Main Channel Fisheries Monitoring – 2015 Report

Metrics for Adaptive Management of Habitat Restoration Sites for the Rio Grande Silvery Minnow

Prepared for

U.S. Army Corps of Engineers
Albuquerque District

Prepared by

SWCA Environmental Consultants

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EXECUTIVE SUMMARY

Habitat restoration is needed to the reduce risk of extinction and to increase recovery potentials for the Rio Grande silvery minnow (*Hybognathus amarus*; silvery minnow) in the Middle Rio Grande of New Mexico. Several restoration approaches have been implemented to improve habitat for the species, including bankline lowering, channel widening, backwater construction, and high flow side channel construction. One metric for evaluating the effectiveness of habitat restoration projects is through monitoring for silvery minnow and the Middle Rio Grande fish community during spring runoff and post-runoff. How the fish community and the silvery minnow respond in the vicinity of habitat restoration projects in the months following recruitment provides a broad measure of project utilization. The use of catch per unit effort metrics during post-runoff monitoring allows for general comparisons among sites and provides an opportunity to assess the effectiveness of the various treatment types.

This report presents results from the 2013 and 2014 collection of baseline main channel fish monitoring data in the vicinity of Middle Rio Grande habitat restoration projects. Additionally, the question persists whether using a beach seine for monitoring the Middle Rio Grande fish community adequately describes relative abundance and size distribution of either the silvery minnow or the Middle Rio Grande fish community. To help address this question, a beach seine and bag seine were used in combination to collect relative abundance fisheries data from main channel habitats adjacent to artificial floodplain habitat restoration sites in the Middle Rio Grande. Samples were collected by rapidly drawing the beach seine in a downstream direction up to the larger oversized bag seine.

Fish capture for both nets was recorded separately and catch from the beach seine was compared to the combined catch to determine if using the beach seine singly provided a sufficient description of the size distribution and relative abundance of the Middle Rio Grande fish community and the silvery minnow. In addition, the combined catch was used to compare species richness, relative abundance of fish, fish distribution among sites, and environmental associations between fish, depth, velocity, mesohabitats, and substrate composition.

Low snowpack in the spring of 2013 and 2014 produced runoff volumes insufficient to produce inundation of the constructed restoration sites. These data provide baseline comparison information that can be used in future years when the habitat restoration features inundate and function as intended—providing recruitment habitat. This report, instead, focuses on comparisons of catch between the beach seine and the combined catch and fish distribution among habitat restoration sites and relative to environmental conditions of sampled mesohabitats.

The combined net method showed that catches of Middle Rio Grande fish vary by species, size, survey, and between the beach seine and the combined catch and these results were consistent during both years of monitoring. Presumably, the combined catch provides a better approximation to Middle Rio Grande fish community population parameters, than using the beach seine alone. From a catch perspective, the beach seine did not produce the same numbers as the combined catch, and the proportion of the fish collected with the beach seine averaged approximately 60% of the combined catch. Over all surveys combined, only three species were

missed by the beach seine; however, the variability in species lists between gear types increased within surveys. The endangered silvery minnow was present at low abundance in the summer and fall of 2013 and 2014. The species was not collected with the beach seine during Surveys 1, 2 and 7, but was collected with the bag seine during all surveys except Survey 5. Overall, 37% of silvery minnow collected during 2013 and 2014 were collected with the beach seine, while 63% were collected with the bag seine. Length frequency of fish species varied between the bag and beach seines and between both nets combined. In general, a higher proportion of small fish were collected with the beach seine, while a higher proportion of larger fish were collected with the bag seine. Silvery minnow collected with the bag seine were larger than those collected with the beach seine. The proportion of silvery minnow that were larger than 50 mm collected with the bag and beach seine was 40% and 9% in 2013 and 7% and 3% in 2014, respectively.

The distribution of fish throughout the study reach show that the fish community varies from upstream to downstream sites with greater species diversity and abundance (2014) at the three upstream most sites. Principal components and canonical correspondence analysis of fish collections showed that the fish distribution within the Middle Rio Grande was fairly stable between years with velocity as the primary driver for fish habitat and environmental associations. The majority of common fish species were most abundant at mesohabitats with little to no velocity, which dictates the sediment composition (silt is common in low velocity habitats) and mesohabitat type (riffles are high velocity habitats, while backwaters are low velocity habitats). Riffle and run habitats were positively associated with flow. Longnose dace (*Rhinichthys cataractae*), flathead chub (*Platygobio gracilis*), and channel catfish (*Ictalurus punctatus*) were associated with these habitat types. The silvery minnow, western mosquitofish (*Gambusia affinis*), fathead minnow (*Pimephales promelas*), white sucker (*Catostomus commersonii*), common carp (*Cyprinus carpio*), and river carpsucker (*Carpiodes carpio*) were most common in shallower, low velocity habitats that were mostly associated with sand-silt, and silt substrates during both years of sampling. The red shiner (*Cyprinella lutrensis*) showed no consistent association with velocity, depth, substrate type, or mesohabitat and was a generalist type species that showed no clear affinity to environmental variables measured during both years of surveys.

Study results demonstrate that using the bag and beach seine combination increases the efficiency of fish community sampling by generating a more complete species list, collecting approximately 40% more fish per sample, collecting approximately 25% more species per sample, providing a more complete transcription of species population length structure, and detecting rare species more frequently than with the beach seine alone. In addition, the fish community within the Angostura Reach of the Middle Rio Grande differs between upstream sites and those sites located within the city of Albuquerque. In conclusion, the bag and beach seine combination appears to be well suited for sampling and document the distribution of the Middle Rio Grande fish community and the endangered silvery minnow. Additional samples should be collected using the methods described in this report, especially during years when relative abundance of silvery minnow is at or above average and during years of high runoff to determine effectiveness of restoration projects in the recovery of the silvery minnow population. The precision of the combined seine methodology could also be compared with that derived from beach seines alone as used for the species' long-term monitoring program.

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1 INTRODUCTION

Bosque habitat restoration treatments have been constructed to benefit both fish and terrestrial species in the Middle Rio Grande. Specifically, the endangered Rio Grande silvery minnow (*Hybognathus amarus*; silvery minnow) may use inundated riparian habitat for spawning and recruitment (Gonzales et al. 2013). Evaluating the effectiveness of habitat restoration projects depends on monitoring the entire fish community, including the silvery minnow, during and after spring runoff. How the fish community and silvery minnow population respond in the vicinity of habitat restoration projects in the months following recruitment provides a broad measure of project effectiveness. The use of catch per unit effort (CPUE) metrics during post-runoff monitoring allows for general comparisons among sites.

Understanding how the abundance of fish stocks increase or decrease relative to management policies, environmental perturbations, or habitat suitability/availability is paramount for maintaining endangered fish populations. The use of relative abundance (CPUE) for assessing the status of fish populations is common for endangered fisheries management because estimating actual abundance is too costly or managers desire to minimize the impact on rare populations (Hubert and Fabrizio 2007).

For relative abundance data to be useful for management purposes, they should reflect the population in question. Relative abundance has numerous underlying assumptions (Hubert and Fabrizio 2007) that are rarely assessed for CPUE data collected from lotic habitats (Gonzales et al. 2012). In many instances, assessments for these assumptions cannot be made because estimating actual abundance is not feasible or is cost prohibitive, so managers use other demographic or fish community parameters to infer the suitability of a particular gear type for sampling a fish population (e.g., see Fago 1998; Clark et al. 2006; Mercado-Silvia and Escandon-Sandoval 2008).

The efficiency of fishing gears varies by species, size of fish, and/or habitat/environmental conditions (Hubert and Fabrizio 2007). For example, fish catchability may be high for beach seines in open water areas with little structure but low in habitats with complexity such as large woody debris or shoreline vegetation. The resultant catch could further be confounded by the variability of a species' ability to escape, which depends on the behavior of individuals during herding and capture (Godo et al. 1999).

In this study, we used a beach and bag seine combination to collect relative abundance fisheries data from main channel habitats adjacent to artificial floodplain habitat restoration sites in the Middle Rio Grande of New Mexico during 2013 and 2014. The method was similar to methods reported by Scheurer et al. (2003) and Widmer et al. (2010) and is expected to yield more accurate and precise data than using a beach seine alone (Widmer et al. 2013). Specifically, the technique can be used to determine baseline main channel fisheries data for Middle Rio Grande restoration projects and to determine presence/absence of silvery minnow during periods of low relative abundance for the species. This report provides an assessment of the relative performance of the beach and bag seine for assessing basic fish population criteria, including fish population length structure, presence/absence of fish species, relative abundance of fish species, and fish distribution throughout the Albuquerque Reach of the Middle Rio Grande.

2 METHODS

2.1 STUDY SITES

Main channel habitats adjacent to 12 Middle Rio Grande Bosque Restoration Project sites were sampled. Sites selected for sampling were spaced longitudinally from upstream of I-25 and the Isleta Diversion Dam in Bernalillo County to the Sandia Pueblo Reservation in Sandoval County (Figure 1). Sites 1A and 1B and Sites 5D and 5E were on opposites sides of the river and were considered a single site for this study (i.e., 1A/B and 5D/E). Four surveys were conducted in 2013; Survey 1 was conducted In July, Survey 2 in August, Survey 3 in September, and Survey 4 in late October/early November (Table 1). In 2014, four additional surveys were conducted at the same sites, Survey 5 in June, Survey 6 in August, Survey 7 in September, and Survey 8 in October.

Table 1. Dates When the Main Channel Adjacent to Each Habitat Restoration Site Was Sampled, 2013 and 2104

Restoration Site	Dates Sampled		Treatment Type	Control
	2013	2014		
1A/B	7/10, 8/15, 9/26, 10/30	6/25, 9/10 10/21	Treat-Retreat-Revegetation, Bank Terracing, High Flow Channel, Bank Scallop	No
1E	7/10, 8/15, 9/26, 10/30	6/25, 8/1 9/10, 10/21	Treat-Retreat-Revegetation, Bank Terracing, High Flow Channel, Marsh Wetland, Willow Swales, Jetty Jack Removal	No
1G	7/10, 8/15, 9/26, 10/30	6/25, 8/1 9/10, 10/21	Treat-Retreat-Revegetation, Willow Swales, Canoe Ramp	Yes
3A	7/9, 8/13, 9/27, 10/29	6/23, 7/31 9/11, 10/20	Treat-Retreat-Vegetation, Bank Terracing, Open Water, Marsh Wetland, Jetty Jack Removal	No
Route 66	7/9, 8/13, 9/27, 10/29	6/23, 7/31, 9/11, 10/20	Treat-Retreat-Revegetation, Wet Meadow Wetland	Yes
4B	7/9, 8/12, 9/24, 11/1	6/27,7/28, 9/9, 10/23	Treat-Retreat-Revegetation, Willow Swales	Yes
4C	7/12, 8/12, 9/24, 11/1	6/27,7/28 9/9, 10/23	Treat-Retreat-Revegetation, Bank Terracing, High Flow Channel, Jetty Jack Removal	No
5B	7/12, 8/14, 9/25, 10/31	6/24, 8/7 9/8, 10/22	Treat-Retreat-Revegetation, Willow Swales, Jetty Jack Removal	Yes
5C	7/8, 8/14, 9/25, 9/25	6/24, 8/7 9/8, 10/22	Treat-Retreat-Revegetation, Willow Swales, High Flow Channel, Jetty Jack Removal	No
5D/E	7/8, 8/14, 9/25, 10/31	6/24, 8/7 9/8, 10/22	Treat-Retreat-Revegetation, Willow Swales	Yes

Note: Habitat restoration treatment types are listed for each site. Habitat restoration sites are considered control sites if prescribed treatments were not intended to benefit the Middle Rio Grande fish community or the silvery minnow.

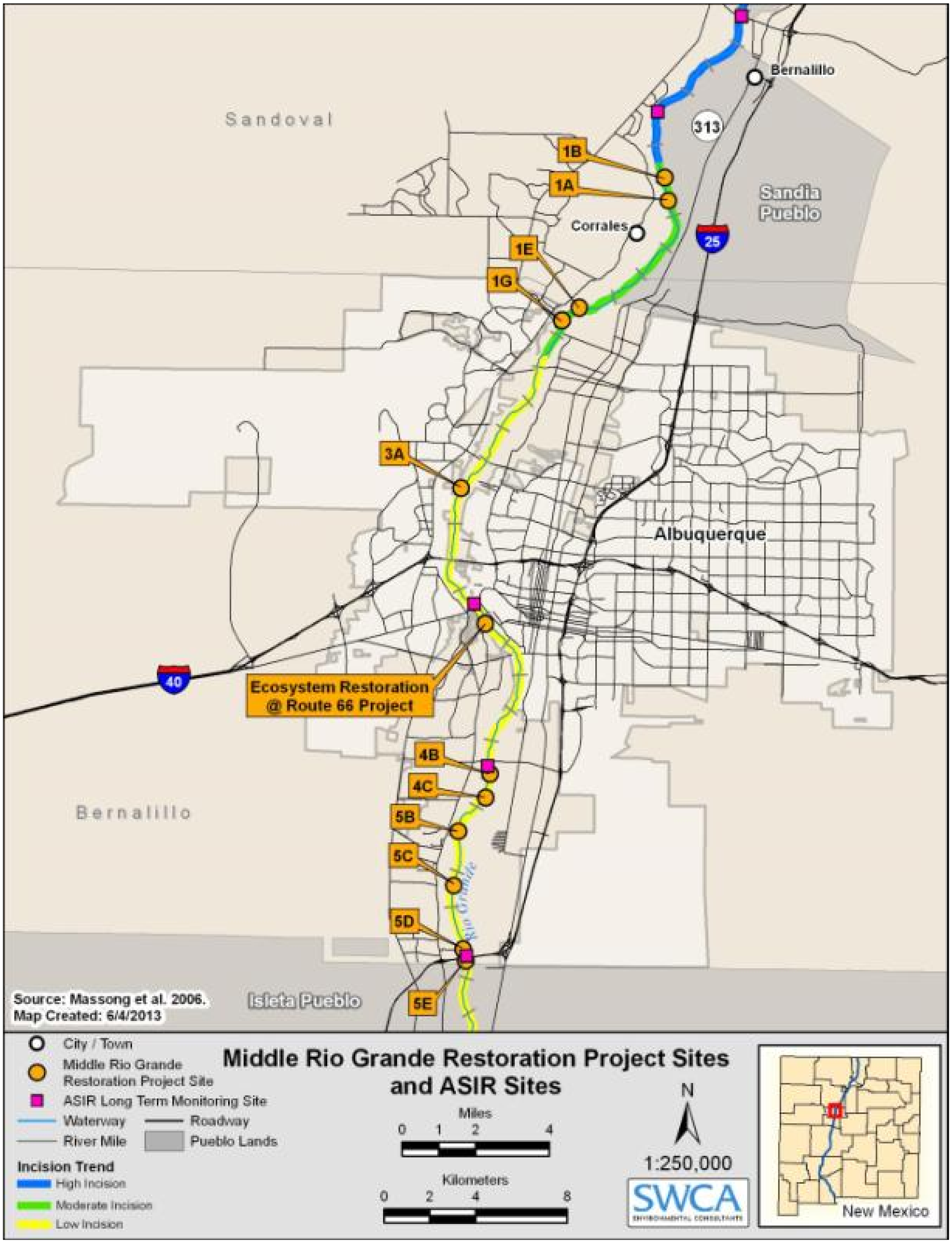

Figure 1. Location habitat restoration sites where main channel habitats were sampled in 2013–2014.

Restoration treatments applied to five of the monitored sites (1A/B, 1E, 3A, 4C, and 5C) were intended to benefit the Middle Rio Grande fish community and the silvery minnow. The other five sites (1G, Route 66, 4B, 5B, and 5D/E) had restoration treatments applied to them that were not intended to provide habitat for the Middle Rio Grande fish community and the silvery minnow. All sites sampled serve as experimental units with the sites where treatments were expected to benefit the Middle Rio Grande fish community serving as the treatment units and the sites where the treatments were not expected to benefit the fish community serving as control sites.

2.2 SAMPLING APPROACH

Seine samples were collected by rapidly drawing a small beach seine (3.1 × 1.8 m [10 × 6 feet] with mesh approximately 3 mm [1/8 inch]) in a downstream direction up to a larger over-sized bag seine (6.0 × 1.5 m [20 × 5 feet] with mesh approximately 3 mm [1/8 inch]). Upon reaching the bag seine, both nets were tilted upwards to capture fish. The bag seine was anticipated to catch adult fish that are normally missed when using the beach seine alone. In 2013, seine samples were collected from three length groups, 5, 10, and 20 m. During 2013, nine seine samples, three from each length group, were collected from each site during each survey for a total of 90 samples. In total, 360 samples (36 from each site) were collected during Surveys 1 through 4. Data collected during 2013 indicated that catch rates were lower for the 20-m seine hauls than the 5- and 10-m seine hauls (SWCA 2014). As a result, in 2014 the 20-m seine hauls were abandoned and five 5-m and five 10-m seine hauls were collected from each site (10 per site per survey). In total, 40 seine hauls were collected from each site during Surveys 5 through 8 (except for at Site 1AB, which was not sampled during Survey 6).

For each sample, fish were held in color-coded buckets that represented fish from the beach and bag seines. All fish were identified to species and counted separately for each seine net. Standard length (mm) was collected for each individual, and wet weight (+/- 0.10 g) was collected from captured silvery minnow. After processing, fish were released to the mesohabitat where they were captured. All collected fish were identified in the field using taxonomic keys provided in Sublette et al. (1990); phylogenetic classification followed Nelson et al. (2004). A head-mounted jeweler's magnifier was used to aid in fish species identification where necessary.

Water depth and water velocity were measured using a Marsh-McBirney Flo-Mate portable velocity meter (Hach Company, Frederick, Maryland) and top-setting wading rod from each sampled mesohabitat. Mesohabitats were visually identified according to definitions adopted from Armantrout (1998) and used by the U.S. Fish and Wildlife Service (Remshardt 2008). All available mesohabitats at each site were sampled at least once. The dominant particle size of the habitat substrate (e.g., sand, small gravel, cobble, etc.) was recorded, as well as presence and type of structure (e.g., woody debris, vegetation, boulders, etc.). Lastly, the area and location of each sampled mesohabitat was recorded with a Trimble GeoXH handheld global positioning system (GPS) unit (Trimble Navigation Limited**,** Sunnyvale, California) with sub-foot accuracy. Maps are provided showing mesohabitat identifications and locations at each site for each survey (Appendix A).

2.3 DATA SUMMARY AND ANALYSIS

A relational database (Microsoft Access) was developed for the storage, analysis, and retrieval of fish and environmental data. All statistical procedures were conducted in R version 3.0.3 (2014)

2.3.1 HABITAT RESTORATION MONITORING

The number of fish collected was generically summarized as total catch and number of species per survey, by habitat restoration site and by habitat restoration treatment type. Only simple counts are presented, which will be expanded upon when additional data become available from subsequent sampling events.

2.3.2 RELATIVE ABUNDANCE AND FISH COMMUNITY COMPOSITION

The number of fish collected was summarized by species, and percent species composition was calculated individually for beach seine, bag seine, and bag and beach seine combined samples for each survey and for all surveys combined.

To determine if the bag seine added information to the beach seine catch, the total number of fish caught per sample was compared between the beach seine and the combined catch with a Wilcoxin paired rank sign test (Zar 1999) for all the data collected in 2013 (360 samples per group) and 2014 (390 samples per group) separately. The analysis was also conducted by survey and presented in tabular form. To determine if the number of fish collected per sample differed between survey years (2013 and 2014), a Wilcoxon rank sum test was used to compare differences (Zar 1999).

To determine if fish counts varied among habitat restoration sites, the total number of fish collected per seine haul (the combined beach and bag seine catch) was compared with a Kruskal-Wallis one-way analysis of variance (ANOVA) (Zar 1999). If significant differences were detected, then a Wilcoxon rank sum test was used to compare differences between each of the habitat restoration sites (Zar 1999). Statistical significance (P <0.05) of multiple comparisons was adjusted with the standard Bonferroni correction (P = 0.05/n).

2.3.3 SPECIES RICHNESS

To determine if using the beach seine alone was missing species collected with the bag seine, we compared the total number of fish species caught (species richness) per sample between the beach seine and the combined catch with a Wilcoxon paired rank sign test (Zar 1999). The analysis was conducted combined and individually for the 2013 and 2014 data sets and individually by each survey. To determine if the number of species collected per sample differed between survey years (2013 and 2014), a Wilcoxon rank sum test was used to compare differences (Zar 1999).

To determine if species richness varied among habitat restoration sites a Kruskal-Wallis one-way ANOVA (Zar 1999) was conducted for the 2013 and 2014 surveys combined using the total catch (beach and bag seine combined). If significant differences were detected, then a Wilcoxon rank sum test was used to compare differences between each of the habitat restoration sites (Zar

1999). Statistical significance (P <0.05) of multiple comparisons was adjusted with the standard Bonferroni correction (P = 0.05/n).

2.3.4 Fish Species Presence/Absence

The presence/absence of fish species was compared between the beach seine and the combined catch. Each sample was binomially coded for each net and a 2 × 2 contingency table was constructed for each species. Fisher's exact test was used to determine if a particular fish species was present at the same proportion in the beach seine as the combined catch (Zar 1999). The analysis was conducted over all the samples collected during the study (2013 and 2014) for each of the 10 most common species.

2.3.5 Size of Fish

Length frequency distributions were compared to determine if size of fish collected with beach seines provided the same information as size of fish collected with the bag seine. Length frequency histograms for each survey were constructed for all fish collected to determine if length structure data varied between the beach seine and the combined distribution. The Kolmogorov-Smirnov goodness of fit test was used to compare length frequencies between beach and between the combined distribution and both nets (Neumann and Allen 2007). A bootstrapped version of the Kolmogorov-Smirnov test that provides correct coverage when the compared distributions are not entirely continuous and that produces unbiased P values when there are ties in the data was used (Sekhon 2011). Each bootstrapped Kolmogorov-Smirnov test was run for 10,000 iterations. The statistical procedure was conducted independently for each of the eight surveys.

2.3.6 Fish Distribution Relative to Habitat Restoration Sites Mesohabitat and Environmental Variables

Fish distribution and environmental associations were analyzed using principal components analysis (PCA) and canonical correspondence analysis (CCA) via the FactoMineR (PCA: Husson et al. 2014) and Vegan (CCA: Oksanen et al. 2014) packages in program R. Patterns in fish distribution, mesohabitat availability at sites, and mesohabitat associations with environmental variables (e.g., substrate, depth, velocity, and mesohabitat type) were assessed using PCA. Simple fish counts were used to assess fish distribution among habitat restoration sites since sampling effort at sites was equal in 2013 and 2014. CCA was used to describe relationships between species abundances (CPUE) and environmental variables (e.g., substrate, depth, velocity, and mesohabitat type). Species that comprised less than 0.005% of the total catch were excluded from the analysis, as were samples where no fish were collected. CPUE data used in CCA was $ln(x+1)$ transformed prior to analyses. Permutation tests (minimum of 200 permutations) were used to test the significance of constraints (environmental variables), and CCA axis interpreted in the analysis (Oksanen et al. 2014).

3 RESULTS

3.1 SAMPLING EFFORT

In total, 750 samples were collected during Surveys 1 through 8: 360 samples were collected in 2013 and 390 were collected during 2014. Site 1AB was not sampled during Survey 6 due to summer monsoonal flood pulse which rendered channel conditions unsuitable for sampling.

Of the 750 samples collected in 2013 and 2014, the majority (522) were collected from run and plunge habitats (107), which are the most common habitat features in the Middle Rio Grande (Figure 2). Substrate at the majority of sampled mesohabitats was classified as sand (391) and silt (276) (Figure 3). Substrate at some mesohabitats was also classified as gravel (49) and a mix of sand-silt (34).

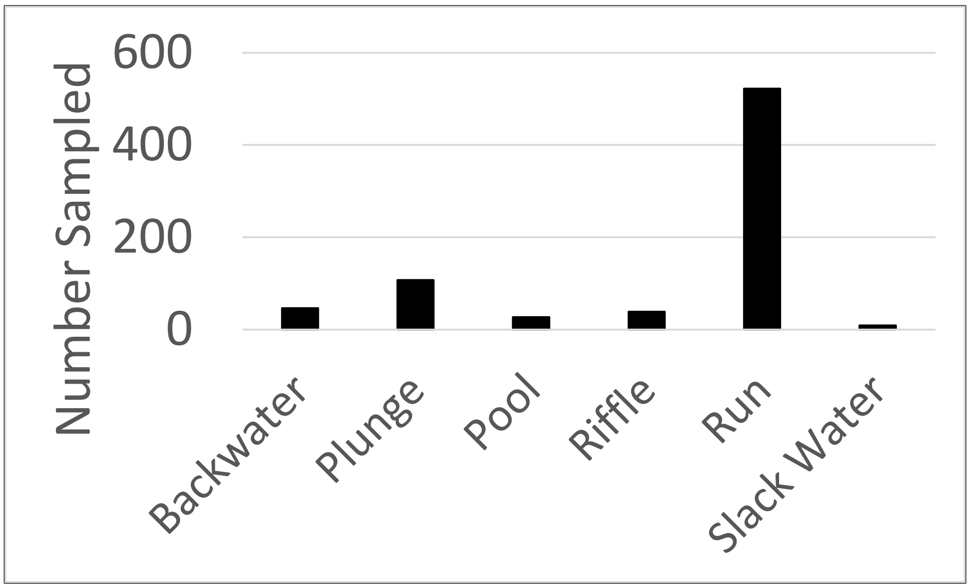

Figure 2. Number of samples collected by mesohabitats during 2013 and 2014.

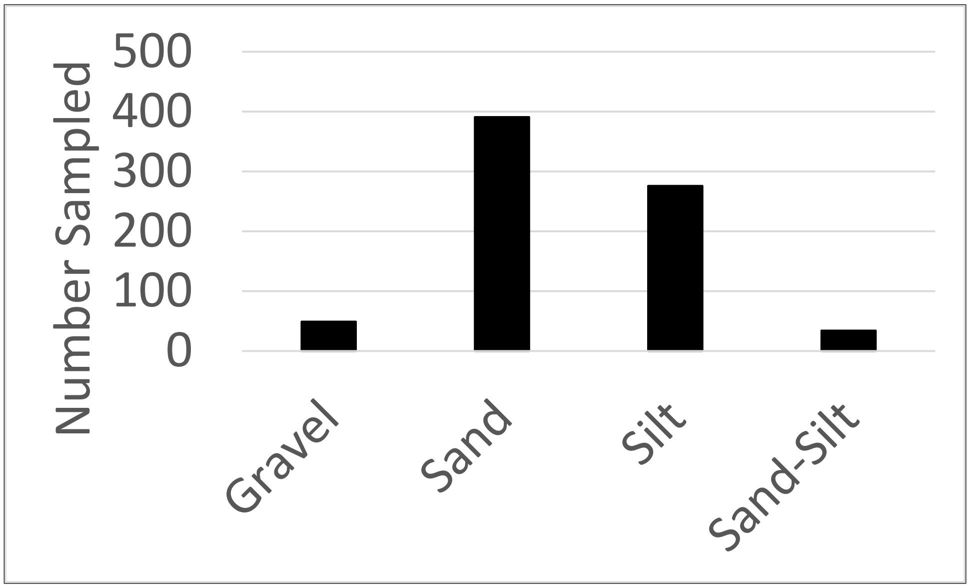

Figure 3. Substrate composition of sampled mesohabitats.

3.2 Habitat Restoration Monitoring

In 2013, catch of Middle Rio Grande fishes varied among habitat restoration sites and surveys, but no consistent patterns or trends were evident (Table 2). Over all four surveys combined in 2013, more fish were collected from Sites 4B and 4C (1,557 and 1,053, respectively), while the fewest fish were collected Site 3A (283). The maximum number of species collected at one site during one survey was 11, while the minimum number collected was four. In general, more species were collected from northernmost sites and fewer were collected from the southernmost sites.

Among surveys, the number of species collected at each site decreased between Surveys 1 and 4 with an average of three fewer species recorded at each site during Survey 4 than during survey 1. Site 1E was the only site where more fish were collected during Survey 4 than during survey 1.

Table 2. Number of Fish and Species Collected at Each Monitoring Habitat Restoration Site during Surveys 1–4

Site	Feature	Survey 1		Survey 2		Survey 3		Survey4	
		# Collected	# Species	# Collected	# Species	# Collected	# Species	# Collected	# Species
1A/B	High Flow Channel, Scallop	213	10	177	11	335	6	169	9
1E	High Flow Channel	83	11	93	4	206	8	234	8
1G	Control	411	11	94	10	119	9	62	7
3A	Bank Terracing	93	9	75	9	38	6	77	5
RT66	Control	320	10	124	7	128	6	165	8
4B	Control	382	9	141	6	848	10	186	10
4C	High Flow Channel, Bank Terracing	335	11	282	5	124	6	312	7
5B	Control	212	9	178	7	74	4	164	7
5C	High Flow Channel	88	8	128	7	91	7	64	4
5D/E	Control	443	8	397	7	85	6	56	5

In 2014, catch of Middle Rio Grande fishes varied among habitat restoration sites and surveys with more fish being collected from the upstream most sites than the downstream most sites (Table 3). Over all four surveys combined in 2014, more fish were collected from Sites 1E and 1G (1,190 and 869, respectively), while the fewest fish were collected Site 4B (252). The maximum number of species collected at one site during one survey was 10, while the minimum number collected was three. Among surveys, the number of species collected at each site increased between Surveys 5 and 6 and then decreased between Surveys 6 and 7 and again between Surveys 7 and 8 where the number of species collected at each site was on average lower than during all other surveys.

Table 3. Number of Fish and Species Collected at Each Monitoring Habitat Restoration Site during Surveys 5–8

Site	Feature	Survey 5		Survey 6		Survey 7		Survey 8	
		# Collected	# Species	# Collected	# Species	# Collected	# Species	# Collected	# Species
1A/B	High Flow Channel, Scallop	94	6	–	–	113	7	227	8
1E	High Flow Channel	513	7	517	10	107	4	53	7
1G	Control	51	5	350	10	364	8	104	6
3A	Bank Terracing	50	5	133	9	127	8	51	5
RT66	Control	98	8	141	8	95	9	208	5
4B	Control	39	7	67	7	96	6	50	5
4C	High Flow Channel, Bank Terracing	76	7	199	9	172	8	411	5
5B	Control	136	7	150	10	74	5	50	5
5C	High Flow Channel	42	7	120	7	23	6	23	3
5D/E	Control	16	5	259	10	109	9	28	5

Catches of individual species from the vicinity of habitat restoration sites shows that some species are widely and similarly distributed, while the distribution of others appears clumped at upstream or downstream sites (Table 4 and Table 5). Channel catfish (*Ictalurus punctatus*), red shiner (*Cyprinella lutrensis*), fathead minnow (*Pimephales promelas*), river carpsucker (*Carpiodes carpio*), and flathead chub (*Platygobio gracilis*) were widely distributed and found at all sites. Species like white sucker (*Catostomus commersonii*) and longnose dace (*Rhinichthys cataractae*) were common at upstream sites. The silvery minnow was collected from all sites except the downstream most site 5D/E in 2013, while in 2014 the species not collected from sites 4B, 4C, and 5C.

Table 4. Number of Fish Collected by Habitat Restoration Site for All Surveys Combined in 2013

Treatment	High Flow Channel, Scallop	High Flow Channel, Bank Terracing	Control	Bank Terracing	Control	Control	High Flow Channel	Control	High Flow Channel	Control
Species/Site	**1A/B**	**1E**	**1G**	**3A**	**RT66**	**4B**	**4C**	**5B**	**5C**	**5D/E**
Channel catfish	55	41	21	104	225	376	378	307	209	488
Red shiner	120	242	107	64	231	383	338	190	85	164
Fathead minnow	77	103	156	49	39	137	77	44	18	153
Western mosquitofish	87	61	12	6	25	529	79	18	5	9
River carpsucker	4	12	217	8	103	42	111	24	9	142
Flathead chub	192	113	95	28	26	27	32	35	35	6
Longnose dace	280	4	2	0	0	3	0	0	0	0
White sucker	40	28	25	9	42	18	14	1	2	7
Common carp	28	4	18	6	5	8	8	3	2	10
Rio Grande silvery minnow	9	3	7	8	15	12	6	4	4	0
Yellow bullhead	1	2	1	1	2	3	9	2	2	2
White crappie	0	0	0	0	4	1	0	0	0	0
Green sunfish	1		0	0	1	0	0	0	0	0
Largemouth bass	0	0	0	0	0	2	0	0	0	0
Black bullhead	0	0	1	0	0	0	0	0	0	0
Unknown	0	3	24	0	19	16	1	0	0	0
Total	**894**	**616**	**686**	**283**	**737**	**1,557**	**1,053**	**628**	**371**	**981**

Table 5. Number of Fish Collected by Habitat Restoration Site for All Surveys Combined in 2014

Treatment	High Flow Channel, Scallop	High Flow Channel, Bank Terracing	Control	Bank Terracing	Control	Control	High Flow Channel	Control	High Flow Channel	Control
Species/Site	**1A/B**	**1E**	**1G**	**3A**	**RT66**	**4B**	**4C**	**5B**	**5C**	**5D/E**
Channel catfish	34	119	74	102	179	93	193	191	123	245
Western mosquitofish	19	20	270	59	62	18	494	13	3	50
Red shiner	68	225	177	69	173	61	77	61	32	22
Flathead chub	143	162	79	25	63	25	32	14	8	14
White sucker	57	409	25	1	10	6	6	15	2	3
Fathead minnow	60	99	185	57	22	19	26	18	7	24
Common carp	1	35	1	4	21	14	19	90	24	9
Rio Grande silvery minnow	14	96	28	8	1	0	0	1	0	4
River carpsucker	0	21	22	32	5	14	5	5	8	31
Longnose dace	35	3	2	2	2			1	1	1
Gizzard shad	1	0	0	0	0	0	0	0	0	6
Unknown	0	0	3	1	0	0	3	0	0	0
Walleye	0	1	2	0	2	0	0	0	0	1
Yellow bullhead	1	0	0	1	1	2	1	0	0	0
Green sunfish	0	0	0	0	0	0	2	0	0	1
Bigscale logperch	0	0	1	0	0	0	0	0	0	0
Flathead catfish	1	0	0	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0	0	0	1
White bass	0	0	0	0	0	0	0	1	0	0
White crappie	0	0	0	0	1	0	0	0	0	0
Total	**434**	**1,190**	**869**	**361**	**542**	**252**	**858**	**410**	**208**	**412**

3.3 Relative Abundance and Fish Community Composition

During Surveys 1 through 8 approximately 40% of the total number of fish collected were missed by the beach seine (Table 6). Overall, the highest catch occurred during Surveys 1 and 3, while the lowest catch occurred during Surveys 5 and 8.

Table 6. Number of Fish Collected per Survey with the Beach Seine and All Nets Combined

Survey	Beach #	Combined #
1	1,423	2,580
2	970	1,689
3	1,101	2,048
4	972	1,489
5	888	1,115
6	1,329	1,936
7	777	1,280
8	638	1,205

3.3.1 Fish Community Composition

Surveys 1–4 (2013)

A total of 7,806 fish comprising 15 different species was collected during the first four main channel surveys (Table 7). Overall, 4,466 fish were collected with the beach seine, while 7,806 were collected with both nets. Channel catfish was the most common species collected during surveys for both nets combined, while it was the second most common species collected with the beach seine. Red shiner was the second most common species collected for both nets combined, while it was the most common species collected with the beach seine. Fathead minnow was the third most common species collected for both nets combined and the beach seine. Other common species included western mosquitofish (*Gambusia affinis*), river carpsucker, and flathead chub. The remaining nine species comprised less than 10% of the total catch. Although not common, 68 silvery minnow were collected during Surveys 1 through 4. More than two times the number of silvery minnow were collected with the bag seine (46) than with the beach seine (22). Only two wild silvery minnow (no marks indicating hatchery origin) were collected with the beach seine, while 25 were collected with the bag seine. No largemouth bass (*Micropterus salmoides*) were collected with the beach seine, and no black bullhead (*Ameiurus melas*) were collected with the bag seine during Surveys 1 through 4.

Table 7. Total Number and Percent Composition of Species Collected with the Beach Seine and All Nets Combined during All Four Surveys in 2013

Common Name	Species	Beach #	Beach %	Combined #	Combined %
Channel catfish	*Ictalurus punctatus*	1,222	27.36	2,204	28.23
Red shiner	*Cyprinella lutrensis*	1,276	28.57	1,924	24.65
Fathead minnow	*Pimephales promelas*	466	10.43	853	10.93
Western mosquitofish	*Gambusia affinis*	428	9.58	831	10.65
River carpsucker	*Carpiodes carpio*	311	6.96	672	8.61
Flathead chub	*Platygobio gracilis*	354	7.93	589	7.55
Longnose dace	*Rhinichthys cataractae*	184	4.12	289	3.70
White sucker	*Catostomus commersonii*	95	2.13	186	2.38
Common carp	*Cyprinus carpio*	40	0.90	92	1.18
Rio Grande silvery minnow	*Hybognathus amarus*	22	0.49	68	0.87
Yellow bullhead catfish	*Ameiurus natalis*	14	0.31	25	0.32

Common Name	Species	Beach #	Beach %	Combined #	Combined %
White crappie	*Pomoxis annularis*	3	0.07	5	0.06
Green sunfish	*Lepomis cyanellus*	1	0.02	2	0.03
Largemouth bass	*Micropterus salmoides*	0	0.00	2	0.03
Black bullhead catfish	*Ameiurus melas*	1	0.02	1	0.01
Unknown	*Unknown*	49	1.10	63	0.81
Total		**4,466**	**100**	**7,806**	**100**

Note: Percentages may not sum exactly due to rounding.

SURVEYS 5–8 (2014)

Fewer fish but more species were collected in 2014 than in 2013. A total of 5,536 fish comprising 17 different species was collected during the four main channel surveys conducted in 2014 (Table 8). Overall, 3,632 fish were collected with the beach seine, while 5,535 were collected with both nets combined. Channel catfish was the most common species collected; however, this species was the second most common species collected with the beach seine. Western mosquitofish was the second most common species collected for both nets combined, while it was the third most common species collected with the beach seine. Red shiner was the third most common species collected for both nets combined, and it was the most common species collected with the beach seine. Other common species included flathead chub, white sucker, fathead minnow, and common carp. The remaining nine species comprised less than 6% of the total catch. More silvery minnow were collected during 2014 (152) than during 2013 (68). Similarly to 2013, the majority of silvery minnow collected in 2014 were not collected with the beach seine (60) but were instead collected with the bag seine (92). Walleye (*Sander vitreum*) and white bass (*Morone chrysops*) were collected with the bag seine but not the beach seine, and no fish were collected with the beach seine that were not collected with the bag seine.

Table 8. Total Number and Percent Composition of Species Collected with the Beach Seine and All Nets Combined during All Four Surveys in 2014

Common Name	Species	Beach #	Beach %	Combined #	Combined %
Channel catfish	*Ictalurus punctatus*	690	19.00	1353	24.44
Western mosquitofish	*Gambusia affinis*	616	16.96	1008	18.21
Red shiner	*Cyprinella lutrensis*	704	19.38	965	17.43
Flathead chub	*Platygobio gracilis*	385	10.60	565	10.21
White sucker	*Catostomus commersonii*	484	13.33	534	9.65
Fathead minnow	*Pimephales promelas*	418	11.51	517	9.34
Common carp	*Cyprinus carpio*	151	4.16	218	3.94
Rio Grande silvery minnow	*Hybognathus amarus*	60	1.65	152	2.75
River carpsucker	*Carpiodes carpio*	78	2.15	143	2.58
Longnose dace	*Rhinichthys cataractae*	31	0.85	48	0.87
Gizzard shad	*Dorosoma cepedianum*	1	0.03	7	0.13
Unknown	Unknown	6	0.17	7	0.13
Yellow bullhead catfish	*Ameiurus natalis*	3	0.08	6	0.11
Walleye	*Sander vitreum*	0	0.00	6	0.11
Green sunfish	*Lepomis cyanellus*	3	0.08	3	0.05
Largemouth bass	*Micropterus salmoides*	1	0.03	1	0.02
White bass	*Morone chrysops*	0	0.00	1	0.02
White crappie	*Pomoxis annularis*	1	0.03	1	0.02
Grand Total		**3,632**	**100.00**	**5,535**	**100.00**

Note: Percentages may not sum exactly due to rounding.

SURVEY 1

During Survey 1, 2,580 fish from 15 different species were collected (Table 9). Overall, 1,423 fish were collected with the beach seine, while 2,580 were collected with both nets combined. Channel catfish and river carpsucker were the most common species collected with both nets during Survey 1. Red shiner was the third most common species collected for both nets combined and the beach seine. Fathead minnow was the fourth most common species collected for both nets combined and the beach seine. White sucker was also commonly collected and comprised 6% of the combined catch. During Survey 1, a total of 11 wild silvery minnow was collected with the bag seine while zero were collected with the beach seine. Green sunfish (*Lepomis cyanellus*) and black bullhead were not collected with the bag seine, while largemouth bass and silvery minnow were not collected with the beach seine.

Table 9. Total Number and Percent Composition of Species Collected with the Beach Seine and All Nets Combined during Survey 1

Common Name	Beach #	Beach %	Combined #	Combined %
Channel catfish	460	32.33	771	29.88
River carpsucker	276	19.4	574	22.25
Red shiner	233	16.37	380	14.73
Fathead minnow	171	12.02	349	13.53
White sucker	72	5.06	151	5.85
Western mosquitofish	77	5.41	109	4.22
Flathead chub	48	3.37	83	3.22
Common carp	21	1.48	58	2.25
Yellow bullhead catfish	10	0.7	18	0.7
Rio Grande silvery minnow	0	0	11	0.43
Longnose dace	4	0.28	10	0.39
Largemouth bass	0	0	2	0.08
Green sunfish	1	0.07	1	0.04
Black bullhead	1	0.07	1	0.04
Unknown	49	3.44	62	2.4
Total	**1,423**	**100**	**2,580**	**100**

Note: Percentages may not sum exactly due to rounding.

SURVEY 2

In total, 1,689 fish were collected during Survey 2: 970 with the beach seine and 719 with the bag seine (Table 10). Channel catfish was the most commonly collected species during Survey 2, comprising 56% of the combined catch. Other common species included the red shiner, fathead minnow, flathead chub, and river carpsucker. Notably, river carpsucker and silvery minnow comprised a greater proportion of the bag seine catch (6.26% and 1.53%, respectively) than the beach seine catch (1.44% and 0%, respectively). Alternatively, longnose dace and white sucker comprised a greater proportion of the beach seine catch (1.03% and 1.34%, respectively) than the bag seine catch (0.14% and 0.28%, respectively). The only species that was not collected by both nets was silvery minnow.

Table 10. Total Number and Percent Composition of Species Collected with the Beach Seine and All Nets Combined during Survey 2

Common Name	Beach #	Beach %	Combined #	Combined %
Channel catfish	534	55.05	943	55.83
Red shiner	244	25.15	380	22.50
Fathead minnow	97	10.00	144	8.53
Flathead chub	40	4.12	82	4.85
River carpsucker	14	1.44	59	3.49
Western mosquitofish	7	0.72	22	1.30
Common carp	7	0.72	16	0.95
White sucker	13	1.34	15	0.89
Rio Grande silvery minnow	0	0.00	11	0.65
Longnose dace	10	1.03	11	0.65
Yellow bullhead catfish	4	0.41	6	0.36
Total	**970**	**100**	**1,689**	**100**

Note: Percentages may not sum exactly due to rounding.

SURVEY 3

More fish were collected during Survey 3 than Survey 2. A total of 2,048 fish comprising 10 species was collected during Survey 3 (Table 11). Western mosquitofish was the most common species collected with both nets; however, percent composition was notably greater for the bag seine (34%) than for the beach seine (25%). Red shiner was the second most common species collected with both nets, followed by channel catfish and longnose dace. Four silvery minnow were collected with the bag (2) and beach seines (2). During Survey 3, no species were missed by the bag or beach seines.

Table 11. Total Number and Percent Composition of Species Collected with the Beach Seine and All Nets Combined during Survey 3

Species	Beach #	Beach %	Combined #	Combined %
Western mosquitofish	271	24.61	590	28.81
Red shiner	258	23.43	456	22.27
Channel catfish	179	16.26	336	16.41
Longnose dace	166	15.08	260	12.70
Fathead minnow	122	11.08	196	9.57
Flathead chub	76	6.90	158	7.71
River carpsucker	14	1.27	26	1.27
White sucker	8	0.73	12	0.59
Common carp	5	0.45	9	0.44
Rio Grande silvery minnow	2	0.18	4	0.20
Unknown	0	0.00	1	0.05
Total	**1,101**	**100**	**2,048**	**100**

Note: Percentages may not sum exactly due to rounding.

SURVEY 4

Fewer fish were collected during Survey 4 than the three prior surveys conducted in 2013. In total, 1,489 fish were collected during Survey 4: 517 with the bag seine and 972 with the beach seine (Table 12). During Survey 4, percent composition varied notably for the most commonly collected species with both nets. Red shiner was the most common species collected with both nets comprising 48% of the combined catch and 56% and 32 % of the beach and bag seine catches, respectively. More fathead minnows were collected with the bag seine (88) than with the beach seine (76), and percent composition for this species was notably different, comprising 17%

and 8% of the bag and beach seine catch. Silvery minnow was more common during Survey 4 than the previous three surveys; however, the majority (41) of the fish collected were of hatchery origin. A single wild silvery minnow was collected during Survey 4 with the bag seine. Yellow bullhead catfish (*Ameiurus natalis*) and green sunfish were only collected with the bag seine.

Table 12. Total Number and Percent Composition of Species Collected with the Beach Seine and Both Nets Combined during Survey 4

Species	Beach #	Beach %	Combined #	Combined %
Red shiner	541	55.66	708	47.55
Flathead chub	190	19.55	266	17.86
Fathead minnow	76	7.82	164	11.01
Channel catfish	49	5.04	154	10.34
Western mosquitofish	73	7.51	110	7.39
Rio Grande silvery minnow	20	2.06	42	2.82
River carpsucker	7	0.72	13	0.87
Common carp	7	0.72	9	0.60
White sucker	2	0.21	8	0.54
Longnose dace	4	0.41	8	0.54
White crappie	3	0.31	5	0.34
Yellow bullhead catfish	0	0.00	1	0.07
Green sunfish	0	0.00	1	0.07
Total	**972**	**100**	**1,489**	**100**

Note: Percentages may not sum exactly due to rounding.

SURVEY 5

Fewer fish were collected during Survey 5 than during any other survey conducted in both 2013 and 2014 (Table 13). In total, 1,115 fish were collected during Survey 5. The majority of fish were collected with the beach seine (888). During Survey 5, white sucker was the most common species collected with both nets comprising 45% of the combined catch and 52% of the beach seine catch, respectively. Silvery minnow were only collected with the beach seine (2), and walleye were only collected with the bag seine (6).

Table 13. Total Number and Percent Composition of Species Collected with the Beach Seine and All Nets Combined during Survey 5

Species	Beach #	Beach %	Combined #	Combined %
White sucker	459	51.69	499	44.75
Common carp	146	16.44	209	18.74
Red shiner	101	11.37	172	15.43
Flathead chub	82	9.23	90	8.07
Fathead minnow	41	4.62	60	5.38
Western mosquitofish	40	4.50	47	4.22
Longnose dace	11	1.24	18	1.61
Channel catfish	1	0.11	6	0.54
Walleye	0	0.00	5	0.45
Unknown	2	0.23	3	0.27
River carpsucker	1	0.11	2	0.18
Rio Grande silvery minnow	2	0.23	2	0.18
Yellow bullhead catfish	1	0.11	1	0.09
White crappie	1	0.11	1	0.09
Total	**888**	**100**	**1,115**	**100**

Note: Percentages may not sum exactly due to rounding.

SURVEY 6

During Survey 6, 1,936 fish were collected with beach and bag seines (Table 14). A single white bass and walleye were missed by the beach seine and collected with the bag seine. Channel catfish was the most common species collected with both nets. Other common species include fathead minnow, red shiner, flathead chub, silvery minnow, and river carpsucker. All other collected species comprised less than 10% of the total catch. More silvery minnow were collected during Survey 5 than during all other surveys conducted in 2013 and 2014. The majority of the collected silvery minnow collected during Survey 5 were collected with the bag seine (75), while less than half were collected with the beach seine (54).

Table 14. Total Number and Percent Composition of Species Collected with the Beach Seine and All Nets Combined during Survey 6

Species	Beach #	Beach %	Combined #	Combined %
Channel catfish	589	44.32	934	48.24
Fathead minnow	269	20.24	304	15.70
Red shiner	188	14.15	224	11.57
Flathead chub	112	8.43	170	8.78
Rio Grande silvery minnow	54	4.06	129	6.66
River carpsucker	51	3.84	84	4.34
Western mosquitofish	31	2.33	41	2.12
White sucker	19	1.43	27	1.39
Longnose dace	7	0.53	8	0.41
Common carp	3	0.23	6	0.31
Unknown	4	0.30	4	0.21
Yellow bullhead catfish	2	0.15	3	0.15
White bass	0	0.00	1	0.05
Walleye	0	0.00	1	0.05
Total	**1,329**	**100**	**1,936**	**100**

Note: Percentages may not sum exactly due to rounding.

SURVEY 7

During Survey 7, 1,936 fish were collected with beach and bag seines (Table 15). Western mosquitofish and red shiner were the most common species collected with both nets. Other common species include channel catfish, fathead minnow, and flathead chub. Silvery minnow and yellow bullhead catfish were missed by the beach seine but collected with the bag seine during Survey 7.

Table 15. Total Number and Percent Composition of Species Collected with the Beach Seine and All Nets Combined during Survey 7

Species	Beach #	Beach %	Combined #	Combined %
Western mosquitofish	307	39.51	470	36.72
Red shiner	244	31.40	347	27.11
Channel catfish	46	5.92	182	14.22
Fathead minnow	77	9.91	112	8.75
Flathead chub	71	9.14	96	7.50
River carpsucker	16	2.06	35	2.73
Longnose dace	4	0.51	10	0.78
White sucker	5	0.64	7	0.55
Gizzard shad	1	0.13	7	0.55
Rio Grande silvery minnow	0	0.00	6	0.47
Common carp	2	0.26	3	0.23
Green sunfish	3	0.39	3	0.23
Yellow bullhead catfish	0	0.00	1	0.08
Largemouth bass	1	0.13	1	0.08
Total	**777**	**100.00**	**1,280**	**100.00**

Note: Percentages may not sum exactly due to rounding.

SURVEY 8

During Survey 8, 1,205 fish were collected with the beach and bag seines (Table 16). Western mosquitofish was the most common fish species collected during Survey 8. Other common species included channel catfish, red shiner, flathead chub, and fathead minnow. All other fish species collected comprised less than 5% of the total catch. Fifteen silvery minnow were collected during Survey 8. The majority of these fish were collected with the bag seine (9).

Table 16. Total Number and Percent Composition of Species Collected with the Beach Seine and All Nets Combined during Survey 8

Species	Beach #	Beach %	Combined #	Combined %
Western mosquitofish	238	37.30	450	37.34
Channel catfish	54	8.46	231	19.17
Red shiner	171	26.80	222	18.42
Flathead chub	120	18.81	209	17.34
Fathead minnow	31	4.86	42	3.49
River carpsucker	10	1.57	22	1.83
Rio Grande silvery minnow	4	0.63	15	1.24
Longnose dace	9	1.41	12	1.00
Yellow bullhead catfish	0	0.00	1	0.08
White sucker	1	0.16	1	0.08
Total	**638**	**100**	**1,205**	**100**

Note: Percentages may not sum exactly due to rounding.

3.3.2 RELATIVE ABUNDANCE

RELATIVE ABUNDANCE OF ALL FISH

The number of fish collected per sample during both years was greater for the combined catch than for the beach seine alone (paired Wilcoxon rank sign test, both years $P < 0.0001$) (Figure 4). Between years, the number of fish collected per sample was greater in 2013 than in 2014 (Wilcoxon rank sum test $P < 0.0001$) (Figure 5). In 2013, 22 fish were collected per sample with 12 of those fish collected with the beach seine. In 2014, the number of fish collected per sample was less than in 2013 and averaged 14 fish per sample with nine being collected with the beach seine.

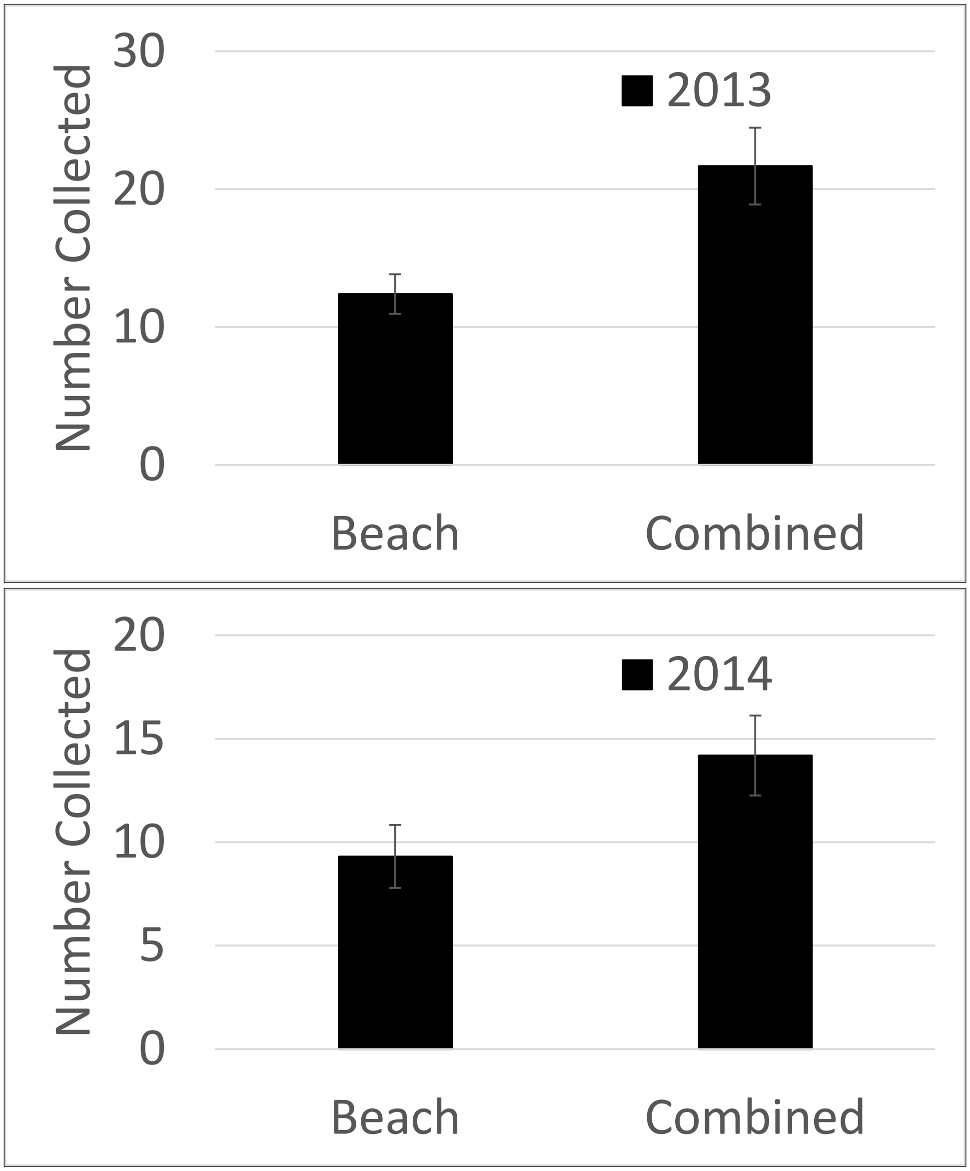

Figure 4. Number of collected fish per sample with the beach seine and for the beach seine and bag seine combined during 2013 and 2014. Error bars denote one standard error.

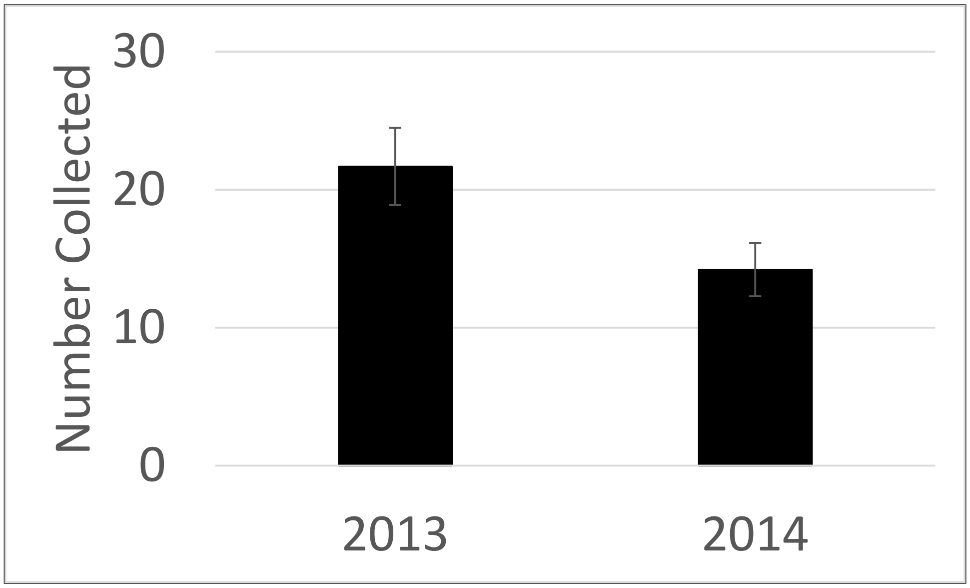

Figure 5. Number of fish collected per sample (both nets combined) in 2013 and 2014. Error bars denote one standard error.

The combined catch was greater than the beach seine catch for all surveys (paired Wilcoxon rank sign test, all surveys $P < 0.0001$). In general, the number of fish collected was greater during surveys conducted in July during both years (Survey 1 in 2013 and Survey 6 in 2014) (Table 17).

Table 17. Average Number of Fish Collected per Sample by Survey for the Beach and Combined Catch

Survey	Beach	Combined	Sample Size	P-value
1	15.81	28.67	90	<0.001
2	10.78	18.77	90	<0.001
3	12.23	22.76	90	<0.001
4	10.80	16.54	90	<0.001
5	8.88	11.15	100	<0.001
6	14.77	21.51	90	<0.001
7	7.77	12.80	100	<0.001
8	6.38	12.05	100	<0.001

Note: P-values are from paired Wilcoxon rank sign test conducted for data collected within each survey.

Among sites, the number of fish collected per sample differed significantly in 2014 (Kruskal-Wallis one-way ANOVA, $P = 0.004$) but not in 2013 (Figure 6). In 2014, pairwise comparisons indicate that the differences among sites were between Sites 1A/B (14.5 fish/sample) and 3B (7.8 fish/sample), 1A/B and 4B (6.3 fish/sample), 1A/B and 5C (5.2 fish/sample), 1A/B and 5D/E (10.3 fish/sample), 1E (17 fish/sample) and 3A (9 fish/sample), 1E and 5C (22 fish/sample), 1G and 5C, 3A and RT66 (13.55 fish/sample), 4B and RT66, 4C (21.5 fish/sample) and 5C, 5C and RT66, and 5D/E and RT 66 (Wilcoxon rank sum test with Bonferroni adjusted P values, all $P \leq 0.05$).

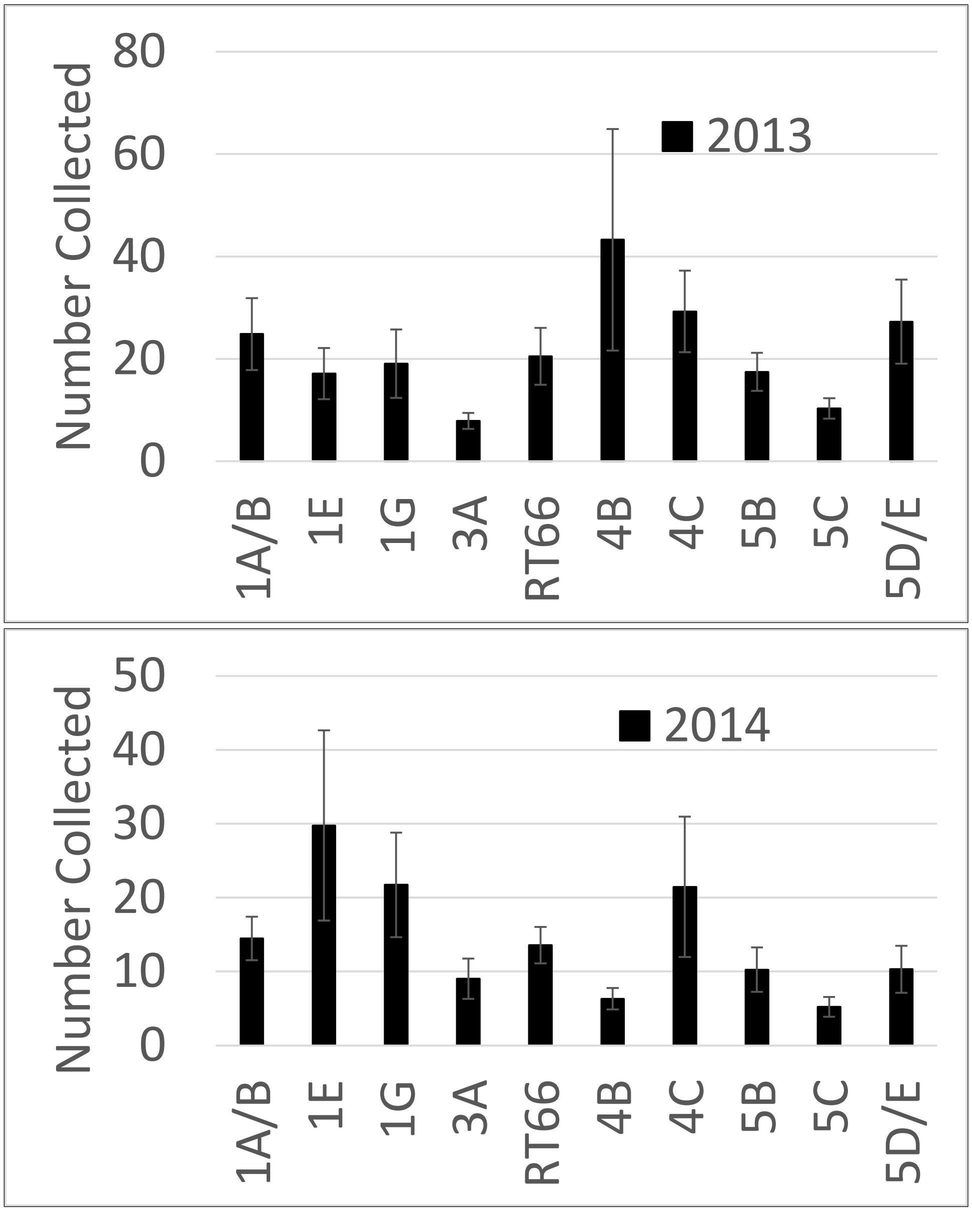

Figure 6. The number of fish collected per sample at site during 2013 and 2014. Error bars denote one standard error.

3.4 Species Richness

The number of species collected per sample was greater for the combined catch than for the beach seine during both 2013 and 2014, and for both years of data combined (paired Wilcoxon rank sign test, both years and combined $P < 0.0001$) (Figure 7). In general, the beach and bag seine together (2.4 species per sample) captured 0.6 species per sample more than the beach seine alone, which collected on average 1.8 species per sample.

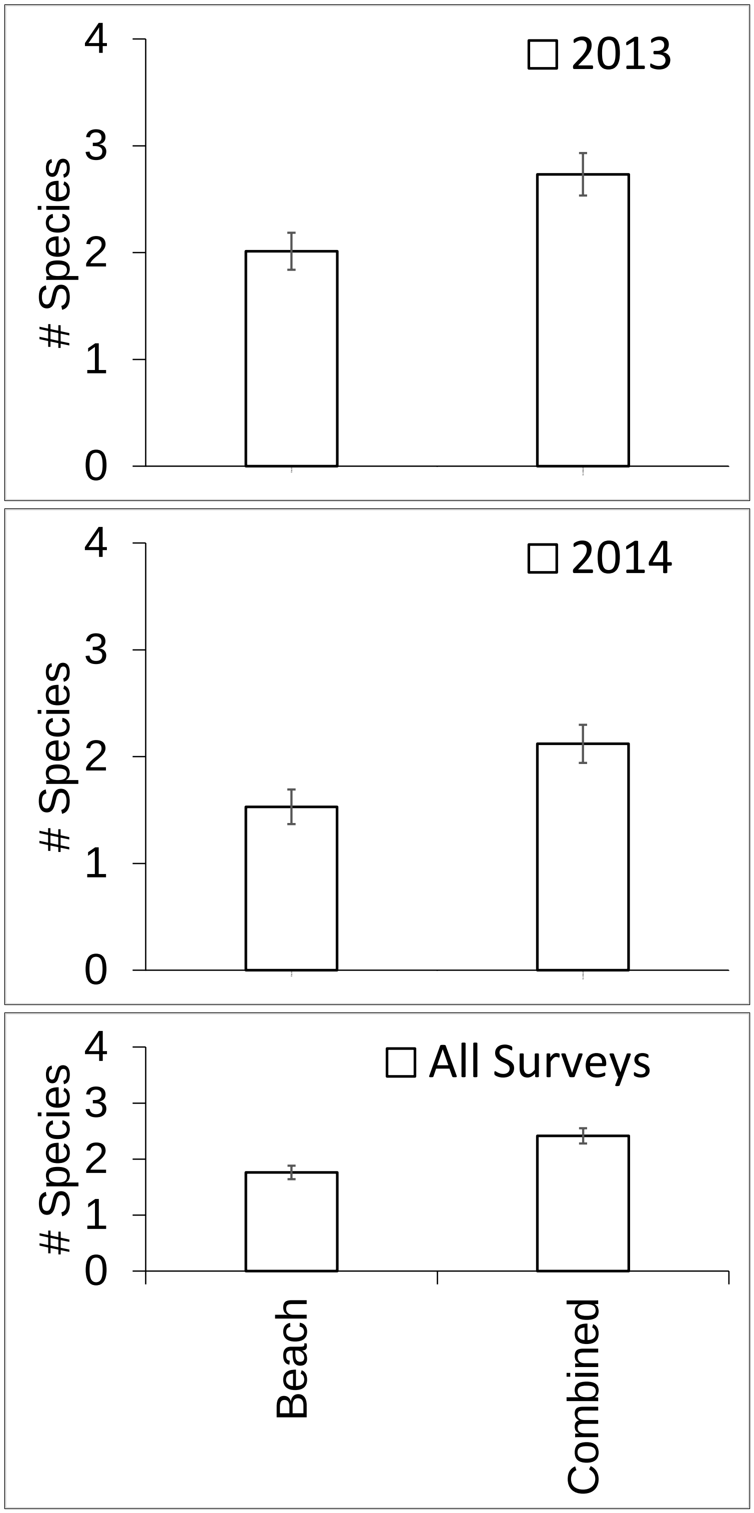

Figure 7. Number of species collected per sample in 2013, 2014, and for all surveys combined. Error bars denote 95% confidence intervals.

Between years more species were collected per sample during 2013 than in 2014 (Wilcoxon rank sum test, $P < 0.0001$) (Figure 8). On average 2.7 species were collected per sample in 2013, while in 2014 2.1 species were collected per sample.

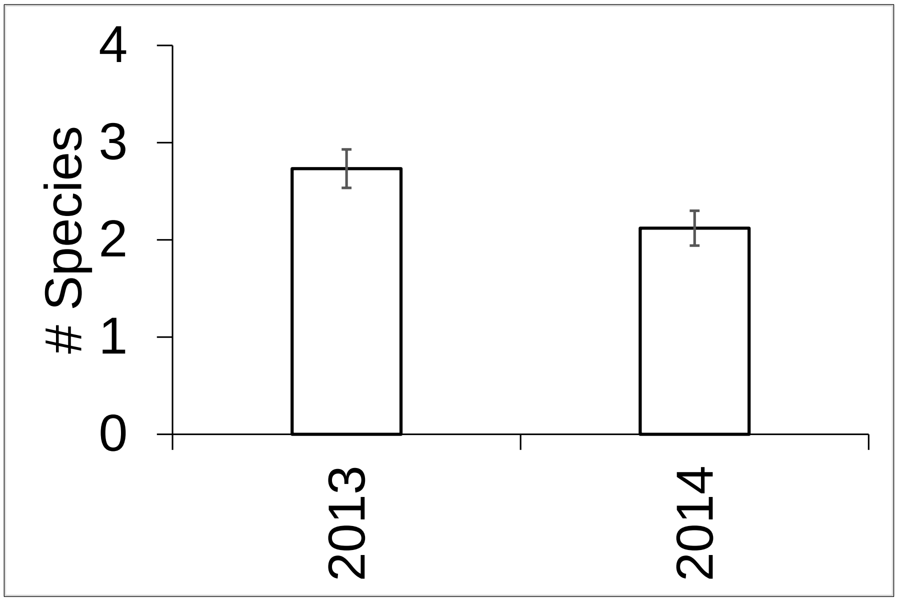

Figure 8. The number of species collected per sample (both nets combined) in 2013 and 2014. Error bars denote 95% confidence intervals.

Within surveys the number of species collected per sample was greater for the combined catch than the beach seine catch for all surveys (paired Wilcoxon rank sign test, all surveys $P < 0.0001$). In general, the number of fish collected was greater during surveys conducted in July in both years (Survey 1 in 2013 and Survey 6 in 2014) (Table 18).

Table 18. The Number of Species of Fish Collected per Sample with the Beach Seine and for the Beach Seine and Bag Seine Combined

Survey	Beach	Combined	Sample Size	P-value
1	2.39	3.78	90	<0.001
2	2.02	2.58	90	<0.001
3	1.82	2.26	90	<0.001
4	1.82	2.32	90	<0.001
5	1.28	1.68	100	<0.001
6	2.31	2.80	90	<0.001
7	1.41	2.13	100	<0.001
8	1.20	1.94	100	<0.001

Note: P-values are from paired Wilcoxon rank sign test conducted for data collected within each survey.

For both years of data combined, the number of species collected per sample was significantly different among habitat restoration sites (Kruskal-Wallis one-way ANOVA, $P = 0.003$) and was generally highest at upstream sites (Figure 9). Pairwise comparisons indicate that the differences between sites were between Sites 1A/B (3.1 fish/sample) and 5C (1.8 fish/sample) (Wilcoxon rank sum test with Bonferroni adjusted P value, $P = 0.0009$), which were sites where the most and least number of fish species were collected per sample. No other comparisons were significant when using the Bonferroni adjustment.

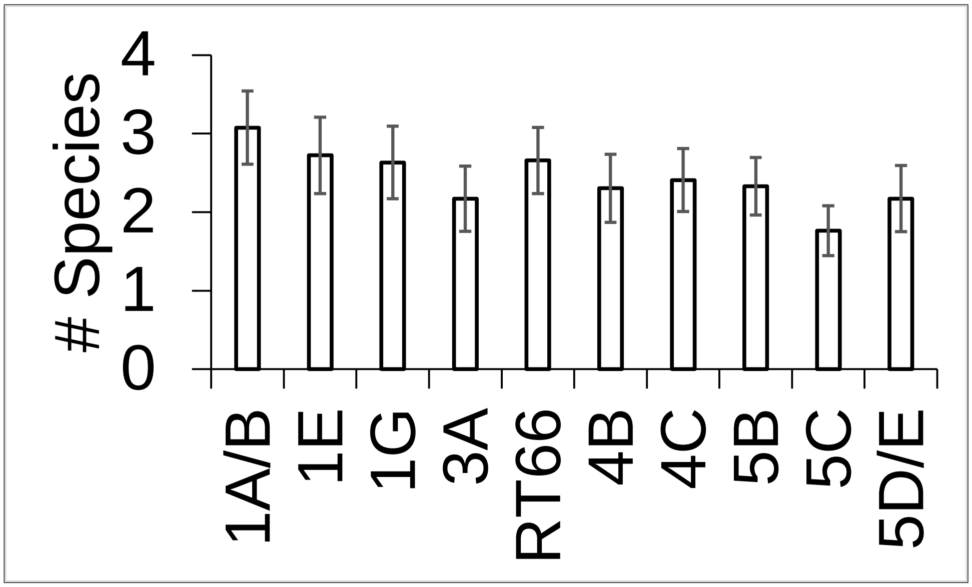

Figure 9. The number of species collected per sample (for both nets combined) from habitat restoration sites. Error bars denote 95% confidence intervals.

3.5 Species Presence Absence

Of the most common species collected during Surveys 1 through 8, nine out of 10 were collected in a higher proportion of samples for the combined catch than for the beach seine alone (Fisher's Exact Test, $P \leq 0.05$). Longnose dace was the only common species collected at the same frequency between the beach seine and the combined catch (Figure 10). The difference in proportions ranged from a 0.15 difference in channel catfish presence between the beach seine (0.38 of samples) and the combined catch (0.54 of samples) to a low of 0.01 difference between the beach seine (0.05) and combined (0.06) catch for longnose dace. Silvery minnow was present in 0.07 of the combined samples and in 0.04 of the beach seine samples. The addition of the bag seine for sampling results in silvery minnow being present 75% more often than it would be present if the beach seine was used alone.

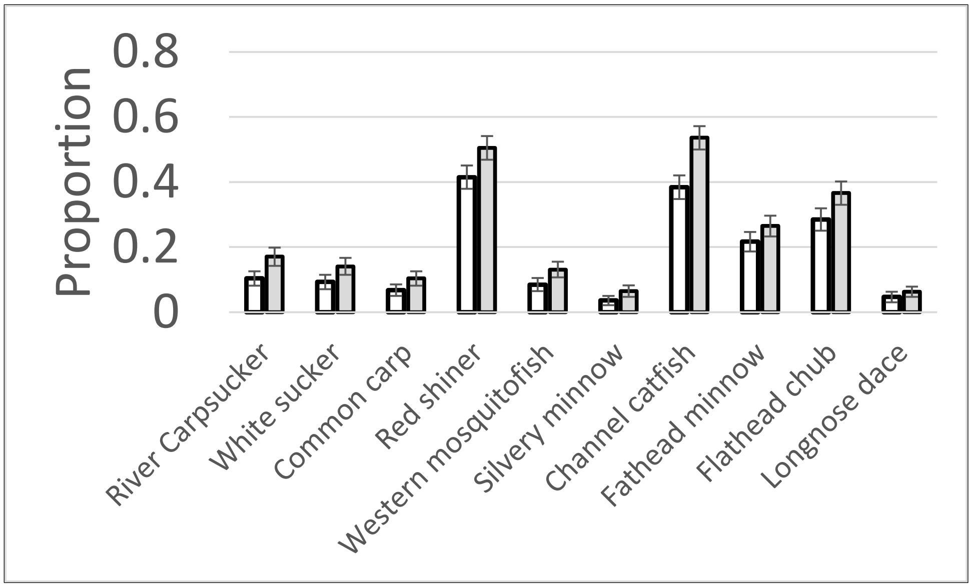

Figure 10. The proportion of samples where each species collected during Surveys 1 through 8 was present in bag seine and beach seine collections.

3.6 Size of Fish

3.6.1 Length Frequency of All Fish

Length frequency of all fish collected during Surveys 1 through 4 was different between the beach seine and the combined catch for all surveys except Survey 3 (Bootstrapped Kolmogorov-Smirnov test, $P \leq 0.01$). In general, a greater proportion of small fish were collected with the beach seine than with the bag seine, while the bag seine tended to collect larger fish than the beach seine (Figure 11). Silvery minnow ranged in size from 26 to 86 mm in 2013. The largest and smallest silvery minnow were collected with the bag seine. The percentage of silvery minnow collected with the beach seine that were greater than 50 mm was 9%, while it was 40% for the combined catch.

Length frequency of all fish collected during Surveys 5 through 8 was different between the beach seine and the combined catch for all surveys (Bootstrapped Kolmogorov-Smirnov test, $P \leq 0.001$). In general, a greater proportion of small fish were collected with the beach seine than with the bag seine, while the bag seine tended to collect larger fish than the beach seine (Figure 12). Silvery minnow ranged in size from 22 to 62 mm in 2014. The smallest silvery minnow were collected with both nets, while the largest silvery minnow was collected with the bag seine. The percentage of silvery minnow collected with the beach seine that were greater than 50 mm was 3%, while it was 7% for the combined catch.

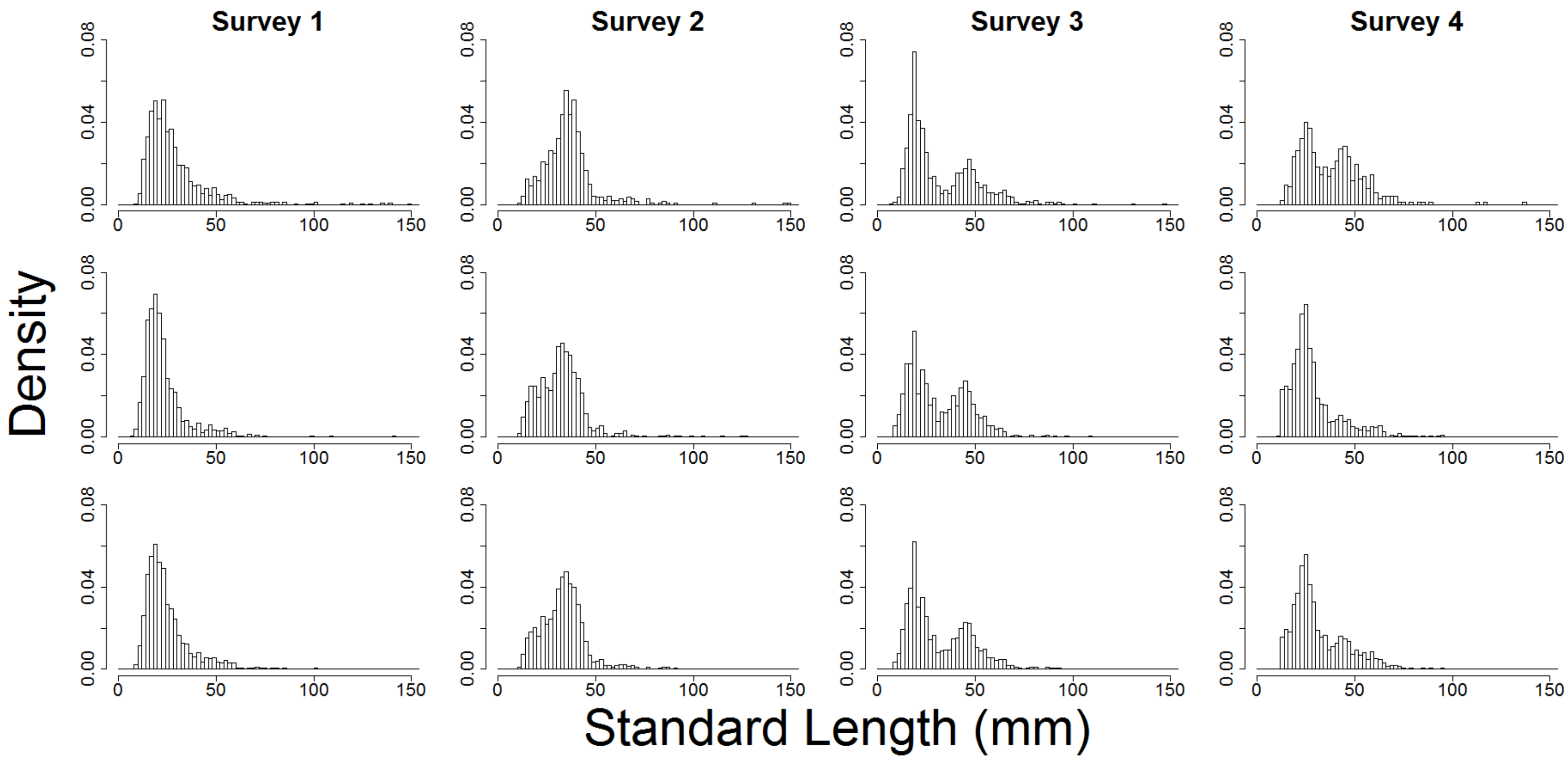

Figure 11. Length frequency of all fish collected during Surveys 1 through 4 (2013). Each figure column represents a single survey starting from the left column with Surveys 1 through 4, which is the rightmost figure column. Fish collected with the bag seine are represented by the top row, fish collected with the beach seine are represented with the middle row, and all fish collected with both nets are represented by the bottom row. One 200-mm white sucker, one 220-mm channel catfish, and one 340-mm river carpsucker collected with the bag seine were excluded from histograms.

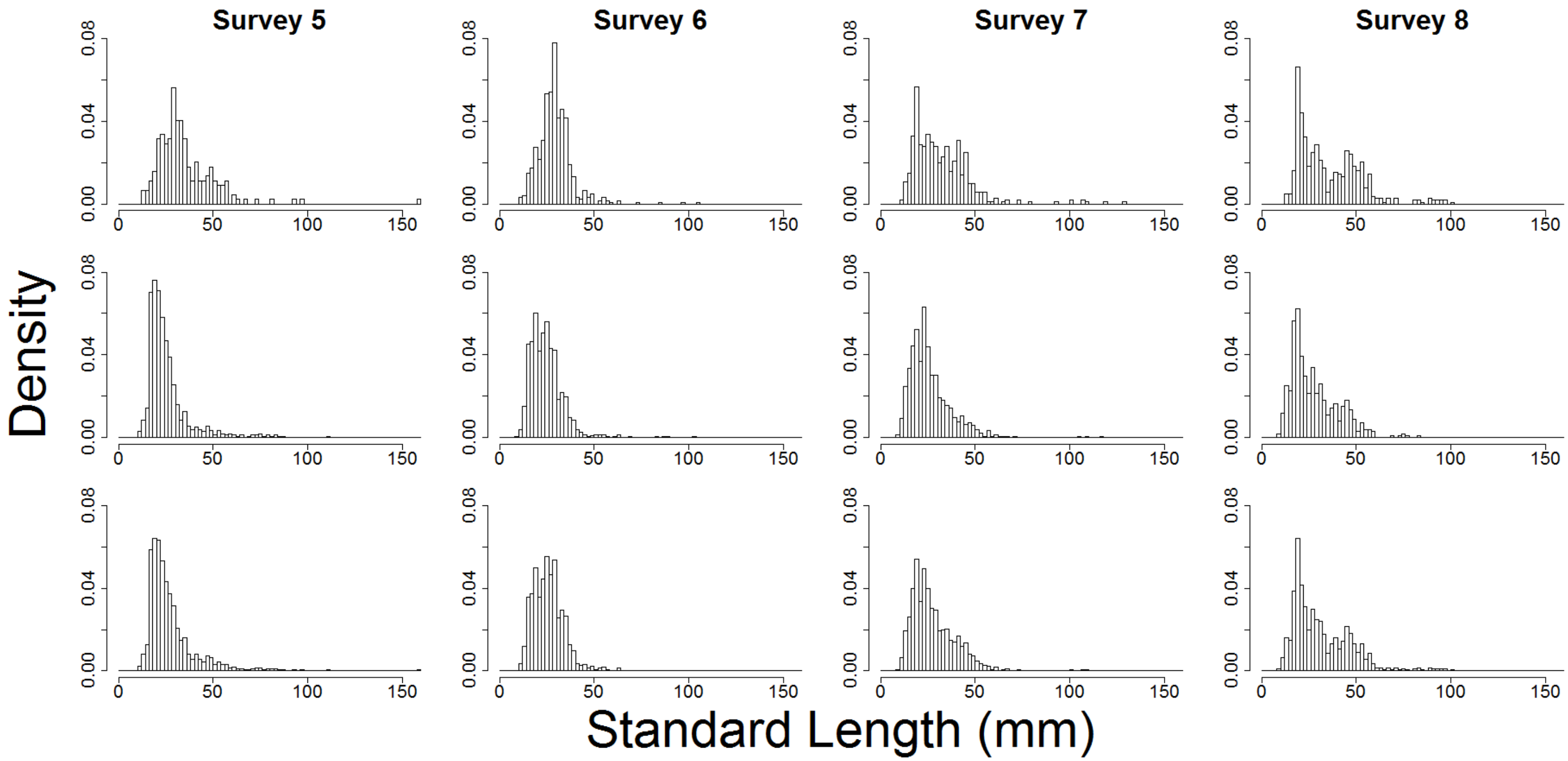

Figure 12. Length frequency of all fish collected during Surveys 5 through 8 (2014). Each figure column represents a single survey starting from the left column with Survey 5 through 8, which is the rightmost figure column. Fish collected with the bag seine are represented by the top row, fish collected with the beach seine are represented with the middle row, and all fish collected with both nets are represented by the bottom row. One channel catfish measuring 440 mm that was collected with the bag seine was excluded from histograms.

3.6.2 FISH DISTRIBUTION RELATIVE TO HABITAT RESTORATION SITES MESOHABITAT AND ENVIRONMENTAL VARIABLES

FISH SPECIES DISTRIBUTION AMONG HABITAT RESTORATION SITES

The PCA of fish species distribution at habitat restoration sites suggest that fish species in the Middle Rio Grande are not uniformly distributed within the reach surveyed in 2013 and 2014. For both survey years combined the first three components accounted for 86% of the variance explained by PCA (Table 19). Visual inspection of the biplots of species and site scores indicated that species composition varied among sites with a greater diversity of species associated upstream sites than with downstream sites. Three groups of fish had positive correlations: 1) red shiner, western mosquitofish, and fathead minnow; 2) silvery minnow, white sucker, flathead chub, and longnose dace; and 3) channel catfish and river carpsucker (Figure 13). The first two groups of fish were common at Sites 1A/B, 1E, and 1G, while the third group of fish were common at Sites 4C and 5D/E.

PCA axis I creates a gradient where the three upstream most sites are separated from the remaining seven sites, which are all downstream and within the city of Albuquerque. River carpsucker and common carp were not closely associated with PCA axis I but were with PCA axis II. Channel catfish had a strong negative association with PCA axis I, indicating that the species was not common at the three most upstream sites but was common at the remaining sites. Silvery minnow, white sucker, and flathead chub had a strong positive association with PCA axis I but not PCA axis II, indicating that these species were more commonly collected from the three upstream most sites.

Table 19. PCA Component Loadings for Fish Species Data Collected over Both Survey Years (2013 and 2014) and Summarized by Habitat Restoration Site

Species or Correlation	Component Loadings		
	1	2	3
River carpsucker (CARCAR)	-0.20	0.88	-0.17
White sucker (CATCOM)	0.92	0.09	0.30
Common carp (CYPCAR)	0.02	-0.20	0.92
Red shiner (CYPLUT)	0.44	0.69	0.54
Western mosquitofish (GAMAFF)	0.43	0.74	-0.09
Rio Grande silvery minnow (HYBAMA)	0.92	0.05	-0.05
Channel catfish (ICTPUN)	-0.79	0.39	0.35
Fathead minnow (PIMPRO)	0.65	0.52	-0.32
Flathead chub (PLAGRA)	0.94	-0.23	0.09
Longnose dace (RHICAT)	0.71	-0.53	-0.12
Eigenvalue and explained variance			
Eigenvalue	4.54	2.60	1.50
Cumulative percent of variance explained	45.41	71.38	86.41

Note: Fish species codes used in biplots are in parenthesis.

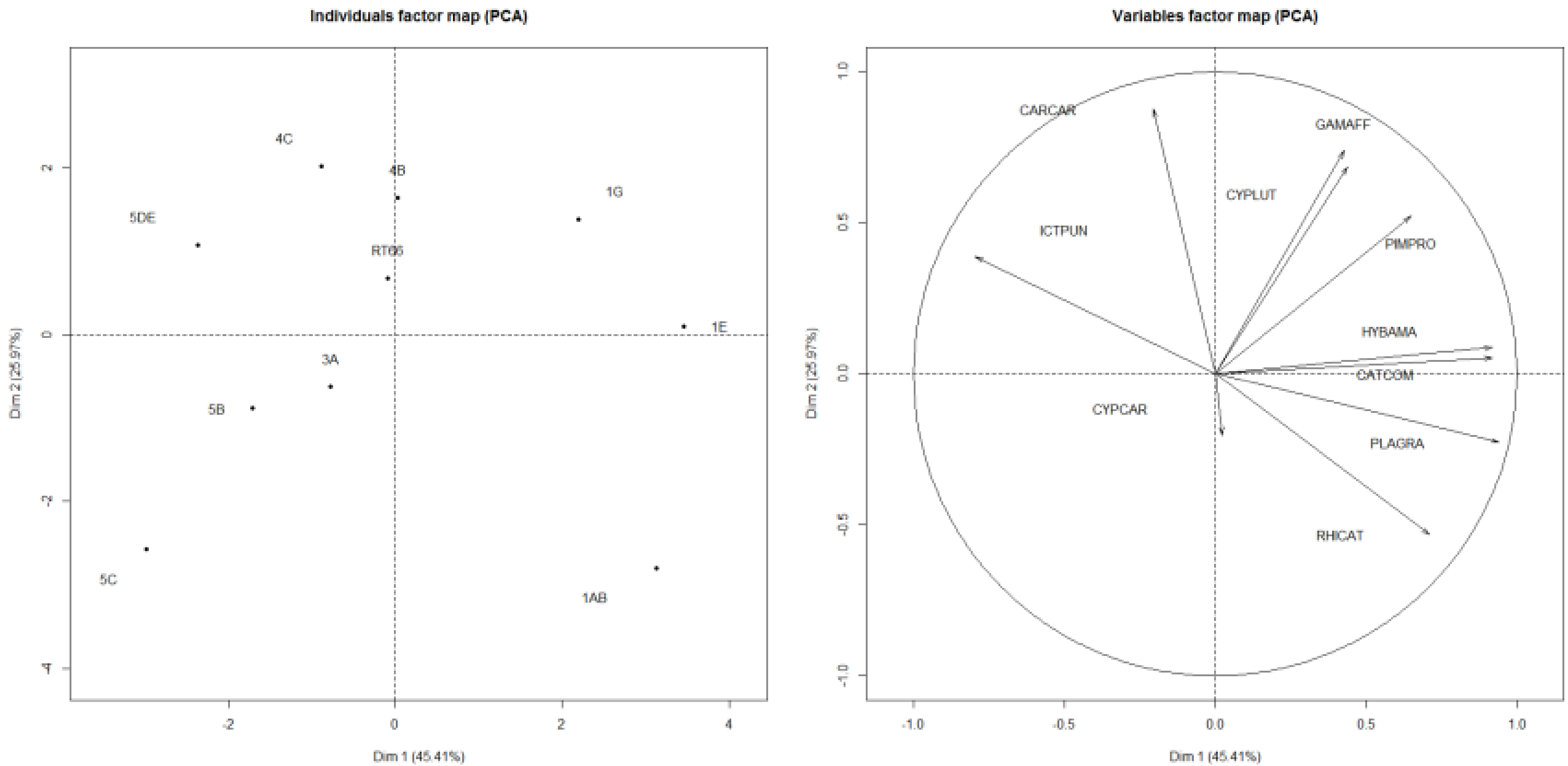

Figure 13. PCA variable factor map and the associated biplot of fish distribution among habitat restoration sites for all surveys combined.

Fish distribution in 2013 was similar to the combined data set presented above. For all 2013 surveys combined the first three components accounted for 80% of the variance explained by PCA (Table 20). Visual inspection of the biplots of species and site scores indicated that species composition varied among sites. Three groups of fish had positive correlations: 1) red shiner, western mosquitofish, fathead minnow, common carp, and white sucker; 2) silvery minnow, flathead chub, and longnose dace; and 3) channel catfish and river carpsucker (Figure 14). The first group of fish was most common at Sites 4B and RT 66, the second group of fish was common at the upstream most sites, 1A/B, 1E, and 1G, while the third group of fish was common at Sites 4C and 5D/E. Of the 10 most common fish species, red shiner and river carpsucker were not strongly associated with PCA axis I but were with PCA axis II. Channel catfish had a strong negative association with PCA axis I indicating that the species was more common at downstream sites.

Table 20. PCA Component Loadings for Fish Species Data Collected in 2013 and Summarized by Habitat Restoration Site

Species or Correlation	Component Loadings		
	1	2	3
River carpsucker (CARCAR)	-0.16	0.73	-0.39
White sucker (CATCOM)	0.81	0.25	-0.03
Common carp (CYPCAR)	0.75	0.19	-0.46
Red shiner (CYPLUT)	0.11	0.83	0.46
Western mosquitofish (GAMAFF)	0.58	0.55	0.54
Rio Grande silvery minnow (HYBAMA)	0.47	-0.13	0.59
Channel catfish (ICTPUN)	-0.66	0.50	0.34
Fathead minnow (PIMPRO)	0.48	0.63	-0.49
Flathead chub (PLAGRA)	0.78	-0.47	0.14
Longnose dace (RHICAT)	0.85	-0.22	0.03
Eigenvalue and explained variance			
Eigenvalue	3.82	2.60	1.60
Cumulative percent of variance explained	38.24	63.81	79.75

Fish species codes used in biplots are in parenthesis.

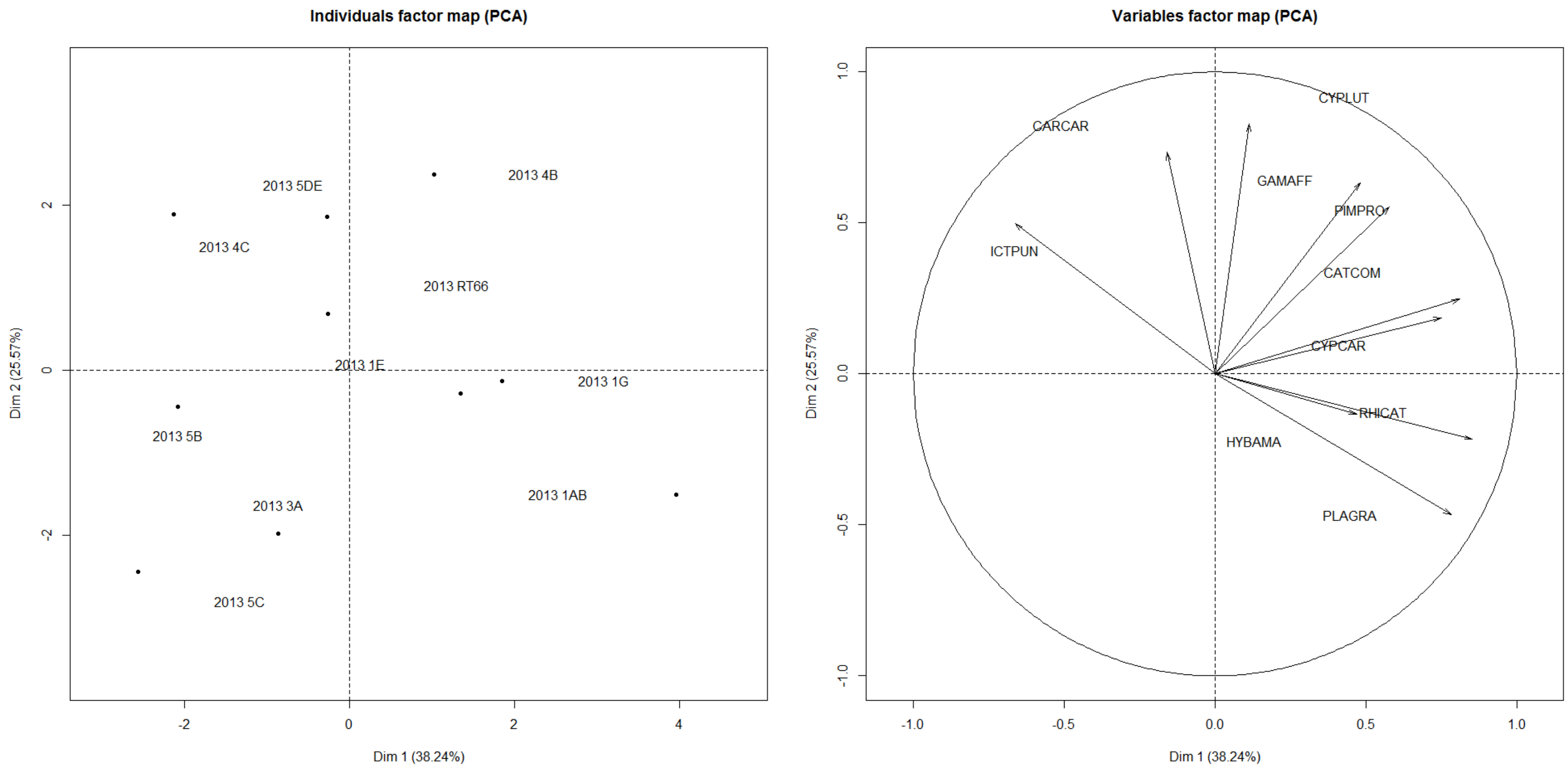

Figure 14. PCA variable factor map and the associated biplot of fish distribution among habitat restoration sites for all 2013 surveys combined.

Fish distribution among habitat restoration sites was similar in 2014 to fish distribution among habitat restoration sites in 2013. For all 2014 surveys combined, the first three components accounted for 84% of the variance explained by PCA (Table 21). PCA axis I forms a gradient for the sites from upstream to downstream. Visual inspection of the biplots of species and site scores indicated that species composition varied among sites and that common carp, channel catfish, and river carpsucker were negatively associated with PCA axis I, indicating they were most common at downstream sites. All other fish species were commonly associated with the three most upstream sites.

Table 21. PCA Component Loadings for Fish Species Data Collected in 2014 and Summarized by Habitat Restoration Site

Species or Correlation	Component Loadings		
	1	2	3
River carpsucker (CARCAR)	-0.20	0.77	-0.18
White sucker (CATCOM)	0.76	0.01	0.59
Common carp (CYPCAR)	-0.57	0.13	0.80
Red shiner (CYPLUT)	0.69	0.41	0.37
Western mosquitofish (GAMAFF)	0.24	0.65	-0.41
Rio Grande silvery minnow (HYBAMA)	0.85	0.22	0.06
Channel catfish (ICTPUN)	-0.70	0.52	0.29
Fathead minnow (PIMPRO)	0.88	0.39	-0.19
Flathead chub (PLAGRA)	0.94	0.05	0.18
Longnose dace (RHICAT)	0.73	-0.60	-0.06
Eigenvalue and explained variance			
Eigenvalue	4.89	2.02	1.48
Cumulative percent of variance explained	48.92	69.20	84.00

Note: Fish species codes used in biplots are in parenthesis.

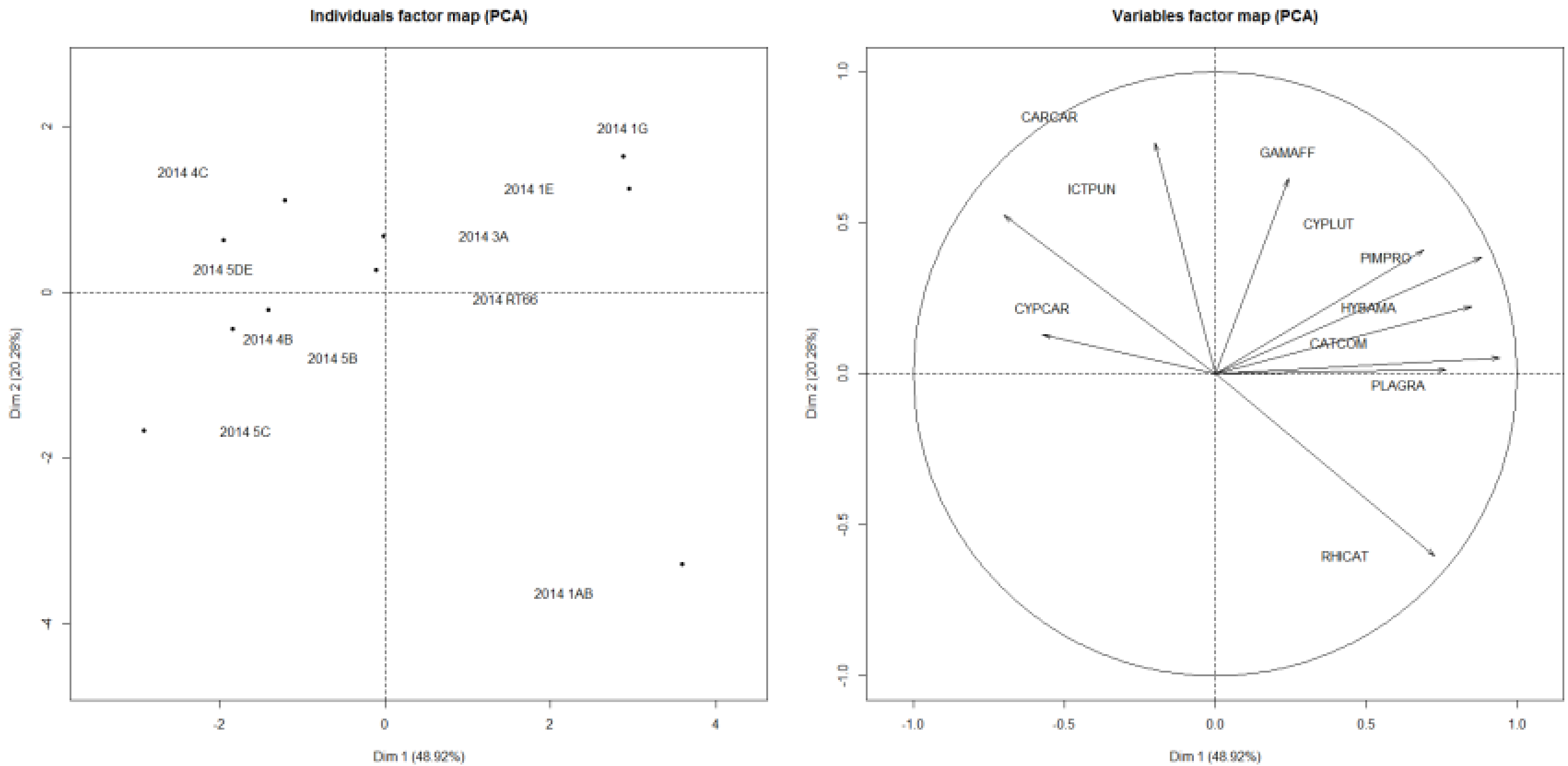

Figure 15. PCA variable factor map and the associated biplot of fish distribution among habitat restoration sites for all 2014 surveys combined.

SUBSTRATE AND MESOHABITAT ASSOCIATIONS WITH SAMPLES COLLECTED FROM HABITAT RESTORATION SITES

Substrate and mesohabitat associations with samples collected from habitat restoration sites was similar for all sites except Site 1A/B. For all surveys combined, the first three components accounted for 78% of the variance explained by PCA (Table 21). PCA axis I forms an obvious gradient between gravel and sand (Figure 16). Riffles and gravel showed a strong negative association with PCA axis I and were associated with Site 1A/B, which was the most upstream site. Pools, slackwater, and sand were strongly associated with PCA axis I but not PCA axis II. Backwaters, runs, and silt were strongly associated with PCA axis II but not PCA axis I.

Table 22. PCA Component Loadings for Mesohabitat and Substrate Data Collected in 2013 and 2014 Summarized by Habitat Restoration Site

Variable or Correlation	Component Loadings		
	1	2	3
Backwater	-0.22	0.85	0.35
Pool	0.78	-0.31	0.37
Plunge	0.36	-0.47	-0.37
Riffle	-0.94	-0.23	0.19
Run	0.41	0.55	-0.65
Slackwater	0.58	-0.04	0.56
Gravel	-0.94	-0.29	0.00
Sand	0.82	-0.18	-0.17
Silt	0.32	0.85	0.16
Sand silt	0.56	-0.40	0.25
Eigenvalue and explained variance			
Eigenvalue	4.12	2.39	1.29
Cumulative percent of variance explained	41.27	65.17	78.06

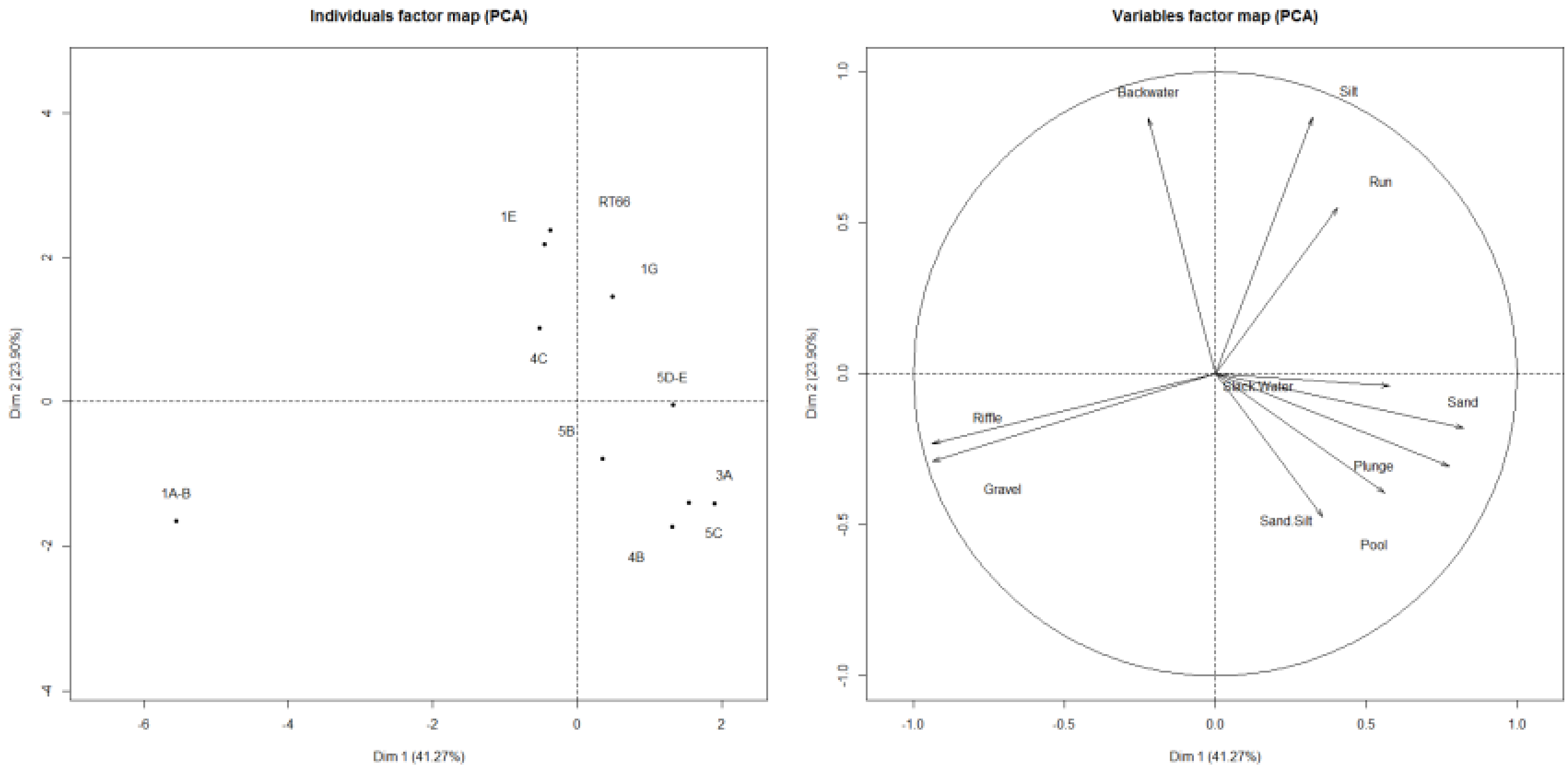

Figure 16. PCA variable factor map and the associated biplot of mesohabitat and substrate distribution among samples collected from habitat restoration sites for all surveys combined.

DEPTH, VELOCITY, AND SUBSTRATE ASSOCIATIONS WITH MESOHABITATS

PCA of depth, velocity, and substrate for mesohabitats suggested differences related to all three factors. The three components accounted for 99% of the variance explained by PCA (Table 23). Visual inspection of the biplots indicated that PCA axis 1 formed a gradient between substrates and mesohabitats found at higher velocities (e.g., sand and gravel, and runs and riffles) and those found at lower velocities (silt, backwaters, and slackwaters) (Figure 17). Silt was negatively associated with PCA axis I, while velocity, gravel, and sand were positively associated with PCA axis I. Depth was not associated with PCA axis one but was strongly associated with PCA axis II. In general, backwaters and slackwater were associated with silt but not depth or velocity, pools were associated with sand/silt and depth, plunges and runs were associated with sand and velocity, and riffles were associated with velocity and gravel.

Table 23. PCA Component Loadings for Depth Velocity and Substrate Data Collected in 2013 and 2014 Summarized by Mesohabitat Type

Variable or Correlation	Component Loadings		
	1	2	3
Depth	0.02	1.00	-0.01
Velocity	0.98	0.02	0.03
Gravel	0.77	-0.39	0.50
Sand	0.80	0.37	-0.46
Silt	-0.99	-0.13	-0.03
Sand/Silt	-0.18	0.89	0.42
Eigenvalue and explained variance			
Eigenvalue	3.22	2.09	0.65
Cumulative percent of variance explained	53.59	88.41	99.18

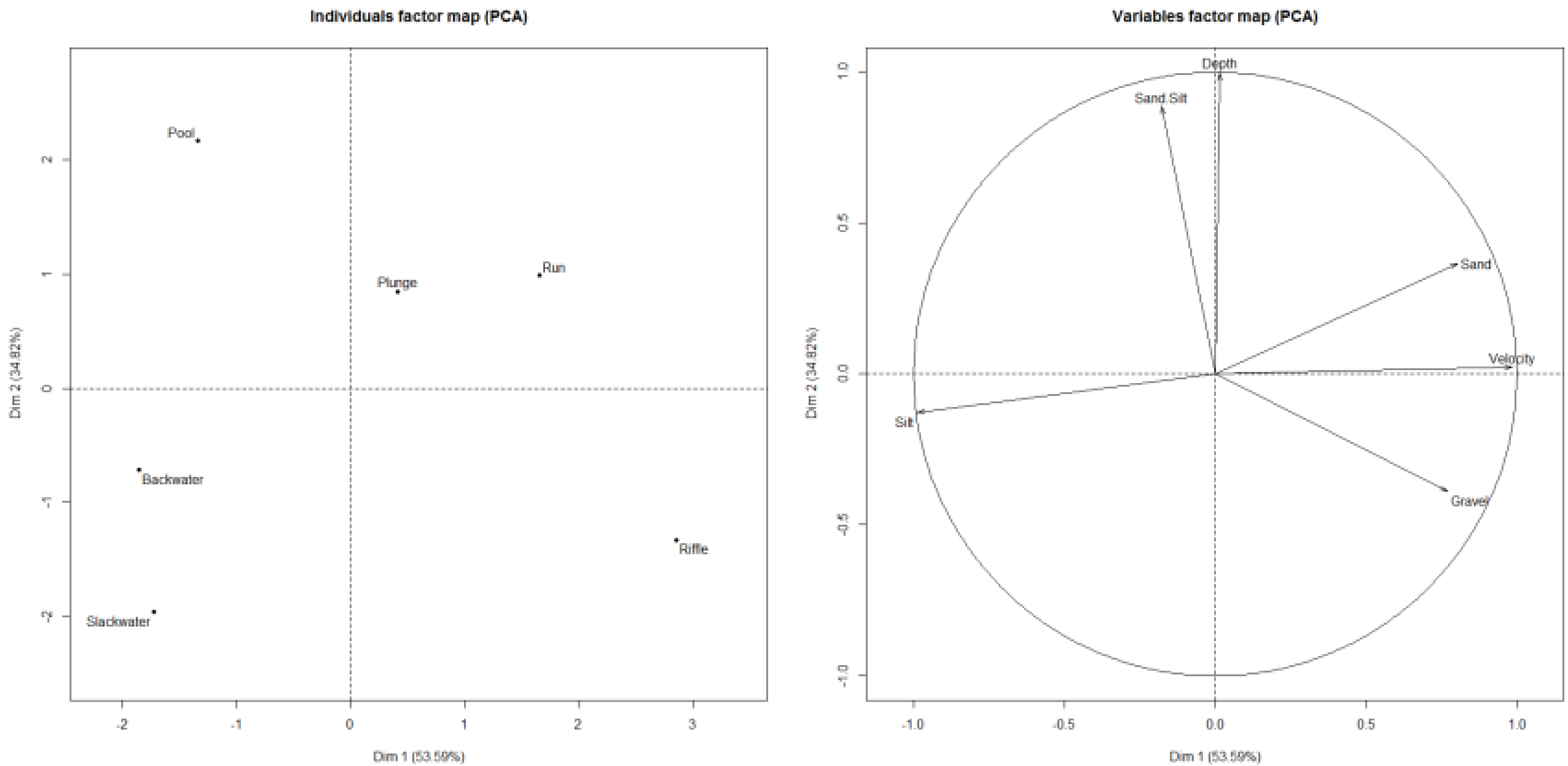

Figure 17. PCA variable factor map and the associated biplot of depth, velocity, and substrate associations with mesohabitats sampled in 2013 and 2014.

MESOHABITAT, DEPTH, VELOCITY, AND SUBSTRATE ASSOCIATIONS WITH FISH DISTRIBUTION

The proportion of the variability in fish CPUE (fish/100 m^2) explained by the CCA model using the collected environmental variables (e.g., depth, velocity, substrate, and mesohabitat) was 13% in 2013 and 17% in 2014. Velocity and riffle habitats explained the largest amount of the variation in species abundance during both years, although other environmental variables were also important. Because the first and second axis explained the most variance (10% and 12%, respectively), the third and fourth axis were not interpreted (Table 24). Permutation test showed that the first and second axis (2013, F = 23.15, P = 0.005, F = 14.28, P = 0.005; 2014, F = 29.70, P = 0.005, F = 15.00, P = 0.005), the full model (2013, F = 4.87, P = 0.005; 2014, F = 6.32, P = 0.005), and environmental constraints (2013, depth, F = 2.53, P = 0.045, velocity, F = 20.91, P = 0.005, substrate, F = 2.13, P = 0.005 and mesohabitat, F = 4.88, P = 0.005; 2014, depth, F = 5.79, P = 0.005 velocity, F = 17.96, P = 0.005 substrate, F = 5.52, P = 0.005, and mesohabitat, F = 3.93, P = 0.005) were statistically significant.

The CCA species scores when plotted in relation to environmental gradients showed similar patterns between years that mostly reflect the effect of velocity on fish, mesohabitat, and substrate distributions (Figure 18). Velocity and riffle habitats had strong negative associations with CCA axis I, while run and sand habitat had a strong positive association with CCA axis II. Longnose dace was the only species strongly associated with velocity and riffle habitats. Channel catfish was associated with run habitat and sand substrates, while flathead chub was associated (not as strongly as longnose dace) with velocity and riffle habitats. In 2013 only flathead chub and longnose dace were negatively associated with CCA axis I, indicating that these species were associated with velocity. In 2014, longnose dace and flathead chub showed a strong negative relationship to CCA axis I, while channel catfish and white sucker showed a weak negative association to the same axis.

In general, the CCA indicates that silvery minnow, western mosquitofish, and fathead minnow were consistently (during both years) positively associated with CCA axis I and negatively associated with CCA axis II, indicating that these species were more commonly collected from shallow, low velocity habitats. Longnose dace was consistently negatively associated with CCA axis I and CCA axis II, indicating that the species was most common in shallow, high velocity, riffle habitats. The flathead chub was consistently negatively associated with CCA axis I, indicating that the species had no depth preference but preferred habitats with some velocity. Channel catfish was consistently positively associated with CCA axis I and CCA axis II, indicating that the species was associated with run habitats that had sand substrate and some flow. All other fish species did not show consistent associations between years with collected environmental variables, indicating general use of habitats available in the Middle Rio Grande.

Table 24. Results of Canonical Correspondence Analysis Run on Environmental Variables and Fish CPUE (fish/100 m^2) Collected from Middle Rio Grande Habitat Restoration Sites in 2013 and 2014

Variable				Canonical Coefficients		
2013	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 1**	**Axis 2**	**Axis 3**
Eigenvalues	0.12	0.07	0.03			
Species-environment correlation	0.56	0.45	0.40			
Cumulative percent variance						
Species data	6.3	10.3	12.1			
Species - environment relation	47.4	76.6	90.1			
Depth				-0.01	0.13	-0.28
Velocity				-0.90	0.28	-0.11
Plunge				0.18	0.08	0.25
Pool				0.22	-0.21	0.01
Riffle				-0.57	-0.31	-0.03
Run				-0.29	0.57	-0.20
Slackwater				0.06	0.05	-0.13
Sand				-0.02	0.61	-0.57
Sand and silt				0.04	-0.03	-0.21
Silt				0.30	-0.14	0.87
2014	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 1**	**Axis 2**	**Axis 3**
Eigenvalues	0.20	0.10	0.08			
Species-environment correlation	0.69	0.51	0.49			
Cumulative percent variance						
Species data	7.7	11.7	14.7			
Species - environment relation	45.7	69.3	87.5			
Depth				-0.02	0.25	-0.57
Velocity				-0.66	0.43	-0.32
Plunge				0.08	0.24	-0.43
Pool				0.23	-0.11	0.33
Riffle				-0.65	-0.38	0.06
Run				-0.22	0.49	0.27
Slackwater				0.12	-0.04	0.29
Sand				-0.05	0.56	-0.47
Sand and silt				0.04	0.07	0.03
Silt				0.39	-0.34	0.47

Note: Shown is the CCA summary table for the first three ordination axis and the canonical regression coefficients for the collected environmental variables with the first three ordination axis.

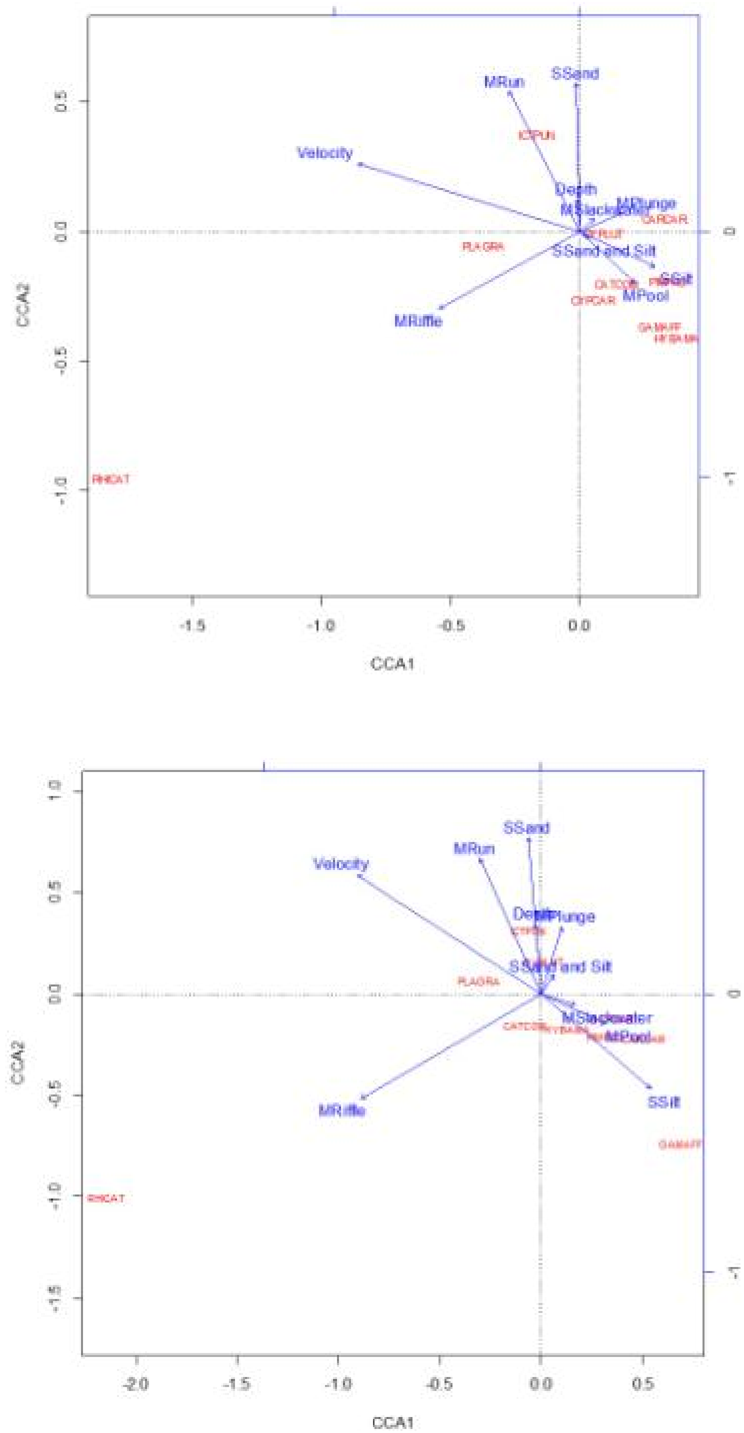

Figure 18. Canonical correspondence analysis biplots for fish species and environmental parameters from the Middle Rio Grande sites sampled during 2013 (top) and 2014 (bottom).

4 DISCUSSION

4.1 HABITAT RESTORATION MONITORING

Samples collected from main channel habitats adjacent to habitat restoration sites during 2013 and 2014 will serve as a baseline for determining effectiveness of habitat restoration sites for the Middle Rio Grande fish community and the silvery minnow. Catches of fish varied among sites and surveys, and no discernible difference was evident between control and treatment sites. The silvery minnow was detected at all sites except the downstream most site (5D/E) in 2013 and Sites 4B, 4C, and 5C in 2014. The majority of silvery minnow collected in 2014 were collected from upstream Sites 1E and 1G. Ideally, monitoring would occur during inundation on habitat restorations sites, in the main channel during low abundance (2013 and 2014; little to no overbanking), average abundance (some overbanking), and high abundance (high overbanking) years for silvery minnow so that contrasts among mesohabitats and sites could be made among and between survey years.

4.2 RELATIVE PERFORMANCE OF BEACH TO THE COMBINED CATCH

Fisheries data collected using the beach and bag seine in combination show that catches of Middle Rio Grande fish vary by species, size, and survey, and between the beach and bag seines. Presumably, the combined catch provides a better approximation to Middle Rio Grande fish community population parameters, and using the beach seine alone would have not produced the same results as using the combined approach.

From a catch perspective, the beach seine did not produced the same numbers as the combined catch, and the proportion of the fish collected with the beach seine was lower during all surveys and years. On average and over all surveys, the beach seine produced approximately 60% of the combined catch, respectively. Catchability of fish is affected by life history, fish size, environment (Hubert and Fabrizio 2007), and the ability of a particular species to escape capture (Godo et al. 1999). Some fish species were more susceptible to capture with the beach seine (e.g., red shiner), while others more susceptible to capture with the bag seine (e.g., silvery minnow). Overall, 37% of silvery minnow collected during 2013 and 2014 were collected with the beach seine, while 63% were collected with the bag seine.

Species richness varied between the beach seine and the combined catch for all contrasts and comparisons. Species richness analysis indicates that the beach seine was missing on average 25% of the species richness provided by the combined catch. The proportion of the combined catch species richness provided by the beach seine varied from 62% during Survey 8 to 83% during Survey 6. Over all surveys combined, three species were missed by the beach seine: largemouth bass in 2013 and white bass and walleye in 2014. It is worth noting that the endangered silvery minnow is a strong swimming species (Bestgen et al. 2010) and was only present at low abundance in the summer and fall of 2013 and 2014. In addition, the species was not collected with the beach seine during Surveys 1, 2, and 7. This indicates that the species was successful at evading the beach seine and the bag seine provided suitable coverage to allow for capture of missed individuals. Species richness and a complete species list would be generated faster using the combined catch than with the beach seine alone.

Presence/Absence of fish species was lower for the beach seine than the combined catch for nine of the 10 common species collected during 2013 and 2014. Of the 10 species compared, only longnose dace was present at the same proportion as for the combined catch. When a species was present in a combined catch sample, the beach seine detected them from 55% (silvery minnow) to 82% of the time (red shiner), depending on species.

Population length structure of fish collected varied between the beach seine and the combined length frequency. In general, a higher proportion of small fish were collected with the beach seine while a higher proportion of larger fish were collected with the bag seine. The largest fish collected with the bag seine was a 440-mm channel catfish, while the largest fish collected with the beach seine was a 14- mm channel catfish. It is worth noting that the proportion of silvery minnow larger than 50 mm collected with the beach and bag seines ranged from 9 and 40% in 2013, and 3 and 7% in 2014, respectively.

4.3 FISH DISTRIBUTION IN RELATION TO HABITAT RESTORATION SITES AND ENVIRONMENTAL VARIABLES

The distribution of fish throughout the study reach show that the fish community varies from upstream to downstream sites with greater species diversity and abundance (2014) at the three upstream most sites (see Figure 6, Figure 9, and Figure 13–Figure 15). PCA and CCA of fish collections showed that the fish distribution within the Middle Rio Grande was fairly stable between years with velocity as the primary driver for fish habitat and environmental associations. PCA of depth, velocity, and environmental variables relative to mesohabitat were clearly separated by depth and velocity. Gravel substrates were associated with riffles and velocity but not depth. Sand substrate was commonly found in run and plunge habitats of moderate depths. Sand and silt substrates were associated with pool habitats which showed a negative association to velocity. Lastly, backwater and slackwater habitats were associated with silt and low to no velocity areas.

Longnose dace was the only fish species strongly associated with Site 1A/B where high velocity riffle habitats with gravel substrate were common in samples. Site 1AB is upstream of the North Diversion Channel where the river runs through a confined channel with a steeper gradient than downstream of the North Diversion Channel. Sites 1E and 1G are downstream of the North Diversion Channel but upstream of the city of Albuquerque. These two sites had more species associated with them during both years than all other surveyed sites and were most commonly associated with low velocity, backwater and run habitats with silt substrates.

CCA analysis of environmental parameters analyzed showed that flow (velocity feet/second) had the greatest effect on fish distribution in the Middle Rio Grande during both years of sampling. The majority of common fish species were most abundant at mesohabitats with little to no velocity, which dictates the sediment composition (silt is common in low velocity habitats), and mesohabitat type (riffles are high velocity habitats, while backwaters are low velocity habitats). Riffle and run habitats were positively associated with flow and longnose dace, flathead chub, and channel catfish were commonly associated with these habitat types. Silvery minnow, western mosquitofish, fathead minnow, white sucker, common carp, and river carpsucker were most common in shallower, low velocity habitats that were mostly associated with sand-silt and silt substrates during both years of sampling. Red shiner showed no consistent association with velocity, depth, substrate type, or mesohabitat and was a generalist type species that showed no clear affinity to environmental variables measured during both years of surveys.

Fish associations with mesohabitats were disproportionate to their availability in the Middle Rio Grande (see Figure 2). Run habitats in the Middle Rio Grande are the most abundant habitat type and only one species was (channel catfish) consistently associated with this habitat. The disproportionate use of habitat by Middle Rio Grande fishes is consistent with findings in the Pecos River of New Mexico (Kehmeier et al. 2007) where small-bodied cyprinids were common at mesohabitats that comprised just 9% of the total mesohabitat volume, with intermediate to low velocities. The majority of the fishes included in the CCA analysis were habitat generalists that favored low velocity habitats. Exceptions to this include the longnose dace, which was strongly associated with riffle habitats that had gravel substrates and high velocities.

4.4 CONCLUSION

Study results demonstrate that using the bag and beach seine in combination increases the efficiency of the beach seine alone by generating a more complete species list, collecting approximately 40% more fish per sample, collecting approximately 17% to 38% more species per sample, providing a more complete transcription of species population length structure, and detecting rare species. These results were consistent between survey years 2013 and 2014 and show that the bag and beach seine combination appears to be well suited for sampling the Middle Rio Grande fish community and the endangered silvery minnow during years of low abundance. Additional samples should be collected using the methods described is this report, especially during years when overbanking occurs and relative abundance of silvery minnow is at or above average. Annual monitoring of silvery minnow shows that the species varies from one of the three most common species found in the Middle Rio Grande as one of the least common species (Dudley and Platania 2013). Data collected for this report shows that when there are fewer and smaller fish in the system (e.g., Survey 5 in 2014) the beach seine collects data that are similar (but analysis shows they are still not the same) to the combined catch. The difference between the beach seine and combined catch becomes more pronounced when there are more fish in the system (e.g., Survey 1 in 2013). Repeating these surveys during years when the silvery minnow is abundant may provide a better understanding of capture efficiency for the beach seine and main channel habitat use and distribution for the species within the Albuquerque Reach of the Middle Rio Grande.

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APPENDIX A
MAPS OF SAMPLED MESOHABITATS

APPENDIX B
WATER QUALITY

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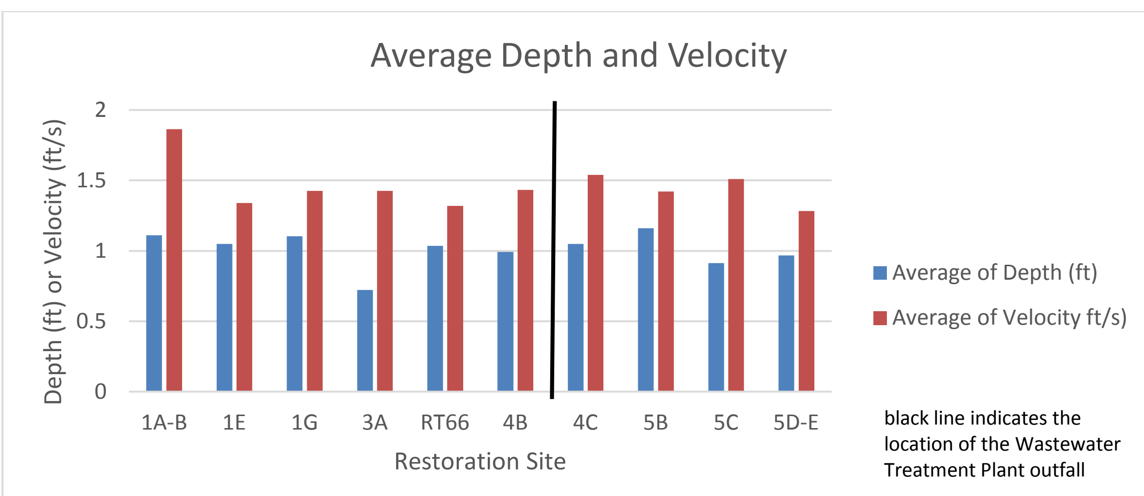
WATER QUALITY

For each restoration site, the data were evaluated by averaging all samples at a site, which were taken at different times of day and during different months. Since samples were not taken at each site and the same time of day every month, water quality parameters are not always readily comparable. While there may be significant differences among sites or trends with increasing distance downstream, these differences may be obscured by diurnal variations in the data. Local storm events and various inputs into the Rio Grande occurring between sites, for which we do not have data, may also influence water quality and obscure trends in the data. These short-term variations in water quality parameters may result in measurements that are not necessarily representative of the water quality at a particular restoration site. The wastewater treatment plant discharge (indicated by black line on graphs below) could also be influencing the water quality parameters at sites downstream of the outfall. To evaluate the influence of the wastewater treatment plant, sites were grouped as either above or below the treatment plant and t-tests were performed to determine the difference between the two groups. Again, water quality measurements were taken on different days of the month and at different times of day, therefore the influence of the discharge may not be apparent for each parameter. Differences among restoration sites were also evaluated by plotting average monthly values for each site. There were no apparent trends for most parameters with time or distance downstream and no apparent differences among sites. Therefore, the monthly averages are not presented here.

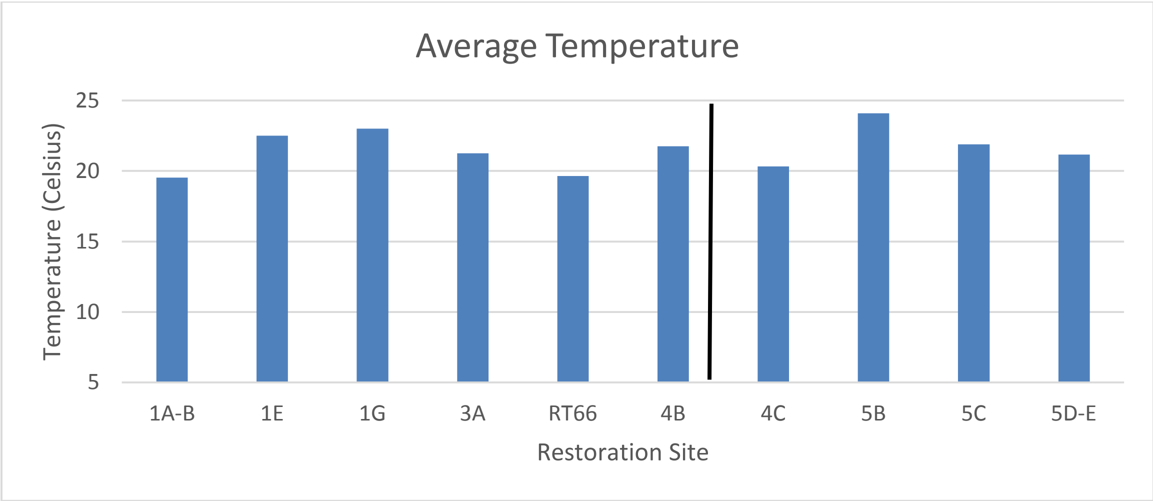
DEPTH AND VELOCITY

Depth was lowest at 3A and greatest at 5B and velocity was lowest at RT 66 and greatest at 1A/B. There were no significant differences among sites or trends observed with distance downstream.



Temperature

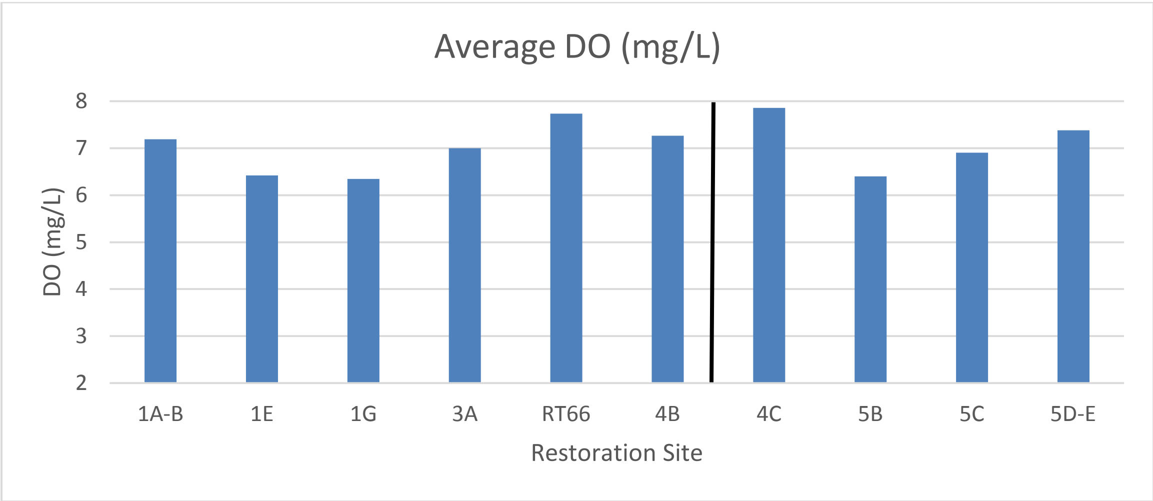
Temperature was lowest at 1A/B and RT66 and highest at 5B. There were no significant differences among sites or trends observed. Temperature decreased from 4B to 4C below the wastewater treatment plant outfall but was similar to observed upstream values. When the data were examined on a monthly basis, temperature also sometimes decreased at 4C.

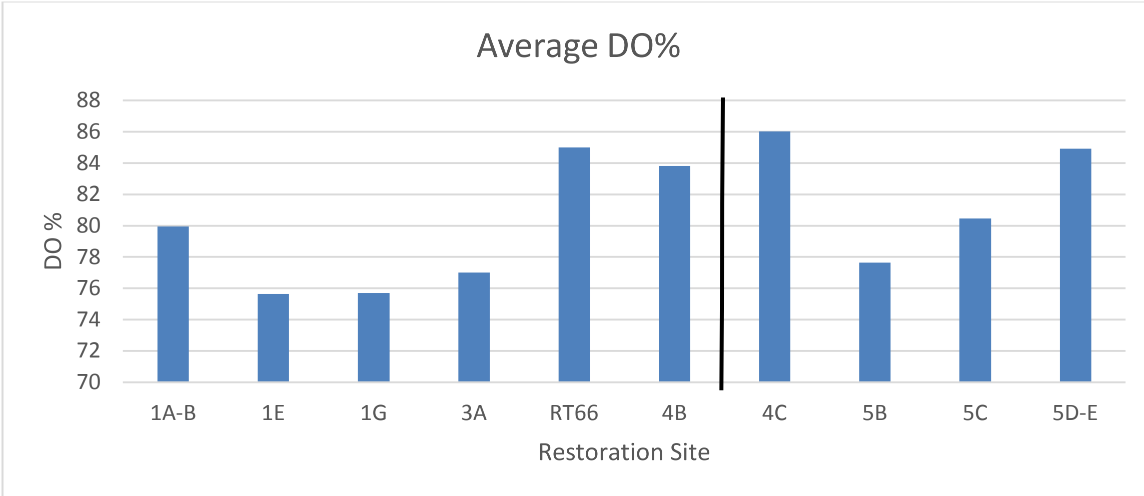


Dissolved Oxygen

Dissolved oxygen (DO) concentrations at RT 66 and 4C were significantly higher than 1E, 1G, and 5B. Dissolved oxygen increases abruptly from 3A to RT 66 and increases slightly below the wastewater treatment plant.

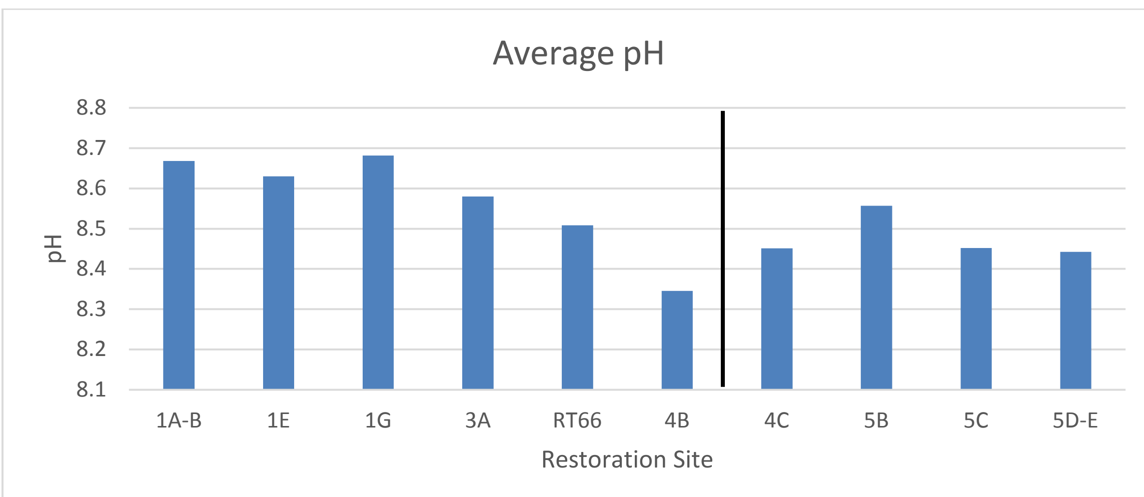
The percent dissolved oxygen at 4C was also significantly higher than 1E and 1G. The t-test indicated that percent dissolved oxygen was significantly higher downstream of the wastewater treatment plant.





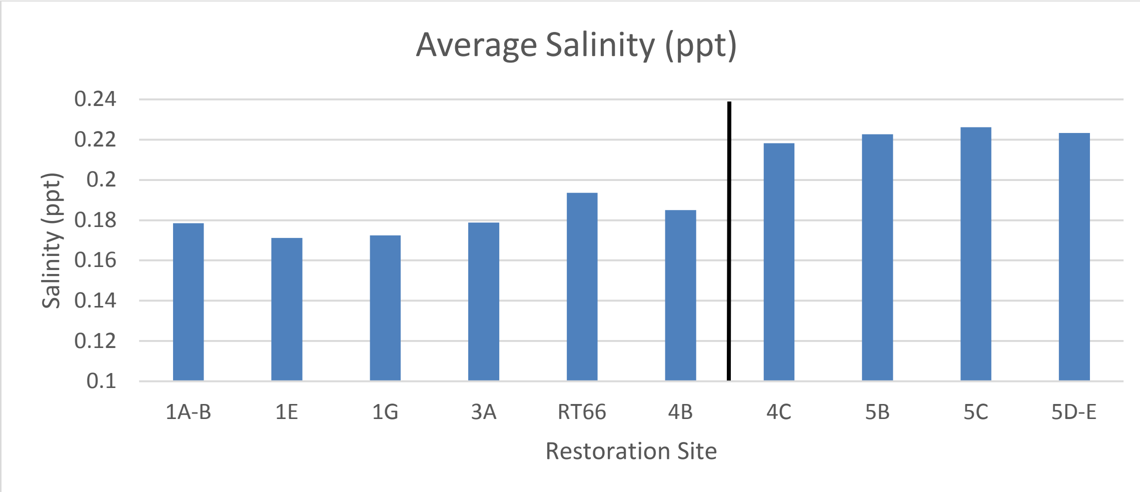
pH

The lowest pH was observed at 4B. pH declines slightly up to 4B then increases from 4B to 5B and then decreases again from 5B to 5D.



Salinity

1E and 1G had the lowest salinity and the highest was observed at 5C. Salinity generally increased downstream with a slight decrease at 4B. Salinity was greater below the wastewater treatment plant. When examined on a monthly basis salinity would sometimes show a sudden increase at 4C, but in some months this would also happen at 4B or 5B. In July 2014, salinity at 3A and RT66 was much higher than the other sites, so the difference might not be attributed to the wastewater treatment plant. However, the t-test indicated that salinity was significantly higher in sites downstream of the wastewater treatment plant.



CONDUCTIVITY AND TURBIDITY

Conductivity (corrected for temperature) was lowest at 1E and highest at 5C. Conductivity generally increased downstream and followed the same trend as salinity. Conductivity starts increasing below the wastewater treatment plant but is not at its highest until 5C.

Conductivity (not corrected for temperature) was lowest at 1A/B and highest at 5B and generally increased downstream with slight decline after 5B. The t-test indicated that conductivity (corrected for temperature and uncorrected) was significantly higher in sites downstream of the wastewater treatment plant.

Turbidity was lowest at 1A/B and 5B and highest at 5C. The turbidity of discharge from the wastewater treatment plant would be expected to be low and it is possible that inputs from the Tijeras Arroyo are increasing turbidity at 5C and 5D/E. 5B could be less turbid because the water in the river (including wastewater treatment plant discharge) was not well mixed with inputs from the arroyo.