 – 5 were plotted against several flow metrics calculated from mean daily discharge (cfs) at Four Corners, CO (Figure 32 – 37). Density of nonnative competitors (fish/100 m^2) collected during SBF monitoring and catch rate (fish/hr) of nonnative predators from annual sub-adult and adult monitoring data were also plotted against densities of native species in Reaches 3 – 5 (Figure 38 and 39). The influence of flow on the density of nonnatives was also assessed using the same discharge data at Four Corners, CO (Figure 39 – 44).

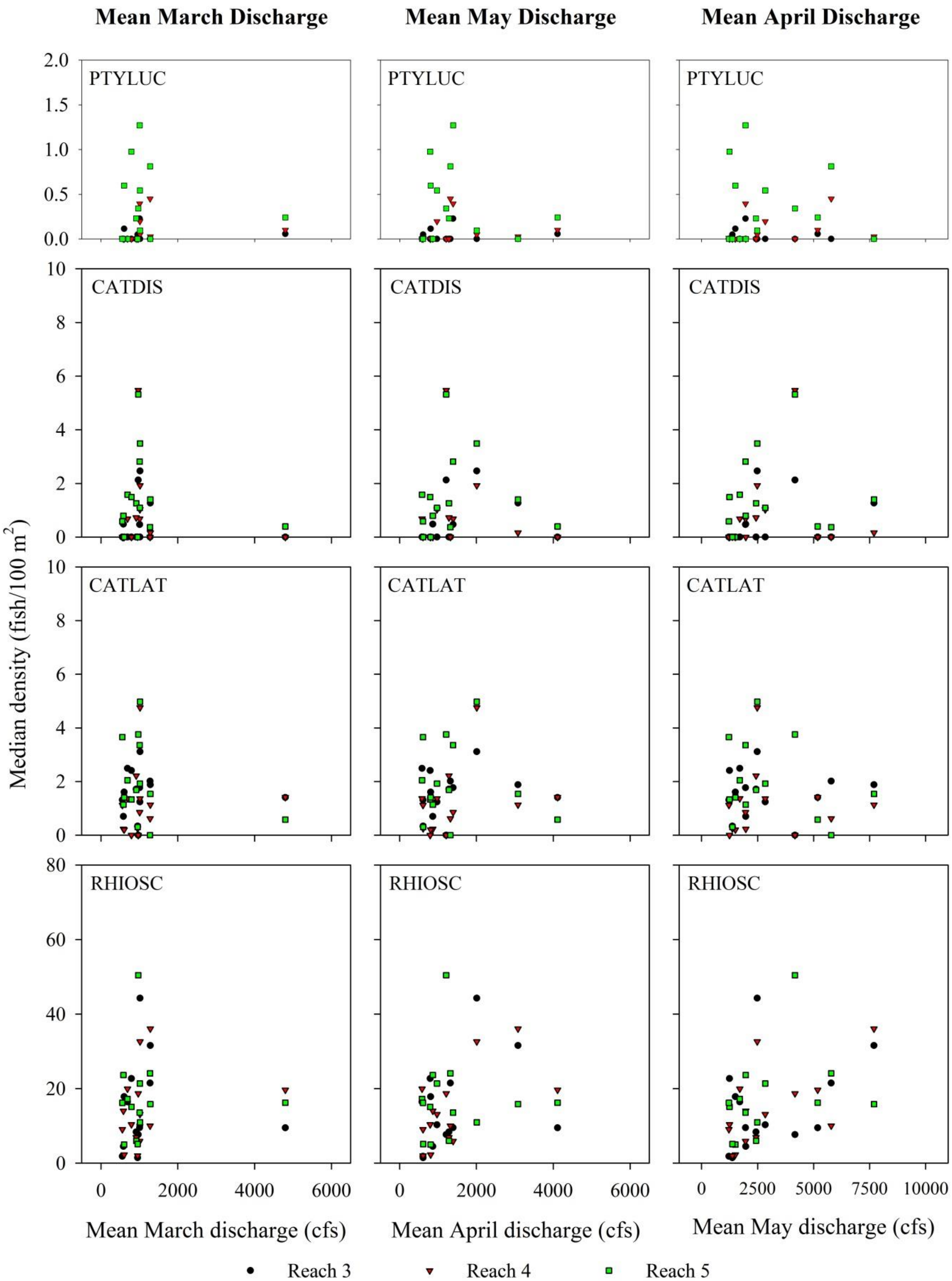


Figure 32. Bivariate relationships between median densities (fish/100 m²) of native Colorado Pikeminnow (PTYLUC), Bluehead Sucker (CATDIS), Flannelmouth Sucker (CATLAT), and Speckled Dace (RHIOSC) in secondary channels of Reaches 3 – 6 and mean March, April, and May discharge (cfs). Discharge metrics were calculated from mean daily discharges at Four Corners, CO (USGS gage: 09371010).

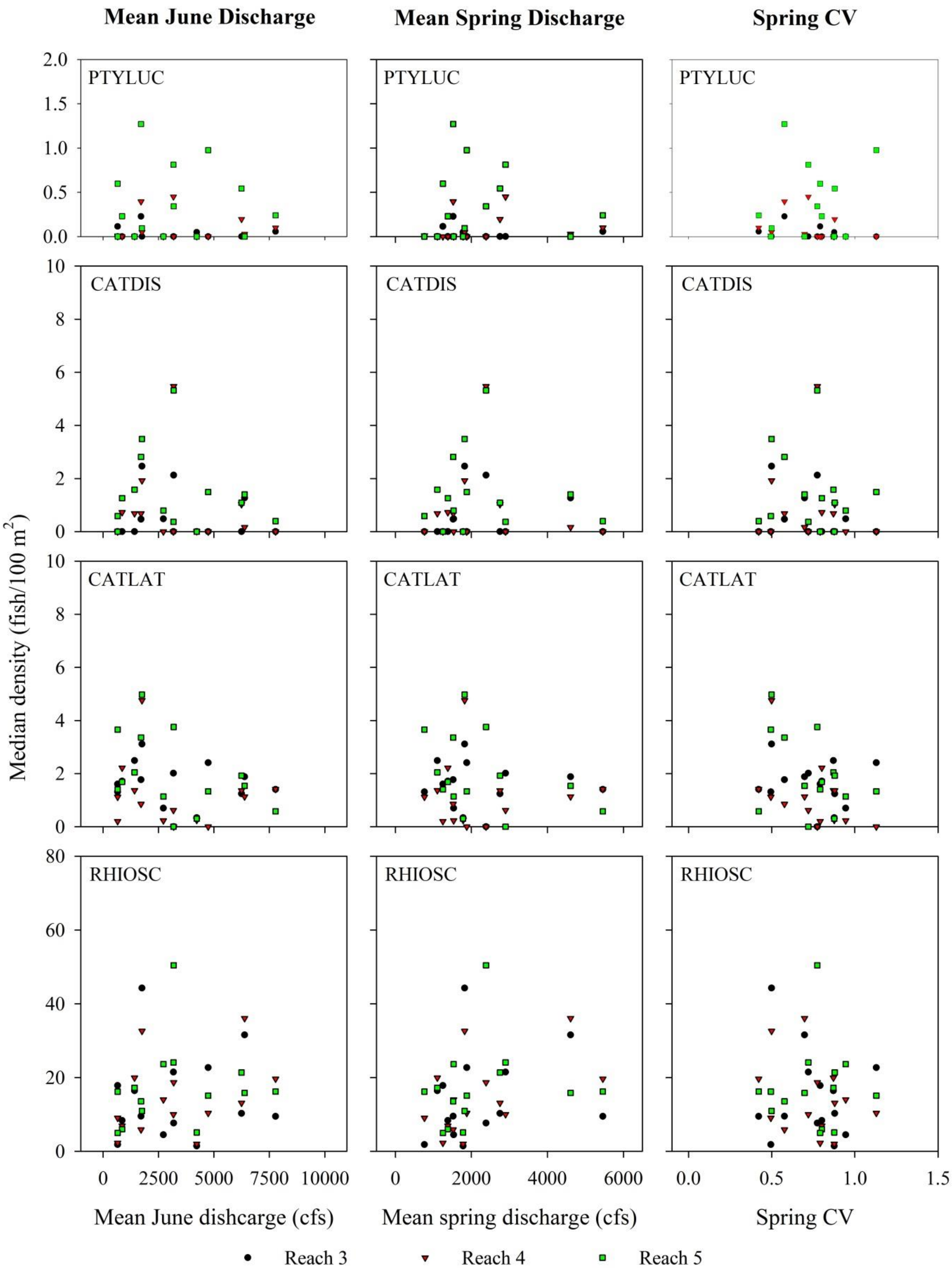


Figure 33. Bivariate relationships between median densities (fish/100 m²) of native Colorado Pikeminnow (PTYLUC), Bluehead Sucker (CATDIS), Flannelmouth Sucker (CATLAT), and Speckled Dace (RHIOSC) in secondary channels of Reaches 3 - 6 and mean June discharge (cfs), mean Spring discharge (cfs), and Spring coefficient of variation (CV). Discharge metrics were calculated from mean daily discharges at Four Corners, CO (USGS gage: 09371010).

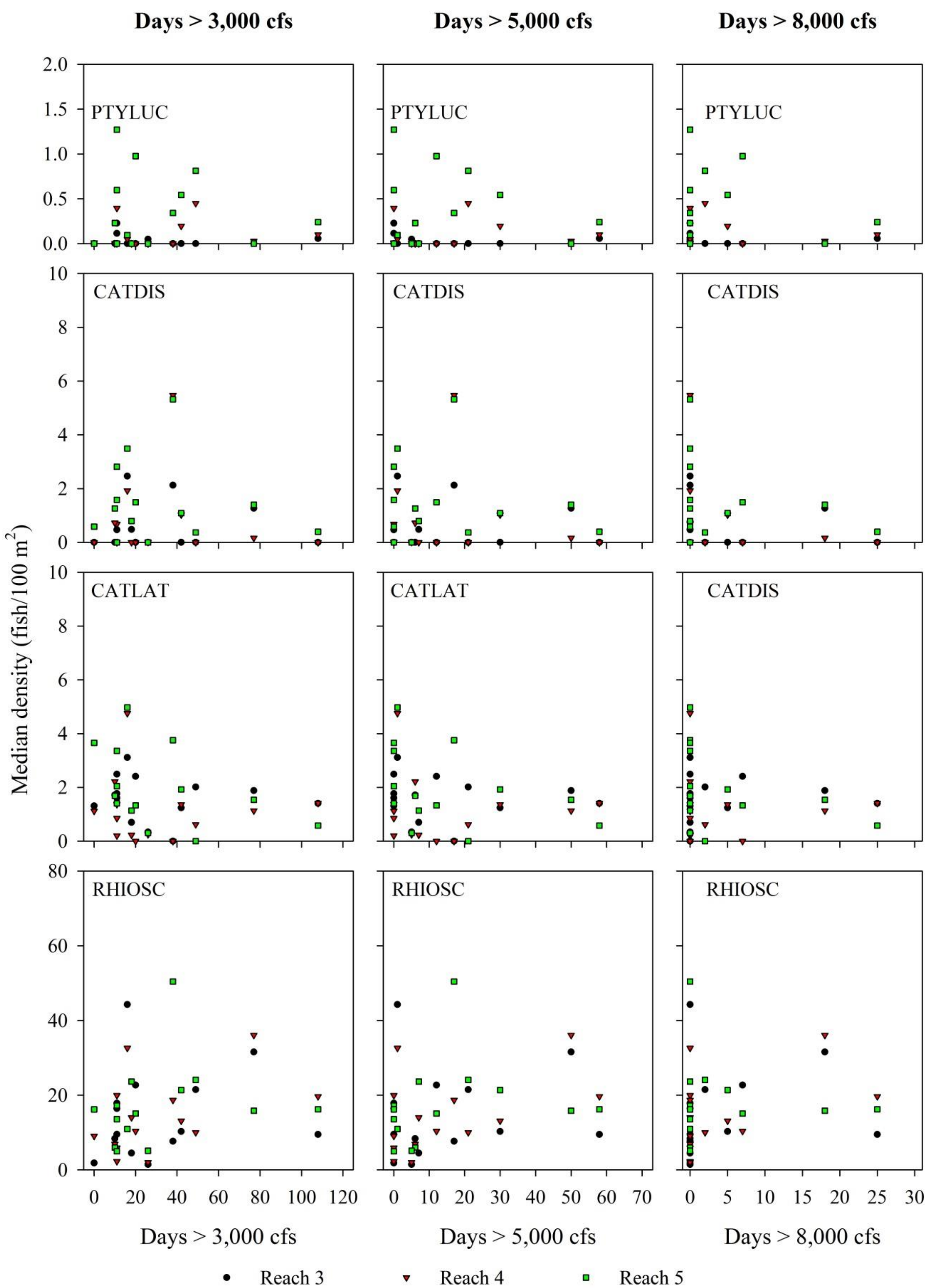


Figure 34. Bivariate relationships between median density (fish/100 m²) of native Colorado Pikeminnow (PTYLUC), Bluehead Sucker (CATDIS), Flannelmouth Sucker (CATLAT), and Speckled Dace (RHIOSC) in secondary channels of Reaches 3 – 5 and the number of Spring days > 3,000 cfs, > 5,000 cfs, and > 8,000 cfs. Discharge metrics were calculated from mean daily discharges at Four Corners, CO (USGS gage: 09371010).

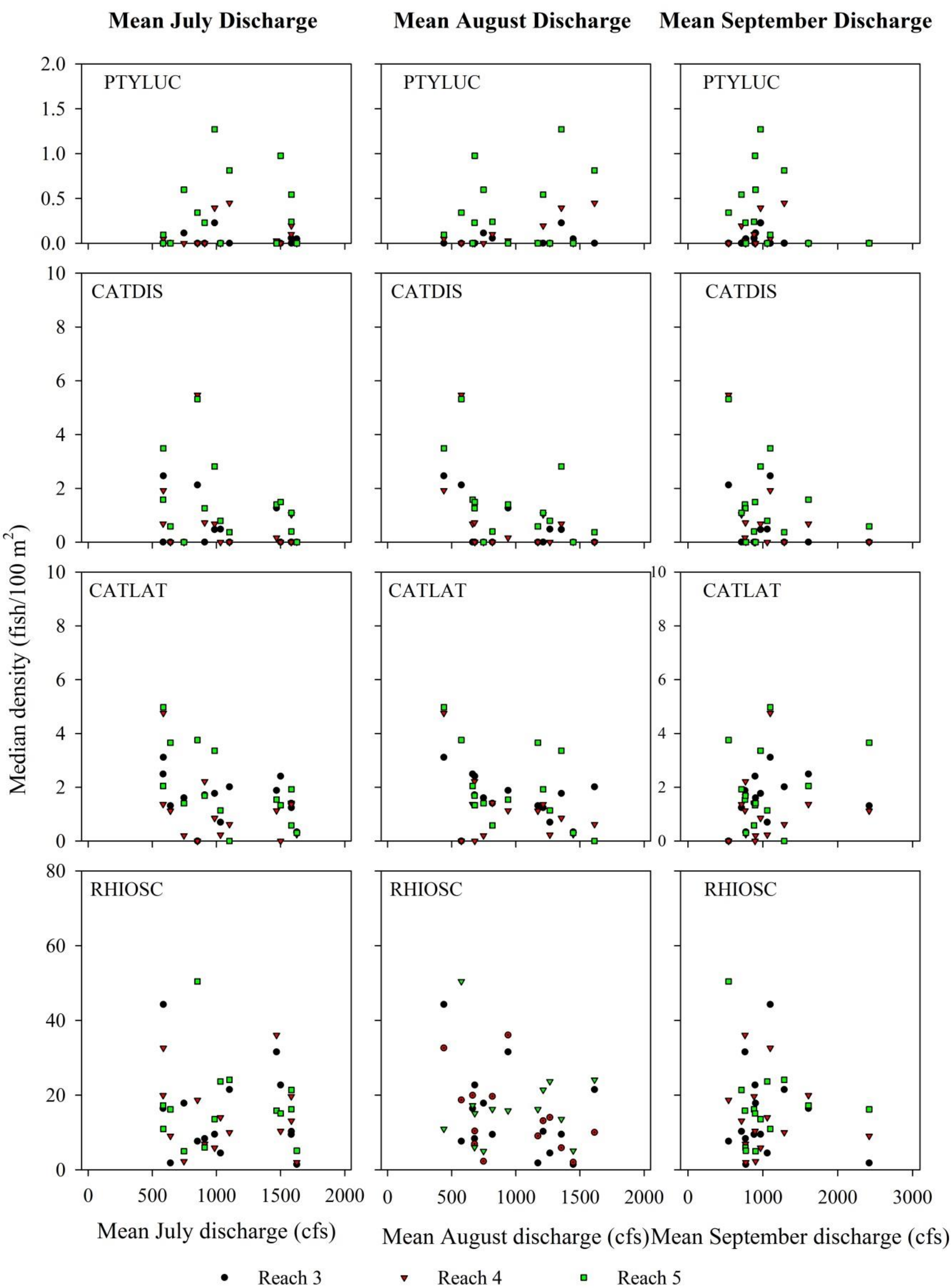


Figure 35. Bivariate relationships between median density (fish/100 m2) of native Colorado Pikeminnow (PTYLUC), Bluehead Sucker (CATDIS), Flannelmouth Sucker (CATLAT), and Speckled Dace (RHIOSC) in secondary channels of Reaches 3 – 5 and mean July, August, and September discharge (cfs). Discharge metrics were calculated from mean daily discharges at Four Corners, CO (USGS gage: 09371010).

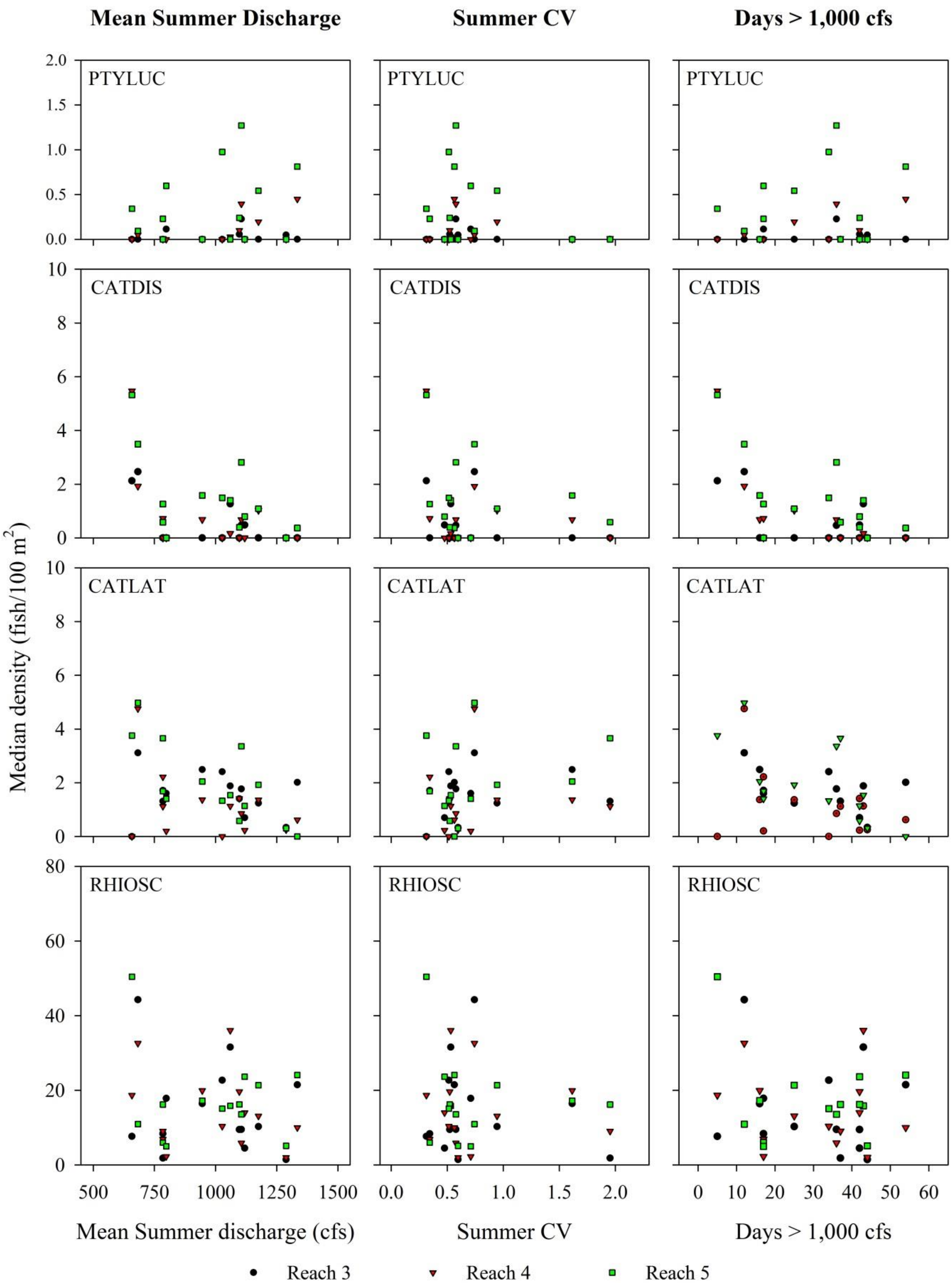


Figure 36. Bivariate relationships between median density (fish/100 m²) of native Colorado Pikeminnow (PTYLUC), Bluehead Sucker (CATDIS), Flannelmouth Sucker (CATLAT), and Speckled Dace (RHIOSC) in secondary channels of Reaches 3 – 5 and mean Summer discharge (cfs), Summer coefficient of variation (CV), and Summer days with discharge greater than 1,000 cfs. Discharge metrics were calculated from mean daily discharges at Four Corners, CO (USGS gage: 09371010).

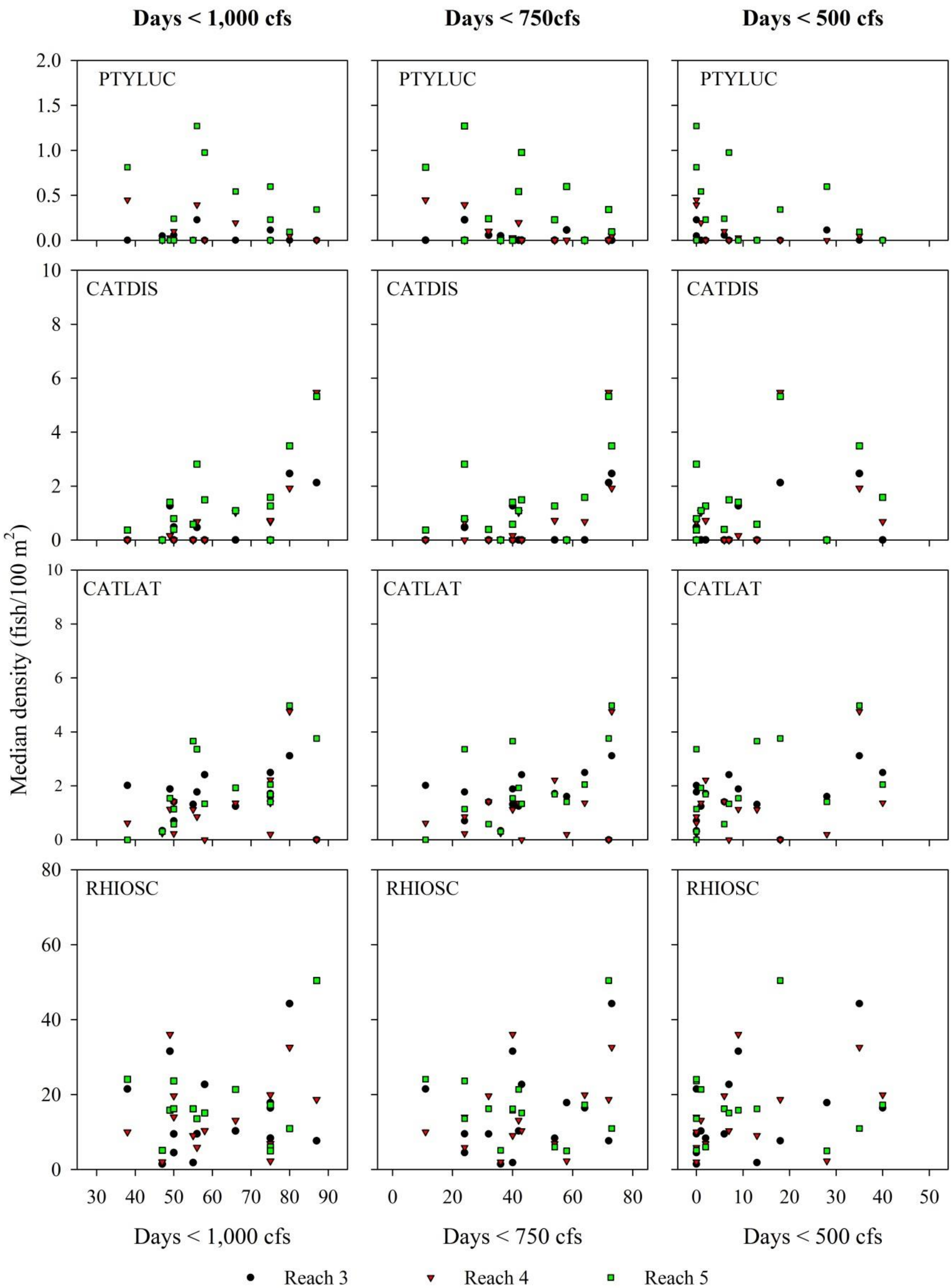


Figure 37. Bivariate relationships between median density (fish/100 m²) of native Colorado Pikeminnow (PTYLUC), Bluehead Sucker (CATDIS), Flannelmouth Sucker (CATLAT), and Speckled Dace (RHIOSC) in secondary channels of Reaches 3 – 5 and Summer days less than 1,000 cfs, 750 cfs, and 500 cfs. Discharge metrics were calculated from mean daily discharges at Four Corners, CO (USGS gage: 09371010).

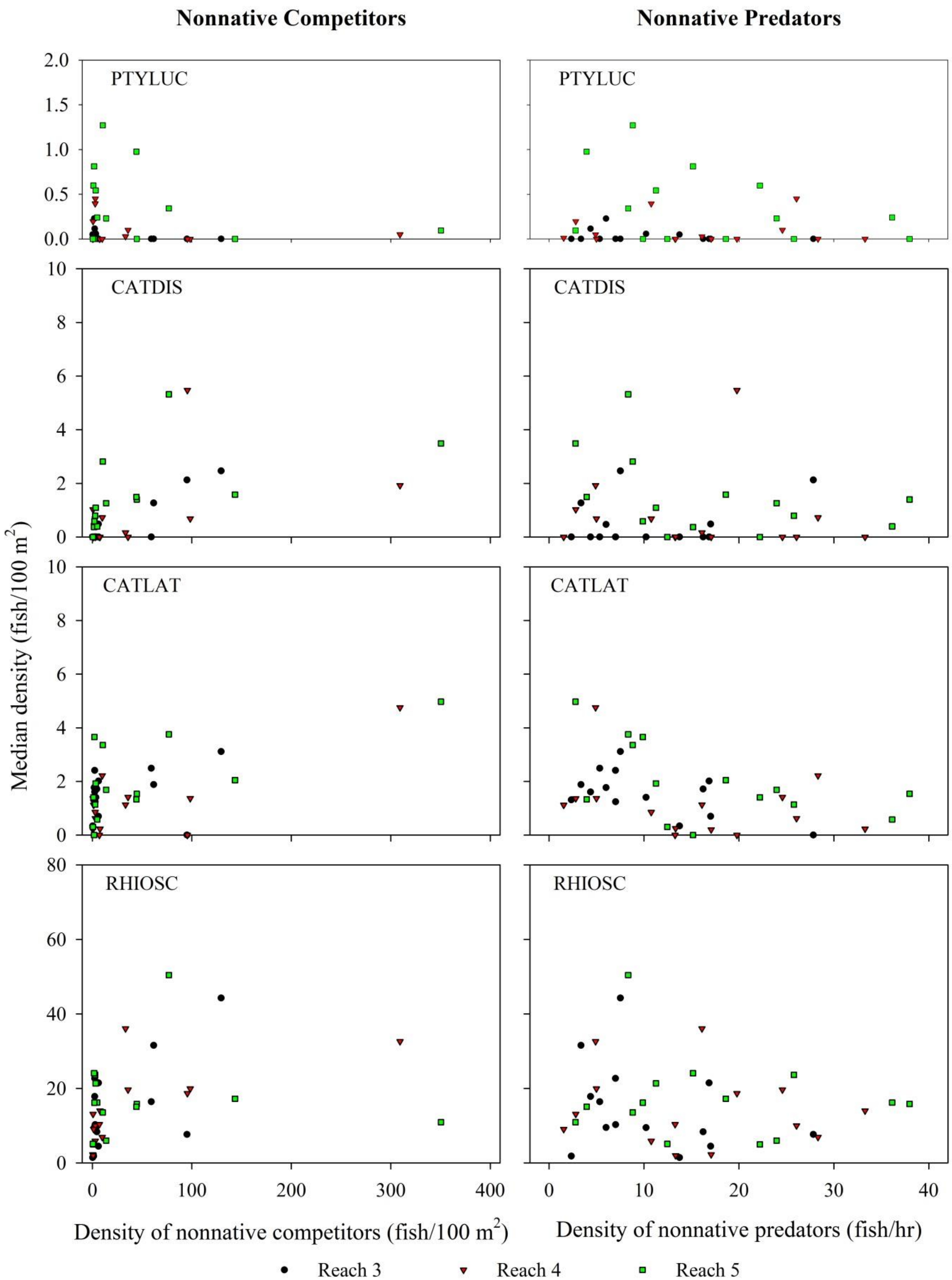


Figure 38. Bivariate relationships between median density (fish/100 m²) of native Colorado Pikeminnow (PTYLUC), Bluehead Sucker (CATDIS), Flannelmouth Sucker (CATLAT), and Speckled Dace (RHIOSC) in secondary channels of Reaches 3 – 5 and density of nonnative competitors (fish/100 m²) and nonnative predators (fish/hr).

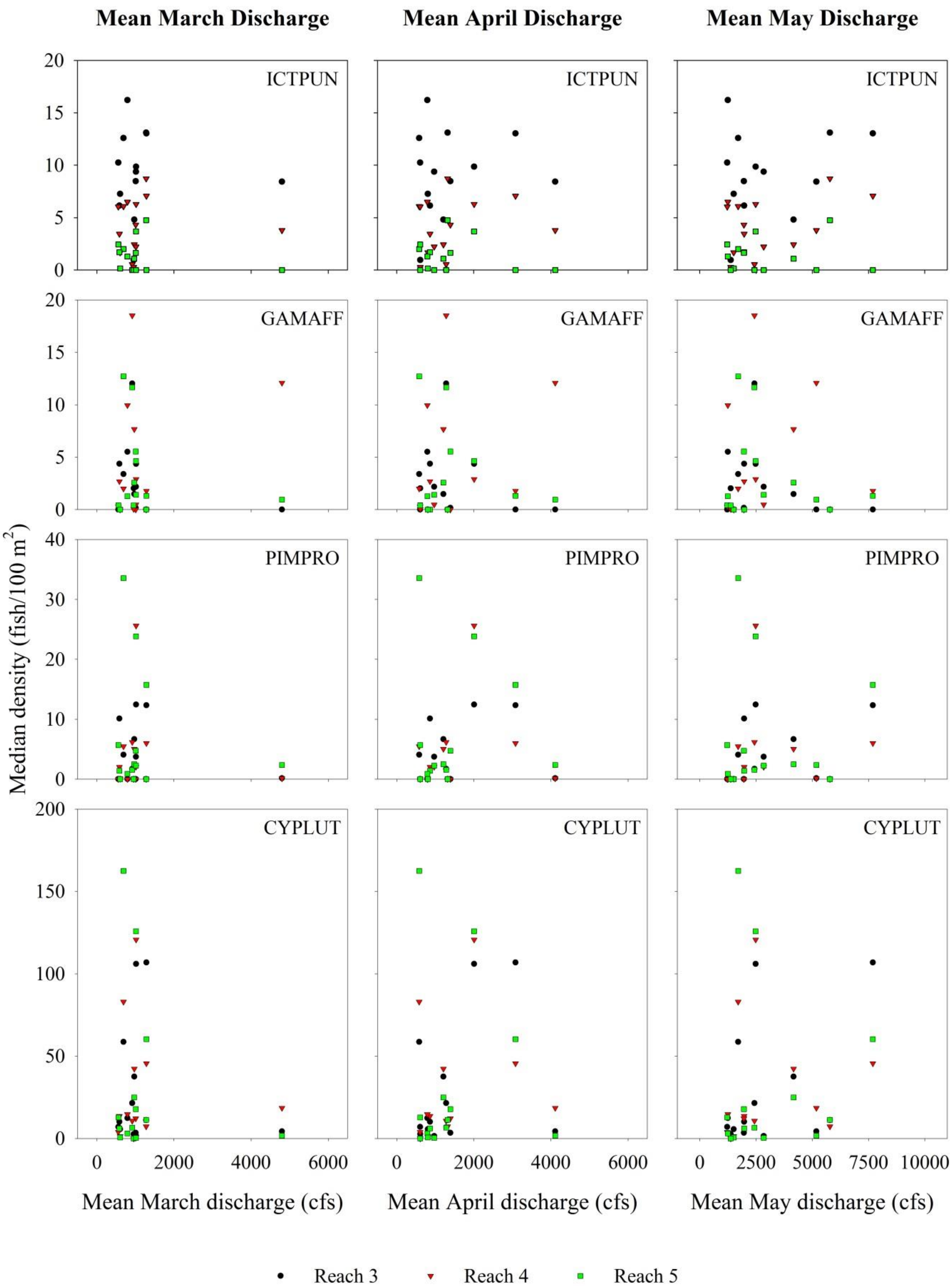


Figure 39. Bivariate relationships between median density (fish/100 m²) of nonnative Channel Catfish (ICTPUN), Western Mosquitofish (GAMAFF), Fathead Minnow (PIMPRO), and Red Shiner (CYPLUT) in secondary channels of Reaches 3 – 5 and mean March, April, and May discharges (cfs). Discharge metrics were calculated from mean daily discharges at Four Corners, CO (USGS gage: 09371010).

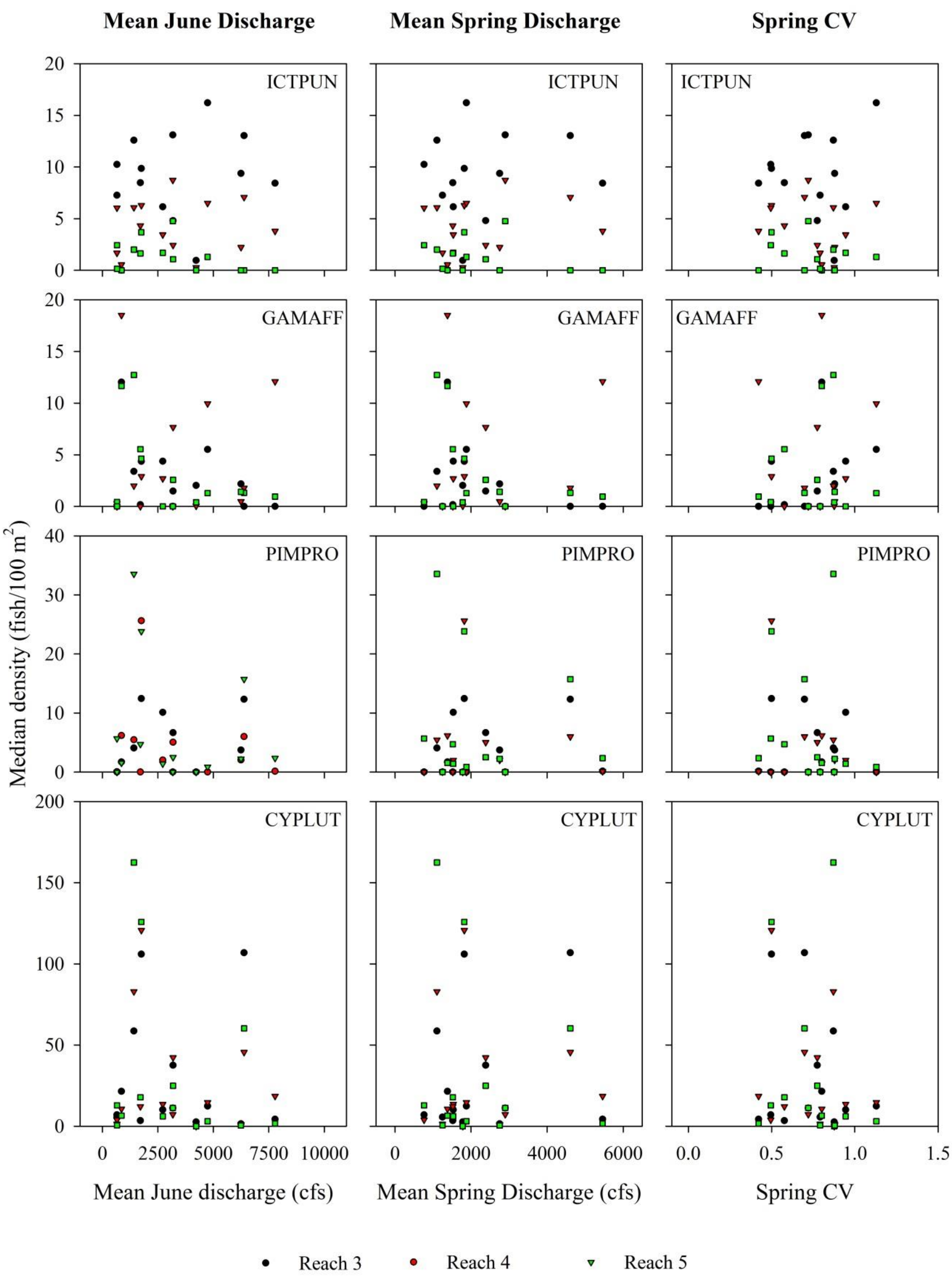


Figure 40. Bivariate relationships between median densities (fish/100 m²) of nonnative Channel Catfish (ICTPUN), Western Mosquitofish (GAMAFF), Fathead Minnow (PIMPRO), and Red Shiner (CYPLUT) in secondary channels of Reaches 3 – 5 and mean June discharge (cfs), mean Spring discharge (cfs), and Spring coefficient of variation (CV). Discharge metrics were calculated from mean daily discharge at Four Corners, CO (USGS gage: 09371010).

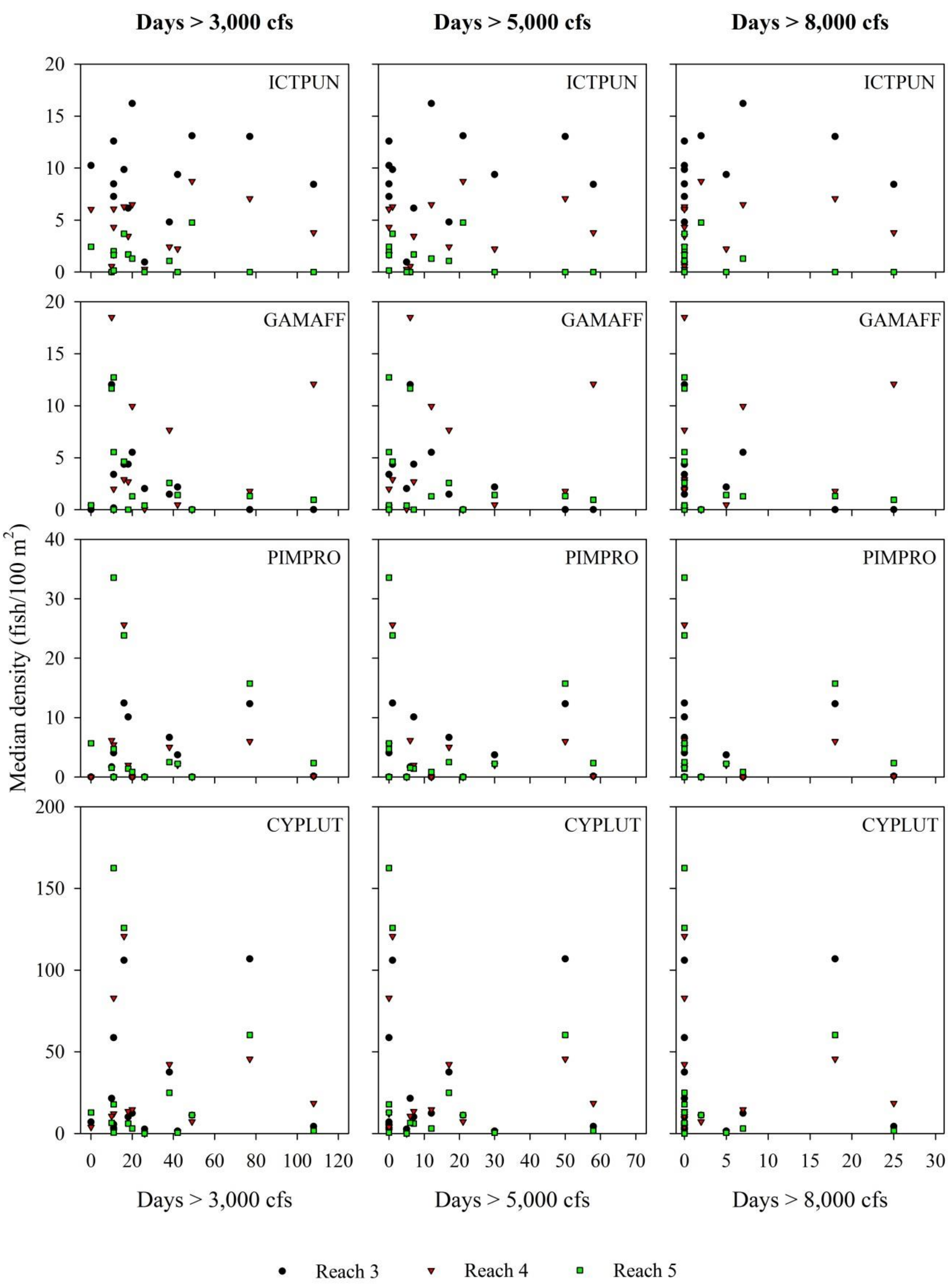


Figure 41. Bivariate relationships between median densities (fish/100 m²) of nonnative Channel Catfish (ICTPUN), Western Mosquitofish (GAMAFF), Fathead Minnows (PIMPRO), and Red Shiner (CYPLUT) in secondary channels of Reaches 3 – 5 and the number of days during the spring that are greater than 3,000 cfs, 5000 cfs, and 8,000 cfs. Discharge metrics were calculated from mean daily discharges at Four Corners, CO (USGS gage: 09371010).

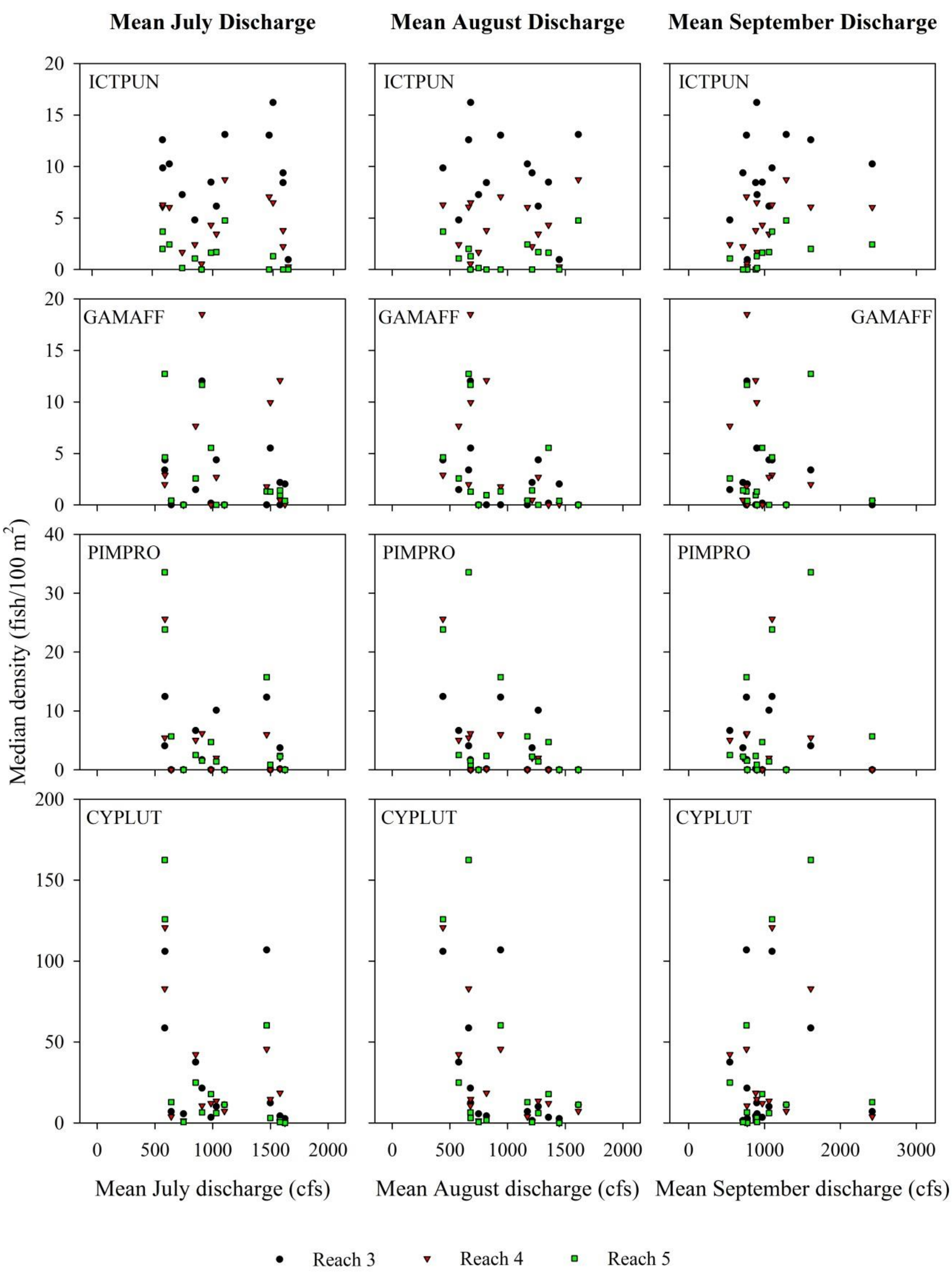


Figure 42. Bivariate relationships between median densities (fish/100 m²) of nonnative Channel Catfish (ICTPUN), Western Mosquitofish (GAMAFF), Fathead Minnow (PIMPRO), and Red Shiner (CYPLUT) in secondary channels of Reaches 3 – 5 and mean July, August, and September discharge (cfs). Discharge metrics were calculated from mean daily discharges at Four Corners, CO (USGS gage: 09371010).

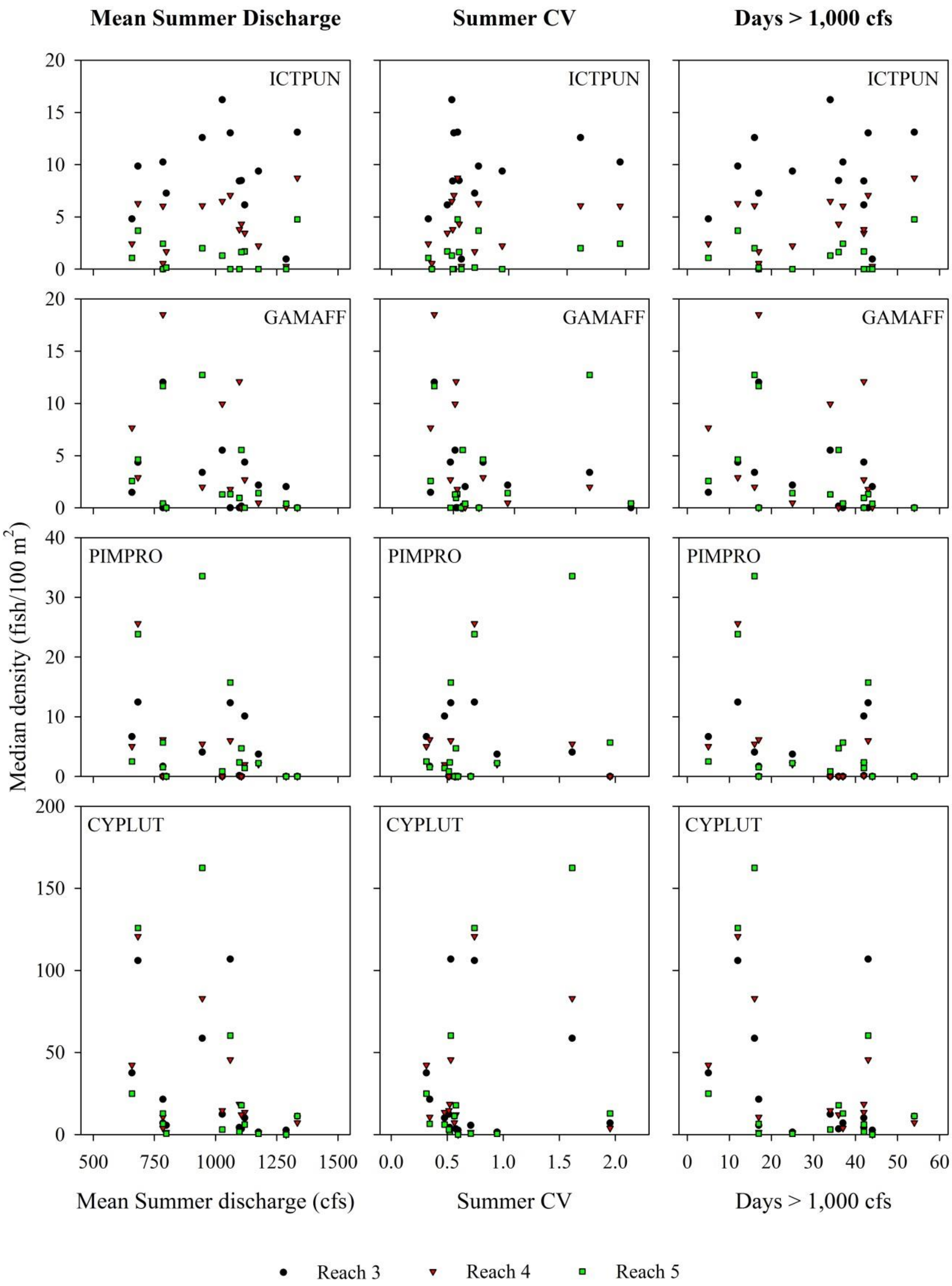


Figure 43. Bivariate relationships between median densities (fish/100 m²) of nonnative Channel Catfish (ICTPUN), Western Mosquitofish (GAMAFF), Fathead Minnows (PIMPRO), and Red Shiners (CYPLUT) in secondary channels of Reaches 3 – 5 and mean Summer discharge (cfs), Summer coefficient of variation (CV), and number of days during the Summer with discharge greater than 1,000 cfs. Discharge metrics were calculated from mean daily discharge at Four Corners, CO (USGS gage: 09371010).

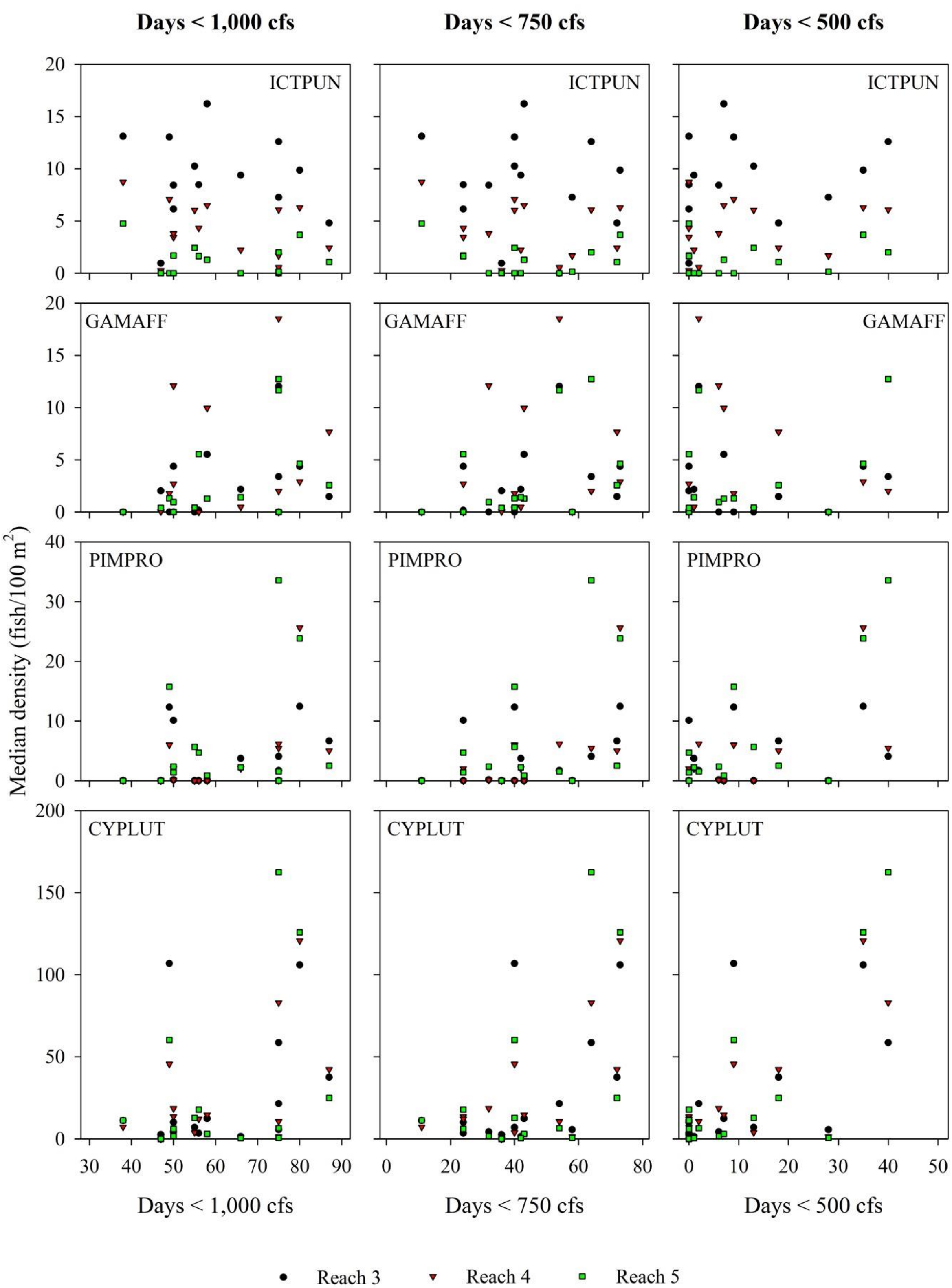


Figure 44. Bivariate relationships between median densities (fish/100 m^2) of nonnative Channel Catfish (ICTPUN), Western Mosquitofish (GAMAFF), Fathead Minnows (PIMPRO), and Red Shiners (CYPLUT) in secondary channels of Reaches 3 – 5 and number of days during the summer where discharge is less than 1,000 cfs, 750 cfs, and 500 cfs. Discharge metrics were calculated from mean daily discharge at Four Corners, CO (USGS gage: 09371010).

River Ecosystem Restoration Initiative (RERI) Secondary Channels

All River Ecosystem Restoration Initiative (RERI) and Reference secondary channels were sampled on 21 September. Similar to the previous two years, few of the RERI (N: 2) and Reference (N: 2) channels were sampled in 2016 because channels were either dry or not located (Table 15). The Reference channel at RM 133.5 was sampled but as a zero velocity channel and therefore not included in data summaries. The low flow (621 cfs, Four Corners CO, USGS gage: 09371010) on the day of sampling may account for some of the channels being completely dry or not flowing.

In 2016, 117 fishes were captured in RERI channels, 97% of which were native. All fishes captured in Reference channels (N: 19) were native. This was the highest number of fishes captured in RERI channels and the third highest number of fishes in Reference Channels since their monitoring began in 2012. The most common species captured in RERI channels was Speckled Dace (N: 109), followed by Bluehead Suckers (N: 3) and Flannelmouth Suckers (N: 2). Three nonnative species were captured in RERI channels, Channel Catfish, Fathead Minnow, and Red Shiner, but only 1 specimen of each species was captured. Two Colorado Pikeminnows were captured in 2016 (Table 16), both within the Reference Channel at RM 129.0. Both Colorado Pikeminnow were age-1 (143 mm TL and 181 mm TL) and were captured in the same seine haul in a run mesohabitat. No Razorback Sucker or Roundtail Chub were captured in either RERI or Reference channels in 2016.

Table 15. Information for River Ecosystem Restoration Initiative (RERI) and Reference secondary channels sampled during small-bodied fishes monitoring in the San Juan River from 2012 - 2016.

		Sampled?				
Site Type	River Mile	2012	2013	2014	2015	2016
Reference	134.3	Yes	No[2]	Yes	Yes	Yes
Reference	133.5	Yes	No[2]	No[2]	No[5]	No[5]
RERI	132.2	No[1]	Yes	Yes	No[1]	No[1]
RERI	132	Yes	Yes	Yes	Yes	Yes
RERI	130.7A	Yes	Yes	No[2]	No[1]	Yes
RERI	130.7B	Yes	No[3]	Yes	No[3]	No[3]
Reference	129	Yes	Yes	Yes	No[1]	Yes
RERI	128.6	No[2]	No[2]	No[2]	No[1]	No[1]
RERI	127.2	Yes	Yes	No[2]	Yes	No[2]
Reference	122.7	Yes	Yes	No[2]	No[2]	No[2]

[1]Channel was dry

[2]Channel was unable to be located

[3]Channel flow exceeded secondary channel definition

[4]Sampled but no fish were captured

[5]Secondaey channel was mostly dry and sampled as a large backwater

Table 16. Captures of Colorado Pikeminnow, Razorback Sucker, native fishes, and nonnative fishes in RERI (River Ecosystem Restoration Initiative) and Reference channels from 2012 - 2016.

	RERI channels				Reference channels			
Year	Colorado Pikeminnow	Razorback Sucker	Native	Nonnative	Colorado Pikeminnow	Razorback Sucker	Native	Nonnative
2012	2	0	55	32	0	0	43	140
2013	1	1	36	14	1	0	42	21
2014	2	0	17	35	0	0	7	1
2015	0	0	15	2	0	0	2	0
2016	0	0	114	3	2	0	17	0

DISCUSSION

The annual variability of river miles sampled, differences in channel types, and the number of different species captured present significant challenges when analyzing and interpreting data collected during SBF monitoring. In addition, the zero inflated dataset further complicates the analysis and precludes the use of more common parametric statistical techniques. The use of the Delta-GLM approach to model density solves some of these problems by accounting for the excessive number of zeros in the dataset. This approach appears to be effective in accounting for these zeros by adjusting positive densities by the probability of presence as determined by the distribution of presence/absence for a particular species. The results of the Delta-GLM are also more easily interpreted than more complex analyses such as mixture models (Fletcher et al. 2005). Furthermore, inclusion of presence/absence modelling allows for the assessment of how the probability of presence for specific species varies between explanatory variables such as geomorphic reach, channel type, and mesohabitat type.

Although the Delta-GLM approach does appear to solve problems with excessive zeros in the dataset, several drawbacks to the approach were observed. First, because some species (e.g., Black Bullheads, Common Carp, White Sucker) are highly uncommon, use of the Delta-GLM approach is difficult due to the low number of seine hauls with captures. Calculation of densities for these uncommon species may not be valuable though because they are so uncommon, but future densities could be calculated if captures of these species increase. Second, high densities were under predicted for almost all species in the $CPUE^{+}$ and Delta-GLM models. This may be due to the overall structure of the dataset with the majority of densities being very low but several extreme density values present, creating a right skewed data distribution. For instance, the median of raw density (i.e., non-Delta-GLM calculated) of Speckled Dace from 2003 - 2016 is 17.6 fish/100 m^2 but ranges from 0.4 – 15,634.4 fish/100 m^2. These extreme outliers complicate the analysis but appear to be largely random within the dataset. Last, covariates used in the Delta-GLM approach did a poor job of describing the presence/absence and density for some species as indicated by several models with $\Delta AIC_c < 2$ and low support (AIC_c weight) for top models. Although modeling ecological data is inherently difficult, additional explanatory variables (e.g., discharge metrics and habitat complexity data) and different methods (e.g., linear mixed models or generalized additive models) to accurately model density of common species in the San Juan River should be explored.

River-wide captures of small-bodied and juvenile fishes were much higher in 2016 than recent years such as 2014 and 2015, and the highest since 2011. In comparison, the capture of 6,513 fishes in 2016 was higher than the combined 2014 and 2015 totals of 3,827. A reason for the increase in captures, especially for Speckled Dace, is currently unknown but the high spring runoff is a potential explanation (Propst and Gido 2004; Gido and Propst 2012). Although given the previous research which indicated that higher spring discharge results in higher densities of native Bluehead Suckers and Flannelmouth Suckers, it is surprising that significant increases in these two species were not also observed. Differences in life history between Bluehead Suckers, Flannelmouth Suckers, and Speckled Dace may be one reason why these three species were influenced differently by the high spring runoff. Speckled Dace spawn during the summer after spring runoff and may benefit from changes in habitat and cleaning of cobble which occurs during high spring runoffs. Relationships between density and spring flows for native Bluehead Sucker, Flannelmouth Sucker, and Speckled Dace seem to support this, with Speckled Dace indicating an increasing relationship with increased spring discharges and both sucker species having higher densities at more moderate spring discharges (Figures 32 – 34).

The significant increase in Channel Catfish density is more difficult to explain, especially given the lack of relationships between density of Channel Catfish and discharge metrics (Figures 39 – 44). A potential reasoning could be a compensatory response to the intensive nonnative removal effort which occurred in 2016, with the majority of effort occurring before Channel Catfish spawned. Although data for the San Juan River is lacking, large-scale removal programs for other species in the western U.S. have shown that removal can shift populations towards earlier maturity and higher fecundity at smaller sizes (Syslo et al. 2011; Cox et al. 2013) or decrease natural mortality such that removal is offset (Meyer et al. 2006). Continuous removal over the past several years could have caused a similar shift in Channel Catfish in the San Juan River, allowing smaller fish, with high fecundities, which are not removed to spawn. Furthermore, removal of larger Channel Catfish could preserve more resources for age-0 fish, increasing their survival. Additional support for this hypothesis is the relationship between adult and age-0 Channel Catfish with higher densities of age-0 Channel Catfish occurring in years with lower catch rates of adult Channel Catfish (Gido and Propst 2012). Additional hypotheses on factors affecting changes in density of age-0 Channel Catfish should be developed and investigated.

Perhaps the most important finding during 2016 SBF monitoring was the capture of wild age-0 rare and endangered fishes (i.e., Colorado Pikeminnow, Razorback Sucker, and Roundtail Chub), and in particular, the capture of 23 age-0 Colorado Pikeminnows. These captures represent the first wild post-larval age-0 Colorado Pikeminnow captured during SBF monitoring since standardized monitoring began in 1998. The capture of these fish raises several questions, but most importantly, how many wild age-0 Colorado Pikeminnow were present river-wide in the San Juan in 2016. Small-bodied fishes monitoring in the San Juan River is designed to monitor the entire fish community and not to specifically target age-0 Colorado Pikeminnow, potentially skewing density estimates based on all sampled habitat. Age-0 Colorado Pikeminnow showed a high affinity for low and zero velocity habitats, a characteristic supported by studies on stocked age-0 fish in the San Juan River (Golden and Holden 2005; Golden et al. 2006) and wild age-0 fish in the upper Colorado River Basin (Tyus and Haines 1991).

An attempt to calculate the potential abundance of wild age-0 Colorado Pikeminnow was made to better understand the potential importance of the 2016 age class for Colorado Pikeminnow. A range of estimated abundances was made using a variety of data from several studies in the San Juan River and on age-0 Colorado Pikeminnow in the Upper Colorado River basin. Information on the amount of low and zero velocity habitat available river-wide was obtained from habitat studies in the San Juan River by Blisner et al. (2009). This total area was then compared to the total area of similar habitats sampled during SBF monitoring to calculate a percentage of total area which was sampled over the same time period (2003 – 2007). Average percentage of habitat sampled (0.8%) during small-bodied fishes monitoring was then used as a baseline to estimate a range of potential percentage of habitats that could have been sampled in 2016 (i.e., 0.5%, 1.0%, 2.5%, 5.0%). Percentage of habitat was then adjusted by area sampled based on (1) RM 108 – 53 and (2) RM 108 – 2.9. The adjustment of habitat was based on (1) area sampled from the first location where age-0 Colorado Pikeminnow were captured downstream to where sampling ended in 2016 and (2) downstream to the Clay Hills, UT take-out. Although little information on capture probabilities of age-0 Colorado Pikeminnow exists, a mark-recapture study by Hines et al. (1998) was used to define a potential range of capture probabilities using seines. We used the range of capture probabilities (0.05 – 0.12) during the first pass from Haines et al. (1998) to define four different capture probabilities (i.e., 0.05, 0.075, 0.10, 0.125). The sampled area and capture probabilities were then used to calculate the potential number of age-0 Colorado Pikeminnow in the San Juan River in 2016 (Figure 46).

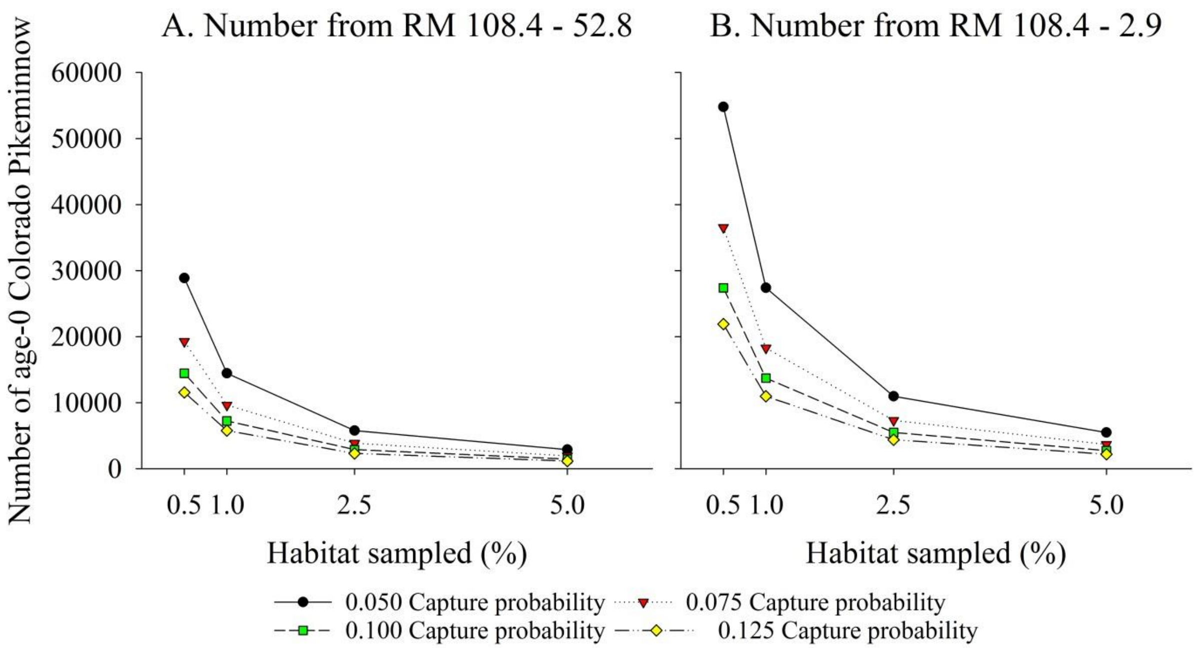


Figure 45. Potential number of age-0 Colorado Pikeminnow in the San Juan River in 2016 from (A) RM 108.4 – 52.8 and (B) RM 108.4 – 2.9 based on the number captured during sampling (N: 23), percent area sampled, and potential capture probabilities.

The potential number of wild age-0 Colorado Pikeminnow in the San Juan River in 2016 showed significant variation based on the potential percentage of habitat sampled and capture probability. Estimates in the section of river from RM 108.4 – 52.8 ranged from 1,155 – 28,883 fish and from 2,192 – 54,805 fish in the section of river from RM 108.4 – 2.9. Although these estimates provide potential bounds on the number of wild age-0 fish in the river, care should be taken as the assumption that habitat was evenly distributed throughout these two sections of rivers was likely violated. Reaches 1 and 2 are geomorphically different than upstream reaches, as both are canyon bound and lack secondary channels, an important habitat for age-0 Colorado Pikeminnow. Reach 2 usually has very little available zero-velocity habitat but Reach 1 often has more backwater area than most upstream reaches (Lamarra and Lamarra 2016), and densities of age-0 Colorado Pikeminnow in this reach could be higher than those observed where sampling occurred. Investigations into potential methods for estimating the number of age-0 Colorado Pikeminnow in the San Juan River should be made, with potential mark-recapture methods utilized once the presence of age-0 Colorado Pikeminnow becomes more common.

Small-bodied fishes monitoring is an important component of the SJRIP and assessing the recovery of endangered Colorado Pikeminnow and Razorback Sucker. The capture of 23 wild age-0 Colorado Pikeminnow, 1 wild age-0 Razorback Sucker, and 3 age-0 wild Roundtail Chub is an important milestone for the SJRIP. These captures indicate that the current protocol for SBF monitoring is adequate for detecting these species when they are present in the river. Although lack of data limits rigorous conclusions, anecdotal evidence indicates that the high and sustained spring runoff in 2016 may have been important for recruitment of these rare fishes from the larval to the post-larval juvenile stages. Continued annual sampling will be important for elucidating these relationships in the future.

Recommendations

The 2016 findings during SBF monitoring highlight several important considerations for SBF monitoring and the SJRIP. Approximately 50 miles of the lower river were not sampled in 2016, limiting a complete assessment of the distribution and density of wild age-0 Colorado Pikeminnow and Razorback Sucker. The SBF monitoring protocol needs to be more flexible to allow for a full assessment of the river when age-0 endangered species are present. Sampling effort should be shifted to areas of the river where these fish are more likely to be present when they are detected during normal sampling. Also, the current SBF monitoring protocol is designed to sample the entire fish community but alterations to the protocol which target specific habitats used by age-0 Colorado Pikeminnow and Razorback Sucker would greatly enhance the knowledge and density estimates for these species. Any alterations to the monitoring protocol would limit comparisons to previous years for common native and nonnative species. Before any changes to the protocol are made, increased efforts outside of the protocol should be made to determine how alterations would benefit the program. This could simply involve making additional seine hauls within low- and zero velocity habitats.

A second consideration for the SJRIP is how to tag small Colorado Pikeminnow and Razorback Sucker. Currently all endangered fish ≥ 150 mm are implanted with a 12-mm PIT tag upon first capture. Although this likely covers the vast majority of fish captured during nonnative removals and annual sub-adult and adult monitoring, small-bodied fishes monitoring routinely captures fish < 150 mm every year. In 2016, 7 of the 19 age-1 Colorado Pikeminnow captured were < 150 mm and 57% (146 of 256) of all age-1 Colorado Pikeminnow captured since 2003 were < 150 mm. This results in a significant amount of lost data for age-1 fish which cannot be tagged until a subsequent capture. Recent advances in PIT tagging technology has resulted in a plethora of studies investigating the use small PIT tags (e.g., 8-mm and 9-mm) for tagging small (i.e., < 150 mm) fishes (Kaemingk et al. 2011; Bangs et al. 2013; Tiffan et al. 2015; Clark 2016). Most of these studies were focused on fish much smaller than 150 mm and results indicated little or no effects on survival and growth after implant with 8- or 9-mm PIT tags. The SJRIP should investigate use of smaller PIT tags for tagging age-1 Colorado Pikeminnow, with eventual alterations to the current PIT tagging protocol to allow for tagging of endangered fish down to 90 mm.

The final recommendation based on this year's SBF monitoring results is potential alterations to the current augmentation protocols. Currently, approximately 400,000 age-0 Colorado Pikeminnow are stocked during the fall each year (Furr 2016). While these augmentation efforts have undoubtedly resulted in the reestablishment of Colorado Pikeminnow in the San Juan River, continued population enhancement when wild age-0 Colorado Pikeminnow are present should be carefully considered. While little information is available for endangered species enhancement programs, a litany of studies have shown the negative consequences of stocking hatchery salmonids into wild populations (Einum and Fleming 2001; Bohlin et al. 2002; Webber and Fausch 2003; Quinones et al. 2013). Even with low retention rates of stocked age-0 Colorado Pikeminnow (Golden et al. 2006); the stocking of several thousand age-0 Colorado Pikeminnow could have detrimental effects on wild fish by competing for space and resources. Development of an adaptive augmentation plan which addresses the presence of wild age-0 Colorado Pikeminnow will not only be important for limiting negative interactions between hatchery and stocked fish but will also allow for the assessment of wild age classes without the influence of hatchery fish. Although age-0 Razorback Suckers are still rare, a similar adaptive augmentation plan should also be developed for them in preparation of future increases in abundance.

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APPENDIX A.

SPECIES SPECIFIC CAPTURES FROM 2003 - 2016

Table A1. Common name, scientific name, and six letter species code for fish species captured during small-bodied fishes monitoring in the San Juan River. Bold type indicates species native to the San Juan River.

Common name	Scientific name	Six letter species code
Bluehead Sucker	***Catostomus discobolus***	**CATDIS**
Flannelmouth Sucker	***Catostomus latipinnis***	**CATLAT**
Mottled Sculpin	***Cottus bairdii***	**COTBAI**
Roundtail Chub	***Gila robusta***	**GILROB**
Colorado Pikeminnow	***Ptychocheilus lucius***	**PTYLUC**
Speckled Dace	***Rhinichthys osculus***	**RHIOSC**
Razorback Sucker	***Xyrauchen texanus***	**XYRTEX**
Black Bullhead	*Ameiurus melas*	AMEMEL
Yellow Bullhead	*Ameiurus natalis*	AMENAT
Common Carp	*Cyprinus carpio*	CYPCAR
Red Shiner	*Cyprinella lutrensis*	CYPLUT
Plains Killifish	*Fundulus zebrinus*	FUNZEB
Mosquitofish	*Gambusia affinis*	GAMAFF
Channel Catfish	*Ictalurus punctatus*	ICTPUN
Green Sunfish	*Lepomis cyanellus*	LEPCYA
Bluegill	*Lepomis macrochirus*	LEPMAC
Largemouth Bass	*Micropterus salmoides*	MICSAL
Rainbow Trout	*Oncorhynchus mykiss*	ONCMYK
Fathead Minnow	*Pimephales promelas*	PIMPRO
Brown Trout	*Salmo trutta*	SALTRU

Table A2. Number of native fishes captured (N) in the primary channel of Reaches 1 and 2 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish, excluding age 2+ Colorado Pikeminnow and Razorback Sucker, captured divided by the total area (Total Area, m^2) sampled for each year. Note that neither Reach 1 or 2 were sampled from 2011 - 2014 and only a small portion of Reach 2 was sampled in 2016.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CATDIS	1	36	1	1			3	2						
CATLAT	8	6	3	1	2	1		7						
COTBAI														
GILROB														
PTYLUC			1	1	4		2	2					1	
Age-0					3									
Age-1				1	1		2	2					1	
Age-2+			1										1	
RHIOSC	23	75	55	51	43	28	14	52					11	10
XYRTEX														
Age-0														
Age-1														
Age-2+														
Total N	32	117	59	54	49	29	19	63					12	10
Total Area	1105	1400	1470	1194	1973	1121	1973	2534					5416	824
Yearly Density	2.9	8.4	4.0	4.5	2.5	2.6	1.0	2.5					0.2	1.2

Table A3. Number of nonnative fish captured (N) in the primary channel of Reaches 1 and 2 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish captured divided by the total area (Total Area, m^2) sampled for each year. Note that neither Reach 1 or 2 were sampled from 2011 - 2014 and only a small portion of Reach 2 was sampled in 2016.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
AMEMEL		1												
AMENAT														
CATCOM														
CYPCAR			3	1		1								
CYPLUT	199	703	199	28	43	5	84	57						
FUNZEB	5													
GAMAFF	1	6	1				3						1	
ICTPUN	182	184	169	113	241	130	48	130					74	125
LEPCYA	1		1				1							
LEPMAC														
MICSAL							1							
ONCMYK														
PIMPRO	2	11	13	1										
POMANN														
SALTRU														
Total N	390	905	386	143	284	136	137	187					75	125
Total Area	1105	1400	1470	1194	1973	1121	1973	2534					5416	824
Yearly Density	35.3	64.6	26.2	12.0	14.4	12.1	6.9	7.4					1.4	15.2

Table A4. Number of native fishes captured (N) in secondary channels of Reaches 1 and 2 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish, excluding age 2+ Colorado Pikeminnow and Razorback Sucker, captured divided by the total area (Total Area, m^2) sampled for each year. Note that neither Reach 1 or 2 were sampled from 2011 - 2014 and only a small portion of Reach 2 was sampled in 2016.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CATDIS														
CATLAT														
COTBAI														
GILROB														
PTYLUC					1									
Age-0					1									
Age-1														
Age-2+														
RHIOSC							4	2						
XYRTEX														
Age-0														
Age-1														
Age-2+														
Total N	n/a	n/a	n/a	n/a	1	0	4	2					n/a	n/a
Total Area	0	0	0	0	49	0	44	43					0	0
Yearly Density	n/a	n/a	n/a	n/a	2.0	0.0	9.1	4.6					n/a	n/a

Table A5. Number of nonnative fish captured (N) in secondary channels of Reaches 1 and 2 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish captured divided by the total area (Total Area, m^2) sampled for each year. Note that neither Reach 1 or 2 were sampled from 2011 - 2014 and only a small portion of Reach 2 was sampled in 2016.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
AMEMEL														
AMENAT														
CATCOM														
CYPCAR														
CYPLUT					5		1							
FUNZEB														
GAMAFF							9							
ICTPUN					8		11	7						
LEPCYA														
LEPMAC														
MICSAL														
ONCMYK														
PIMPRO														
POMANN														
SALTRU														
Total N	n/a	n/a	n/a	n/a	13	0	21	7					n/a	n/a
Total Area	0	0	0	0	49	0	44	43					0	0
Yearly Density	n/a	0.0	n/a	n/a	26.5	n/a	47.7	16.1					n/a	n/a

Table A6. Number of native fishes captured (N) in zero velocity channels of Reaches 1 and 2 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish, excluding age 2+ Colorado Pikeminnow and Razorback Sucker, captured divided by the total area (Total Area, m^2) sampled for each year. Note that neither Reach 1 or 2 were sampled from 2011 - 2014 and only a small portion of Reach 2 was sampled in 2016.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CATDIS														
CATLAT														2
COTBAI														
GILROB														
PTYLUC					1			1						7
Age-0					1									6
Age-1								1						1
Age-2+														
RHIOSC		2												
XYRTEX														1
Age-0														1
Age-1														
Age-2+														
Total N	0	2.0	0.0	n/a	1	0	0	1					n/a	10
Total Area	33	35	70	0	125	19	51	258					0	169
Yearly Density	0.0	5.6	0.0	n/a	0.8	0.0	0.0	0.4					n/a	5.9

Table A7. Number of nonnative fish captured (N) in zero velocity channels of Reaches 1 and 2 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish captured divided by the total area (Total Area, m^2) sampled for each year. Note that neither Reach 1 or 2 were sampled from 2011 - 2014 and only a small portion of Reach 2 was sampled in 2016.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
AMEMEL														
AMENAT														
CATCOM														1
CYPCAR														
CYPLUT	15	24	59					3						
FUNZEB														
GAMAFF		1				2	1							
ICTPUN	8		1		10	1	2	2						18
LEPCYA	1													
LEPMAC														
MICSAL			2											
ONCMYK														
PIMPRO	1	1	13											
POMANN														
SALTRU														
Total N	25	26	75	n/a	10	3	3	5					n/a	19
Total Area	33	35	70	0	125	19	51	258					0	169
Yearly Density	75.7	73.4	107.2	n/a	8.0	15.5	5.9	1.9					n/a	11.2

Table A8. Number of native fishes captured (N) in the primary channel of Reaches 3 - 6 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish, excluding age 2+ Colorado Pikeminnow and Razorback Sucker, captured divided by the total area (Total Area, m^2) sampled for each year.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CATDIS	27	247	60	148	45	60	228	197	28	112	133	57	69	64
CATLAT	127	233	50	52	115	101	190	589	89	246	363	112	60	191
COTBAI														
GILROB										1				
PTYLUC														
Age-0					5									4
Age-1		3	1	6	15	3	6	23	33	23	3	19	10	8
Age-2+		1		1			2	3	5	2	8			
RHIOSC	481	4591	1087	2273	1960	1172	2930	1954	656	995	1398	453	324	2674
XYRTEX														
Age-0														
Age-1														
Age-2+			1										2	
Total N	635	5074	1198	2479	2140	1336	3354	2763	806	1377	1897	641	463	2941
Total Area	2485	5920	4031	4932	6705	5510	5857	8105	10459	15312	7027	8929	9849	7215
Yearly Density	25.6	85.7	29.7	50.3	31.9	24.2	57.3	34.1	7.7	9.0	27.0	7.2	4.7	40.8

Table A9. Number of nonnative fish captured (N) in the primary channel of Reaches 3 - 6 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish captured divided by the total area (Total Area, m^2) sampled for each year.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
AMEMEL		1	1						4				1	2
AMENAT								4						
CATCOM														1
CYPCAR		5				1					1	1		
CYPLUT	1502	8625	2194	134	166	173	2485	164	250	413	39	61	15	29
FUNZEB	16	29				1	13	3	2	18	5	4	2	2
GAMAFF	36	113	9	2	2	5	27	3	38	158	15	7	62	28
ICTPUN	167	392	228	209	480	370	63	324	506	105	299	74	23	331
LEPCYA	1	1				1	4	1	2	1	1		3	
LEPMAC									1				1	
MICSAL		3	1		1		4		1	3		1	2	
ONCMYK														
PIMPRO	99	1039	206	12	8	15	48	12	3	31	26	41	26	74
POMANN														
SALTRU							1	2		1	2	1		
Total N	1821	10208	2639	357	657	566	2645	513	807	730	388	190	135	467
Total Area	2485	5920	4031	4932	6705	5510	5857	8105	10459	15312	7027	8929	9849	7215
Yearly Density	73.3	172.4	65.5	7.2	9.8	10.3	45.2	6.3	7.7	4.8	5.5	2.1	1.4	6.5

Table A10. Number of native fishes captured (N) in secondary channels of Reaches 3 - 6 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish, excluding age 2+ Colorado Pikeminnow and Razorback Sucker, captured divided by the total area (Total Area, m^2) sampled for each year.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CATDIS	19	122	7	60	12	43	101	173	204	45	34	9	47	254
CATLAT	105	112	22	58	79	191	74	285	61	202	138	62	54	88
COTBAI														
GILROB									1	1		2		
PTYLUC														
Age-0					2									8
Age-1		2	1	1	13	6	1	17	21	2	2	9	5	8
Age-2+		2		1				1			3		1	1
RHIOSC	244	1329	173	252	819	999	1067	886	521	211	596	212	207	1459
XYRTEX														
Age-0														
Age-1														
Age-2+											1		1	1
Total N	368	1565	203	371	925	1239	1243	1361	808	461	770	294	313	1817
Total Area	1412	1735	1044	1965	2372	3204	2354	2748	2412	3738	2973	4099	5568	5271
Yearly Density	26.1	90.2	19.4	18.9	39.0	38.7	52.8	49.5	33.5	12.3	25.9	7.2	5.6	34.5

Table A11. Number of nonnative fish captured (N) in secondary channels of Reaches 3 - 6 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish captured divided by the total area (Total Area, m^2) sampled for each year.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
AMEMEL	9	6	3	1		3	1		8	1				5
AMENAT			1	3		2	5			3		2	1	
CATCOM														1
CYPCAR	1	10				5	4				1			6
CYPLUT	1632	6896	923	157	160	289	1671	378	197	336	43	24	5	18
FUNZEB	4	32				3		1	16	2				2
GAMAFF	31	153	45	4	1	76	27	28	221	323	12	3	26	133
ICTPUN	65	98	74	39	209	97	41	115	182	13	187	101	13	192
LEPCYA		1					2		3	2			3	1
LEPMAC														
MICSAL		6				10	6	2	6	6				
ONCMYK														
PIMPRO	303	2070	104	30	4	116	19	50	22	74	5	2	2	68
POMANN														
SALTRU														
Total N	2045	9272	1150	234	374	601	1776	574	655	760	248	132	50	426
Total Area	1412	1735	1044	1965	2372	3204	2354	2748	2412	3738	2973	4099	5568	5271
Yearly Density	144.9	534.3	110.1	11.9	15.8	18.8	75.4	20.9	27.2	20.3	8.3	3.2	0.9	8.1

Table A12. Number of native fishes captured (N) in zero velocity channels of Reaches 3 - 6 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish, excluding age 2+ Colorado Pikeminnow and Razorback Sucker, captured divided by the total area (Total Area, m^2) sampled for each year.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CATDIS	3	5	43		1	6	26		794	1	22	33	29	29
CATLAT	4	5	123		3	24	29	56	15	1	95	14	1	78
COTBAI														
GILROB														3
PTYLUC														
Age-0					16								1	5
Age-1					2		1	2	2					2
Age-2+						1								
RHIOSC	4	19	37	1	28	110	38	19	100	8	66	30	57	212
XYRTEX														
Age-0														
Age-1														
Age-2+														1
Total N	11	29	203	1	50	140	94	77	911	10	183	77	88	329
Total Area	242	404	475	53	435	449	969	471	1188	596	347	787	705	1754
Yearly Density	4.6	7.2	42.7	1.9	11.5	31.2	9.7	16.4	76.7	1.7	52.7	9.8	12.5	18.8

Table A13. Number of nonnative fish captured (N) in zero velocity channels of Reaches 3 - 6 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish captured divided by the total area (Total Area, m^2) sampled for each year.

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
AMEMEL	12						121	8	44					3
AMENAT					1		1	1	1					
CATCOM														1
CYPCAR		4	1			2	3							1
CYPLUT	305	1284	529	3	61	288	2370	197	2693	218	6	99	19	26
FUNZEB	1	24	4			1		3	11	11	4	2	11	1
GAMAFF	20	15	26			4	440	25	133	921	17	25	10	26
ICTPUN	2	20	1		22	36	5	9	19			1		50
LEPCYA						1	89		1	9				1
LEPMAC														
MICSAL						6	21							2
ONCMYK														
PIMPRO	175	393	113	2	12	34	182	24	88	111	189	60	3	47
POMANN														
SALTRU														
Total N	515	1740	674	5	96	372	3232	267	2990	1270	216	187	43	158
Total Area	242	404	475	53	435	449	969	471	1188	596	347	787	705	1754
Yearly Density	213.0	430.8	141.8	9.4	22.1	82.9	333.4	56.7	251.6	213.0	62.2	23.8	6.1	9.0

Table A14. Number of native fishes captured (N) in the primary channel of Reach 7 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish, excluding age 2+ Colorado Pikeminnow and Razorback Sucker, captured divided by the total area (Total Area, m^2) sampled for each year.

Species	2012	2013	2014	2015	2016
CATDIS	24	42	69	18	13
CATLAT	15	292	85	59	2
COTBAI		1			
GILROB					
PTYLUC					
Age-0					
Age-1					
Age-2+					
RHIOSC	556	510	426	217	49
XYRTEX					
Age-0					
Age-1					
Age-2+					
Total N	595	845	580	294	64
Total Area	886	821	824	947	549
Yearly Density	67.2	103.0	70.4	31.1	11.7

Table A15. Number of nonnative fish captured (N) in the primary channel of Reach 7 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish captured divided by the total area (Total Area, m^2) sampled for each year.

Species	2012	2013	2014	2015	2016
AMEMEL					
AMENAT					
CATCOM					
CYPCAR					
CYPLUT			2		3
FUNZEB		1	1		
GAMAFF	1	5	2		3
ICTPUN					
LEPCYA	1	1			
LEPMAC					
MICSAL					1
ONCMYK					
PIMPRO	2	12	12	6	59
POMANN					1
SALTRU	1	2			
Total N	5	21	17	6	67
Total Area	886	821	824	947	549
Yearly Density	0.6	2.6	2.1	0.6	12.2

Table A16. Number of native fishes captured (N) in secondary channels of Reach 7 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish, excluding age 2+ Colorado Pikeminnow and Razorback Sucker, captured divided by the total area (Total Area, m^2) sampled for each year.

Species	2012	2013	2014	2015	2016
CATDIS	4	56	10	12	
CATLAT		146	19	16	
COTBAI					
GILROB					
PTYLUC					
Age-0					
Age-1					
Age-2+					
RHIOSC	5	242	77	87	
XYRTEX					
Age-0					
Age-1					
Age-2+					
Total N	9	444	106	115	n/a
Total Area	125	314	401	508	0
Yearly Density	7.2	141.5	26.4	22.6	n/a

Table A17. Number of nonnative fish captured (N) in secondary channels of Reach 7 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish captured divided by the total area (Total Area, m^2) sampled for each year.

Species	2012	2013	2014	2015	2016
AMEMEL		1			
AMENAT					
CATCOM					
CYPCAR					
CYPLUT					
FUNZEB				5	
GAMAFF				4	
ICTPUN					
LEPCYA					
LEPMAC					
MICSAL					
ONCMYK					
PIMPRO	1	8	1	1	
POMANN					
SALTRU					
Total N	1	9	1	10	n/a
Total Area	125	314	401	508	0
Yearly Density	0.8	2.9	0.2	2.0	n/a

Table A18. Number of native fishes captured (N) in zero velocity channels of Reach 7 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish, excluding age 2+ Colorado Pikeminnow and Razorback Sucker, captured divided by the total area (Total Area, m^2) sampled for each year.

Species	2012	2013	2014	2015	2016
CATDIS	11				3
CATLAT					1
COTBAI					
GILROB					
PTYLUC					
Age-0					
Age-1					
Age-2+					
RHIOSC	2				34
XYRTEX					
Age-0					
Age-1					
Age-2+					
Total N	13	n/a	n/a	n/a	38
Total Area	76	0	0	0	60
Yearly Density	17.1	n/a	n/a	n/a	63.1

Table A19. Number of nonnative fish captured (N) in zero velocity channels of Reach 7 of the San Juan River from 2003 to 2016. Yearly density (fish/100 m^2) was calculated as the total number (Total N) of fish captured divided by the total area (Total Area, m^2) sampled for each year.

Species	2012	2013	2014	2015	2016
AMEMEL					
AMENAT					
CATCOM					
CYPCAR					
CYPLUT					5
FUNZEB	4				2
GAMAFF	66				
ICTPUN					
LEPCYA					
LEPMAC					
MICSAL					
ONCMYK					
PIMPRO	37				4
POMANN					
SALTRU					
Total N	107	n/a	n/a	n/a	11
Total Area	76	0	0	0	60
Yearly Density	141.0	n/a	n/a	n/a	18.3

APPENDIX B.

RESPONSE TO REVIEWER COMMENT

Reviewer: Tom Wesche

Comment: On pages 58 to 71, you present a tremendous amount of information on the influence of flow and non-natives on fish density. However, you only dedicate 3 sentences in your write-up (p. 58) to all of these results. Given the wealth of information you've generated here, a more detailed discussion of what it all means would seem appropriate.

***Response**: Presenting these graphs was an initial attempt to reassess the effects of flow on the density of native and nonnative fishes in the San Juan River. I did not provide in-depth explanations of the graphs because no statistical analyses were conducted. Looking at the majority of the graphs, it appears that there is just a lot of variation with very few evident relationships. I think it would be prudent to now begin running statistical analyses using these hydrologic metrics and others, so we can begin to truly assess how the current flow recommendations are affecting native and nonnative fish densities.*

Comment: On p. 75, the Hines et al 1998 citation is not in the Lit Cited section.

***Response**: We added this citation to the References section.*

Comment: The Executive Summary could benefit from a bit more information being added. For example, you may want to briefly summarize your recommendations here.

***Response**: We added additional information including the recommendations based on 2016 findings to the Executive Summary.*

Reviewer: Benjamin Schleicher

Comment: This was a very well written report and lengthy at that, a way to shorten the overall length would be to decrease the repetitiveness with descriptions of analyses ran for each species. Rather than describe the same analysis over and over, state it for one species and refer back to it with subsequent species.

Response*: The results of the E(CPUE) modelling was repeated across species because different explanatory variables were identified in the top model for different species. Future reports may benefit from just presenting a single table with the variables included in the top model for each species.*

Comment: The extrapolation of how many age-0 CPM in the system appears to be open for much debate on how accurate those numbers are. Personally I have done similar methods in the past and have received a rather intense push back from certain PR and BC members. Your estimates come out to be 17% of your total catch this past year to 443% of your total catch this past year and that was just using the estimates from RM 109-53. Like you did with the single RBS capture, maybe make mention that it is important but there were not enough captured to do any analysis on.

Response*: We disagree that there is any problem with the age-0 Colorado Pikeminnow estimates. A range of potential capture probabilities and sampled habitat estimates were used to predict lower and upper boundaries on the number of age-0 fish that were present in the river. We believe that these numbers are accurate estimates and should provide information for management decisions.*

Comment: Could there have been a deleterious effect by the spike later in the summer on the smaller BH and FM? SD seem to prefer faster moving water than BH and FM.

Response*: It is possible that the August storm spike had some effect on the density of Bluehead Sucker and Flannelmouth Sucker in 2016 but it would be extremely difficult to detect it. Speckled Dace do prefer faster moving water (i.e., riffles) than Bluehead Sucker or Flannelmouth Sucker but the August spike likely had no positive effect on Speckled Dace density as the spike was a short-term stochastic event and not an increase/change in habitat.*

Comment: While I agree with this being a likely possibility for an explanation, another could be that the high water could have created more habitat to support more age-0 catfish this past year.

Response*: It is possible that an increase in habitat for age-0 Channel Catfish was caused by the high 2016 spring runoff, previous analysis have failed to relate any flow metrics to increases in their density, decreasing the probability of this explanation. It is more likely that removing subadult and adult Channel Catfish in large numbers increases the amount of resources for age-0 fish, increasing their survival.*

Reviewer: Scott Durst

Comment: Are the different categorical explanatory variables equally represented across samples? If not, how might that influence the results? Farrington and I have spoken about at length about how the similar larval analyses result in different top models with each year of data included. To me that's an indication that the model set is not particularly predictive. Did you run any models sets iteratively with different years added to test that kind of effect? Any thoughts on what results might be?

Response: *The different categorical explanatory variables we used for the analysis are well represented across samples. Even so, our models were not very good at predicting E(CPUE) as indicated in Table 5. Running models iteratively with different years may help to elucidate some of the reasons why the explanatory variables are not good predictors. I think it is also prudent for us to continue investigating additional statistical techniques for modeling E(CPUE), as well as additional explanatory variables.*

Comment: We think the PO wants to make a major shift towards simplifying annual reports. While we appreciate all this effort and analysis, we think you're going to need to find a way to distill the major message. The way we've talked about it internally, annual reports for long-term projects will only be a few pages of summary tables and figures. More detailed analyses would occur in final reports or every 3-5 years.

Response: *We completely agree that some annual reports, specifically the annual monitoring reports, could be distilled down to a few graphs or tables. We believe that the PO needs to determine what format and information needs to be included in these abbreviated reports. Furthermore, the current hypotheses in the 2012 Program Monitoring Protocols document needs to be updated or made more flexible (along with the entire document). We do not find it necessary to continually revisit these same hypotheses every year or even every 3 years.*

Comment: What do you think about presenting model results and summarizing E(CPUE) for important variables but not going into detail on the $CPUE_{0/1}$ or CPUE+?

Response: *It would be possible to just provide a table with the top model for E(CPUE) for each species instead of discussing each one in the text. This would greatly reduce the length of the report but may not be favored by some BC members and peer reviewers.*

Comment: Am I missing something, why didn't you include these in the E(CPUE) models to see what factors were important predictors and just show those? So much data is presented in the report, I find it difficult to follow. I don't think it's important for this report but I think finding a way to streamline this for the future will be useful.

Response: *The hydrology metrics were not included in the E(CPUE) models because we thought it more prudent to simply assess their relationships with E(CPUE) using graphical visualization at this time. Future reports will include statistical analyses to assess the relationships between hydrology and E(CPUE).*

Comment: Again, I think it's a case of covering so much ground but given the vast data presented in the results section there's little discussion of what it all means. It leaves me feeling why did you do all that work and not talk about it.

***Response**: The report is long simply because of the amount of information we need to present (i.e., several species, three channel types for each species). We tried to keep the Discussion brief and focus only on the points we thought were important instead of discussing every single detail included in the Results.*