SAN JUAN RIVER BASIN
RECOVERY IMPLEMENTATION PROGRAM

DETAILED REACH STUDY

2009 FINAL REPORT

prepared by

Ron Bliesner
Keller-Bliesner Engineering, LLC
78 East Center
Logan, Utah 84321
(435) 753-5651

Ernesto De La Hoz
Paul Holden
BIO-WEST, Inc.
Logan, Utah 84321

and

Vince Lamarra
Ecosystems Research Institute
975 South Highway 89-91
Logan, Utah 84321
(435) 752-2580

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EXECUTIVE SUMMARY

Habitat availability and use were assessed for the final year for three detailed reaches located at RM 82, RM 131 and RM 137[1]. A two-pass fish survey was completed in each reach in March and August 2009. Detailed mapping was completed coincident with the fish surveys. Colorado pikeminnow capture data from the small-bodied monitoring program were included in habitat selection studies. Habitat association was examined utilizing data from the detailed reach, non-native removal, adult monitoring and larval fish studies.

The detailed reach study and associated habitat association studies have demonstrated the importance of the more complex portions of the San Juan River to a range of life stages of the endangered Colorado pikeminnow and razorback sucker. The habitat types associated with larger sizes of both species are very abundant in the river, but the abundance and persistence of low velocity habitats, particularly backwaters, are low. Further, the complexity that appears to be important to all life stages is diminishing with time (Bliesner et al. 2009).

The study has also found that the difficulty of integrating habitat and fish capture results, particularly for younger life stages, is more related to the timing of mapping than the scale. Even though the increased detail of mapping was beneficial, it would not be sufficient to integrate fish and habitat data if the habitat mapping and fish sampling were not completed at the same time.

Following are the specific findings:

DETAILED REACH

Three reaches were surveyed in four separate passes, two in March and two in August, in 2009, similar to 2007 and 2008. Colorado pikeminnow captures totaled 74 in 2009, 58 in March and 16 in August. The habitat selection and association analyses use the combined total fish from all years (n=147 in March and 98 in August). The following findings are for the combined data from 2007 through 2009:

- Young (<100 mm) Colorado pikeminnow appear to select for lower velocity habitats with selection for backwaters, embayments and pools indicated. These habitats also tend to have fine substrates. These young fish also appear to select against riffle, cobble shoal and slackwater.
- Important habitat associations within the seined area for young Colorado pikeminnow listed in order of decreasing selection ratio are: pools with sand shoals, backwaters with runs, pools and backwaters. Beyond 5 meters, the importance of specific habitats is weaker and is not improved by habitat combinations, indicating a relatively small range of movement during the sampling time. No assessment was made of movement between sampling times or during other times of the day.
- Older (>100 mm) Colorado pikeminnow appear to select for riffles and against runs when looking at the target habitat analysis. They use a wider variety of habitats with higher and more varied velocities than the younger fish. They also show selection for cobble and against sand/silt substrates.

[1] The geomorphology portion of the detailed reach study was completed in 2008. See Bliesner et al. 2009.

- The habitat associations in the vicinity of the captures of older Colorado pikeminnow indicate an affinity for more varied habitat and a larger range. The selection ratios for habitat combinations remain higher than for individual habitats from the capture location up to 20 meters away. Habitat associations that include cobble shoals, riffles and slackwaters appear important, with higher selection ratios than for any individual habitat. Since many of the targeted riffle samples also included some slackwaters or cobble shoals, the association of these habitats contributes to the selection for riffles.
- On a larger scale, the capture locations across all years tend to group in the same areas within the detailed reaches with some influence from flow during sampling. The areas of capture tend to be the most complex areas of the complex reaches where a variety of habitats are available over a large range of flows.

SMALL-BODIED MONITORING HABITAT SELECTION

Conclusions from the small-bodied monitoring data analysis for Colorado pikeminnow from 2007-2009 compare to the detailed reach results as follows:

- Young Colorado pikeminnow appear to select for backwater habitat, as indicated by the detailed reach study.
- Young Colorado pikeminnow appeared to select against run habitat, but no such relationship was found in the detailed reach study.
- Older Colorado pikeminnow did not show any selection, likely due to the small number of captures relative to the large effort when all three years were combined.
- The sampling effort among habitat types is different for the two studies which may lead to some of the differences in conclusions.

NON-NATIVE REMOVAL AND ADULT MONITORING HABITAT ASSOCIATION

In 2009 both Colorado pikeminnow and razorback sucker captures with GPS locations increased by over 2.5 times compared to 2008. The large increase in captures likely contributed to differences in results between the two years. Because of the inability to normalize the GPS data for uniform representation over the range of captures, the large-bodied monitoring capture data were analyzed at the river-mile scale, utilizing just the sampled river miles. Following are the specific findings:

Findings from Analysis of Combined GPS Data

- In 2008, Colorado pikeminnow appeared to be associated more strongly with islands and island complexes. In 2009 islands did not show significance, but riffle and cobble habitats did. Sand type habitats were more prevalent in 0.1 mile reaches with no captures. Although the precise habitats that show significance are different, they are all associated with areas of the river that are more complex.
- In 2008, razorback suckers appeared to have an affinity for 0.1 mile reaches with cobble habitats and islands, similar to Colorado pikeminnow. In 2009, reaches with higher density of pool and riffle habitats were significantly related to capture but sand habitats were found more frequently in reaches without captures. As with Colorado pikeminnow, the habitats from both years are associated with more complex areas of the river, but with slightly less affinity for the highest velocity habitats.

- The effort is not uniform within reach, potentially biasing results to the habitats most likely to occur in the lower end of Reach 6 and the upper end of Reach 5. Also, the multiple pass sampling of the non-native removal program may displace fish downriver and away from their preferred locations.
- Habitat associations are based on 2007 habitat data and there is less reliability in fish-habitat relationships as the time between habitat mapping and fish sampling increases. Since river-wide habitat mapping is not planned in the next few years, GPS data collection may be dropped until the river is mapped again.

Findings from Analysis of Large Bodied Monitoring Data

- The data set includes 369 Colorado pikeminnow and 76 razorback sucker captures form RM 166 to RM 4.
- Complex river miles with a wide variety of habitat and a high number of mapped habitat polygons were associated with Colorado pikeminnow captures. The associations with capture were greatest for river miles with islands, overhanging vegetation, cobble and riffle habitats. The selection ratios for the most important habitats were larger for Colorado Pikeminnow compared to those for razorback sucker.
- Complex river miles with a wide variety of habitat and a high number of mapped habitat polygons were also associated with razorback sucker captures. The associations with capture were greatest for river miles with pools, islands, riffles and overhanging vegetation.
- Both the GPS analysis and this analysis indicate affinity for complex areas in the river.
- Only 15 of the 95 sampled miles analyzed had no Colorado pikeminnow captures. As densities increase the utility of this presence/absence approach on a river mile scale will diminish.
- Until river-wide habitat mapping is completed again, repeating this analysis is not recommended. The time between the fish capture and habitat mapping is too great for accurate habitat association.

LARVAL RAZORBACK SUCKER HABITAT USE AND AVAILABILITY

- Larval razorback sucker were captured in a variety of low velocity habitats but over 90% of the fish were captured in backwaters.
- Samples with larval razorback sucker had significantly greater maximum depths than those without. This relationship is heavily influenced by backwaters, as they tend to have greater maximum depths than the other habitats sampled.
- Cover (overhanging vegetation, inundated vegetation or debris) was not significantly associated with larval fish capture.
- Most backwaters present during early larval razorback sucker captures did not persist even one month. Only 4% of the habitats sampled in May were available to be sampled in June.
- Backwater persistence improved after runoff, but no backwaters persisted more than three months given the flow variability seen in 2009.
- Only one habitat with larval razorback sucker in May retained fish until June (n=52 and 2, respectively). It was a backwater in May and an isolated pool in June, located at RM 3.3.

- Low persistence and low abundance of backwaters are likely negatively influencing retention of larval razorback suckers in the San Juan River.
- Habitat persistence assessment could be improved by sampling and measuring the same backwaters each trip if they are available.

CHAPTER 1: INTRODUCTION

During integration of San Juan River Basin Recovery Implementation Program (SJRIP) monitoring data from 1999-2003, it became obvious that integration of habitat data and fish data was extremely difficult (Miller 2005) because these two datasets were taken at different levels of detail and at different times. Adult fish monitoring data were too coarse to allow association with habitat data and habitat mapping units were possibly too large to see details that were often the focus of sampling by larval and juvenile fish sampling programs. Although larval and small-bodied fish sampling collect habitat data, the habitat categories did not match those in the habitat mapping program. Finally, although GPS locations are provided for recently collected larval and small-bodied fish sampling programs, the accuracy is not sufficient to place them on the habitat maps with sufficient precision to combine the two datasets and the timing differences means the habitat is very likely different than it was when mapped, especially for the rare habitats that are affected by flow rate.

Backwater habitat has been hypothesized as important to larval and young juvenile endangered fishes. Backwater habitat is low in abundance in the San Juan River and has declined substantially since 1995 (Bliesner and Lamarra, 2006). However, sampling for age-0 and age-1 Colorado pikeminnow in the last several years has indicated that they use other low velocity habitat that is not necessarily mapped by the standard mapping program (Golden et al. 2006).

To identify the habitat utilized by young endangered fishes and to provide information to allow this habitat to be mapped more broadly in the river, the following tasks as stated in the RFP were addressed:

1. Sample for young-of-year Colorado pikeminnow and razorback sucker within the two complex[2] reaches to determine habitat use of endangered fish.
2. Map habitat in each complex reach each time fish sampling occurs.
3. Use supplemental data on young Colorado pikeminnow and razorback sucker captures of any size class throughout the San Juan River from other SJRIP sampling efforts and use these data to add to the habitat use information in the complex reaches.

Habitat use data from the following studies are included in the habitat selection and association studies reported here:

Detailed Reach studies at RM 82, RM 131 and RM 137
Larval fish survey
Small-bodied monitoring
Large-bodied monitoring
Non-native removal – GPS locations of fish captures.

Habitat association for large bodied fish capture locations used the 2007 river-wide mapping, the last year of available data.

[2] In 2008 a third detailed reach was added to increase capture numbers and improve statistical power of habitat use analyses.

This study began in 2005 and included geomorphology, habitat and modeling tasks through 2008. The 2008 annual report included the results of those studies. In 2006 it was recognized that the largest limitation to the integration of fish sampling and habitat data was that it was not collected at the same time. In 2007 fish sampling was added to the detailed reach study with habitat mapping occurring simultaneously with sampling. The field work for this study was completed in the summer of 2009. This is the final report for the habitat utilization/association portion of the detailed reach study.

SAN JUAN RIVER STUDY AREA

The seven-year research program defined eight geomorphically distinct reaches in the San Juan River (Bliesner and Lamarra, 2000; Figure 1.01). One detailed reach (DR 82) is located in Reach 3 and two (DR 131 and DR 137) are located in Reach 5. The data from the larval fish survey come from Reaches 1 through 5. GPS fish location data from the non-native removal and large-bodied monitoring programs were taken from reaches 3 through 6. Large-bodied monitoring capture data by river mile cover reaches 1 through 6.

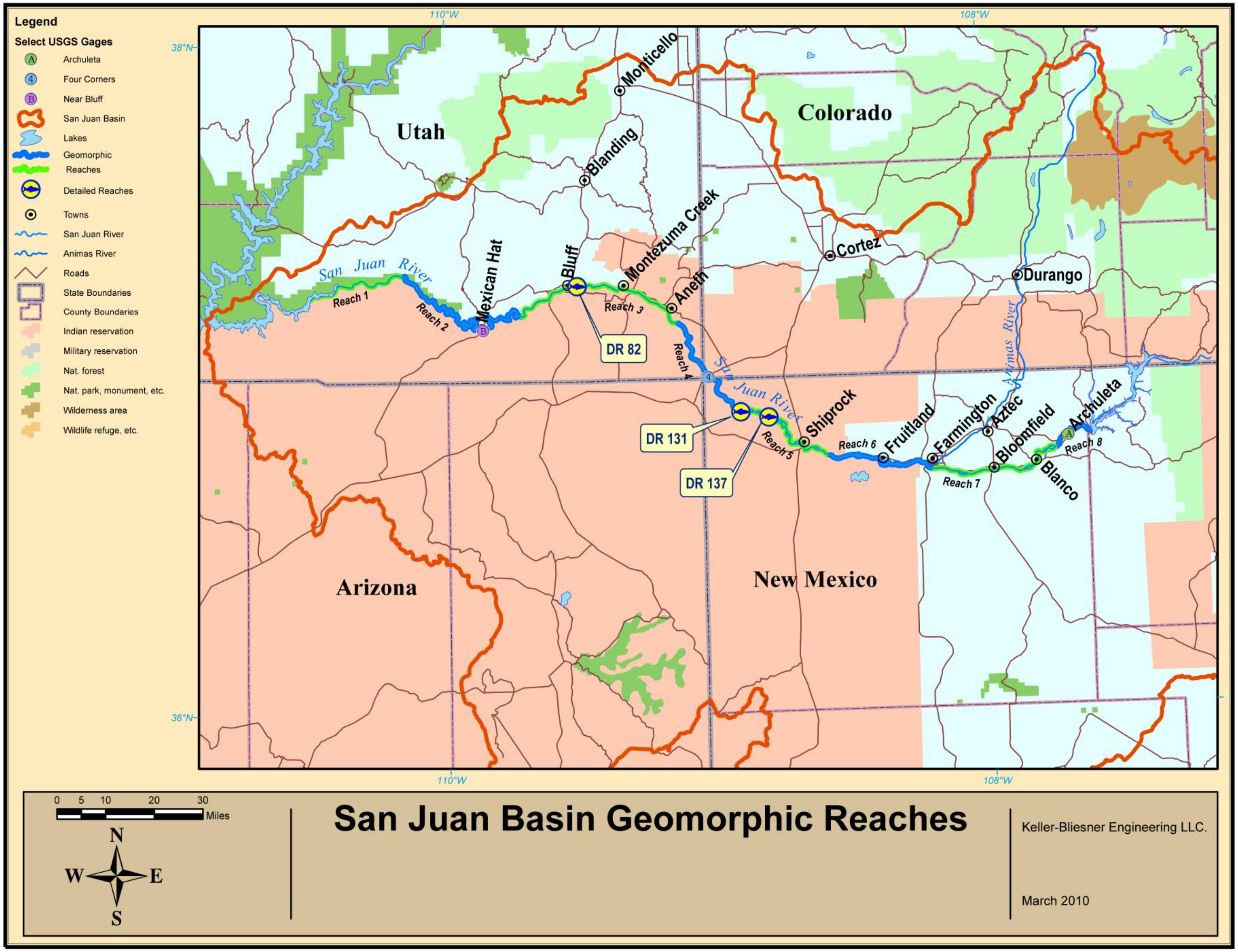


Figure 1.01. San Juan Basin location map showing geomorphic reaches

CHAPTER 2: DETAILED REACH FISH SURVEY (2007-2009)

INTRODUCTION

Given the scarcity of habitat for some life stages of endangered fishes in the San Juan River and the need to better understand the relationship between fish habitat availability and use, the goal of this study was to identify specific habitat types utilized by young endangered fishes and to provide information to allow this habitat to be mapped more broadly in the San Juan River. Our objectives were: (1) sample for young-of-year Colorado pikeminnow and razorback sucker within at least two complex reaches to assess habitat use, (2) map habitat in each complex reach each time fish sampling occurs to assess habitat availability, (3) determine if habitat selection is occurring with the rare fish, and (4) use supplemental data on young Colorado pikeminnow and razorback sucker captures of any size class throughout the San Juan River from other SJRIP sampling efforts to add to the habitat use and selection information gathered in the complex reaches.

Young Colorado pikeminnow are stocked in the San Juan River at age-0 in the fall, which provides sufficient numbers to be collected the following year. Razorback sucker are stocked as subadult or adult fish, so juveniles, if captured, would likely be wild fish.

METHODS

Fish were intensively sampled along 2 complex reaches in August 2007 and along 3 complex reaches in March and August of 2008 and 2009. Reaches sampled in 2007 included river miles 82 and 137. In addition to these reaches, river mile 131 was also sampled in 2008 and 2009. In this study we refer to these reaches as Detail Reach (DR); DR82, DR131, and DR137, respectively. Each reach was sampled twice within a six-day period during each sample period. Typically the first sampling event occurred over the course of one day; with the second sample taking place after two days of "rest". This “rest” period was intended to allow displaced fish to redistribute among available habitats.

“Block” seining was the primary method used to capture fish in August sampling. This method involved using two 2m x 9m double weighted seines with a 6mm mesh. To sample a particular location, one seine was dragged downstream through the sample area while the other was held in place at the downstream end and pivoted towards the shore behind the first seine. Samples were also collected using a single seine of the same size or smaller (i.e., 2m x 3m seine with a 3mm mesh size) as appropriate based on habitat area and flow conditions. A single seine (2m x 3m with 6 mm mesh) was typically used during March sampling.

Total and standard lengths were recorded for all Colorado pikeminnow and razorback sucker captured. For other species captured, length measurements of up to 50 individuals of each species were recorded. A PIT tag reader was used to scan all Colorado pikeminnow and razorback sucker over 150 mm TL for PIT tags. Numbers of PIT tags detected were recorded and a new tag was inserted when detection did not occur. All Colorado pikeminnow that were less than 150 mm TL were marked with a VIE tag (VIE marking color and location: pink right dorsal) during the first pass. Mark and recaptured data were used to estimate the population size of Colorado pikeminnow by reach.

The selection of sampling habitats was intended to be proportional to the occurrence of habitats within the complex reaches. However, previous sampling has shown that Colorado pikeminnow with total length greater than 100mm (TL > 100 mm) tend to use fairly complex portions of the river with some current, but smaller Colorado pikeminnow (TL < 100 mm) occur more often in backwaters and shoals (Golden et al. 2006, Robertson and Holden 2007). Based on this evidence, some habitats were sampled in a relative lower or higher proportion than they occurred in each reach. Backwaters, embayments, and eddies are relatively uncommon and all or the majority of these low-velocity habitat types were sampled. Conversely, runs are among the most common habitat types but only a small area of this habitat type was sampled. In addition, water depth and velocity also prevented sampling this (and other habitat types) in proportion to their occurrence. For these reasons, the assessment of habitat selection by fish, described below was based on the area sampled by habitat type rather than on the total area present (i.e., total area mapped by habitat type).

Prior to each field data collection event, a plan for selecting sample sites was developed based on previous mapping efforts and anticipated number of samples that could be collected in the allocated sample period. It was anticipated that approximately 40 samples could be collected during a single day/pass. After the initial sampling pass, the habitats sampled were reviewed and the second pass was intended to sample habitats that were missing and/or that were not sampled in approximate relative proportion during the initial sampling pass. The second pass also served to increase the number of seine hauls pulled, to boost Colorado pikeminnow captures, and if possible, to calculate endangered fish mark-recapture population estimates. Approximate site locations were selected in advance (except for backwaters and other low velocity habitats) using maps from the previous year as well as a grid and random number generator. In the field, many of these sites were no longer in the same habitat category or were not suitable to sampling with seines. Thus, sample sites were adjusted as needed. Overall, despite detailed planning, the final allocation of sampled habitat types was more closely associated with habitat conditions observed in the field than the anticipated sample locations determined from previous mapping efforts.

In all sampling efforts, a single habitat type was targeted for sampling. However, effective sampling of small habitat features often required beginning a seine haul in one habitat feature, passing through the targeted habitat, and completing the sample in the second or even possibly a third habitat feature. In such cases, effort was focused on minimizing the area sampled in adjacent habitats. All captured organisms were presumed to have been captured in the target habitat for data analysis. Simultaneously with fish collection, all available habitats in the complex study reaches were mapped on an ortho-rectified digital photograph base map. Sample locations were identified and drawn on the habitat map. GPS coordinates were also recorded at each sampling site. Habitat types mapped follow Bliesner et al. (2009).

Physical characteristics recorded at each habitat sampled included multiple depth and velocity measurements, primary and secondary substrate types, and primary and secondary cover features (if present). The habitat type, area sampled (width and length of seine haul) and water temperature were also recorded. Depth and velocity measurements were collected at 3 to 5 locations per site and were chosen to be representative of the range of conditions within the site. Velocity measurements were collected at 60 percent below the water surface in all locations with depth less than 2.5 feet. If depth was greater than 2.5 feet, velocity was measured at 20, 60, and 80 percent below the surface and the average velocity was calculated. Depth and mean velocity for each of the 3-5 locations were then averaged to find a mean depth and velocity for the sample site. Substrate was classified as silt, sand, fine gravel (<1 in.), coarse gravel (1-3 in.), small cobble (3-6 in.), large cobble (6-10 in.), or boulder (>10 in.). Categories for cover included inundated vegetation, roots, small woody debris, large woody debris, overhanging vegetation/roots, boulders, and bedrock shelves.

Other San Juan River fish studies were also reviewed for the potential to use them in the habitat selection analysis. Data from the larval fish, non-native fish removal, adult monitoring, and small-bodied monitoring studies were evaluated. These studies were also reviewed as part of the habitat association analysis discussed below.

Data Analysis

For each sampling event and reach, the total area mapped, sample frequency, and total area sampled by habitat type were calculated. Habitat selection of fishes was analyzed by examining the proportional use of individual habitat types (number of fish of a single species, or species assemblage, captured in a singular habitat divided by the total number of individuals of that species, or species assemblage, collected in the study area on a given date or dates) in relation to their proportional availability (amount of a specific habitat sampled divided by the total amount of habitat sampled in the study area). Habitat selection analyses were conducted for Colorado pikeminnow, as well as for the entire fish assemblage, the native fish assemblage, the non-native fish assemblage, and other individual fish species of interest (i.e., bluehead sucker- *Catostomus discobolus*, flannelmouth sucker- *Catostomus latipinnis*, speckled dace *Rhinichthys osculus*, channel catfish- *Ictalurus punctatus*, fathead minnow- *Pimephales promelas*, and red shiner- *Cyprinella lutrensis*). Analyses of Colorado pikeminnow habitat selection were conducted by individual reach and by combining the use and available habitat of all complex study reaches. Analyses of habitat selection for DR 82 were not conducted separately because of the small number of Colorado pikeminnow captured in this reach. In addition, the habitat availability and use by Colorado pikeminnow was pooled to conduct habitat selection analyses by fish size. This involved pooling the data and running separate assessments for small (TL< 100 mm) and large (TL > 100 mm) young Colorado pikeminnow.

Two types of chi-square analysis were used to test the null hypothesis that fish are randomly selecting habitats in proportion to their availability. These tests of “no selection” included the Pearson chi-square statistic ($\chi 2p$), which is driven by differences between the observed and expected number of used resource units of each type and the Log-likelihood statistic ($\chi 2$ l), which is based on the ratio of the observed and expected resource units used. Significant chi-square values ($p<0.05$) are indicative that selection occurs (Manly et al. 1993). Selection of particular habitat unit types was determined by the proportional use and availability (given by the area of habitat sampled) of each habitat type. Resource selection ratios (w) were calculated for each habitat type by dividing the proportion of fish using the habitat type by the proportion of habitat sampled (Manly et al. 2002). The selection ratio statistic allowed for the determination of habitat selection. Selection ratios equal or close to one ($w=1$ or $w\approx1$) indicate no selection. Values much smaller than one ($w<1$) suggest selection against a particular habitat type and ratios greater than one ($w>1$) indicate selection. Selection becomes increasingly stronger as the statistic increases further from one. The Z-squared statistic was used to test the hypothesis that a particular selection ratio equals one. Statistical significance ($p<0.05$) of this test is based on p-values calculated using the chi-squared distribution minus one degree of freedom. All habitat selection analyses were conducted using the Stats-Alive RSTool program developed by Ken Gerow (2007) of the University of Wyoming.

In addition to analyses of habitat availability, use, and selection, basic fish information for the complex reaches sampled including fish captured, capture per unit of effort (CPUE), and endangered fish size information were summarized. Colorado pikeminnow population estimates by reach were also calculated using the Lincoln-Petersen estimator as described in Young and Young (1998). Estimates were calculated for August 2007 - DR 137, March 2008 - DR131, August 2008 - DR 131 and 137, and March 2009 – DR 137. Given the low number of Colorado pikeminnow captured it was not possible to calculate a population estimate for August 2009.

RESULTS

Fish Captures and Habitat Utilization

Fish sampling efforts over the course of the study resulted in the capture of 243 young Colorado pikeminnow from a variety of habitats (Table 2.01) but no razorback sucker. In general, more Colorado pikeminnow were captured during March than in August. Across all reaches, 89 Colorado pikeminnow were captured in March 2008 and 58 were captured in March 2009. During August sampling, 24, 56, and 16 Colorado pikeminnow were captured across all reaches in 2007, 2008, and 2009, respectively. Sampling conditions were generally similar between same month samples in that the river was turbid (normal for the San Juan River) but flow varied between sampling years and days. During August 2009 the river was uncharacteristically clear during the first part of the sampling trip, turning turbid the last few days. Five of the Colorado pikeminnow captured in the first part of the August 2009 trip were excluded from the assessment of habitat selection because it was clear that block seining was not effective during clear water conditions for this species and determination of selection requires a methodology that has a reasonable chance of capturing the target species.

Colorado pikeminnow captured ranged in size from 35 mm to 269 mm TL (Figure 2.01). Most of the Colorado pikeminnow captured in March were small (TL <100 mm) whereas the young Colorado pikeminnow captured in August typically ranged between 100 mm to 200 mm TL. Given that only 11 of the Colorado pikeminnow captured had TL > 200 mm, all fish with TL> 100 mm were pooled for the purposes of habitat selection analyses by fish size.

Colorado pikeminnow were captured in all habitats sampled except plunge and isolated pool habitats. Overall, Colorado pikeminnow collected during March were typically captured in pool (30%), backwater (20%), and run (20%) habitat; Colorado pikeminnow captured in August were primarily from slackwater (39%), riffle (22%) and cobble shoal (19%) habitat (Figure 2.02).

In total, 6,668 fish (natives and non-natives) were collected from various habitats during the study. Most of the fish were captured in slackwater, shoal habitat types, backwaters, and pools (Table 2.02). In addition to Colorado pikeminnow, other native fishes captured included bluehead sucker, flannelmouth sucker, and speckled dace; no razorback suckers were captured. Non-natives included channel catfish, red shiner, and fathead minnow. Over the course of the study, the most common native and non-native fish species collected along all reaches were speckled dace and channel catfish, respectively (Table 2.03). Differences were observed between the proportion of native and non-native fish captured by habitat type (Figure 2.03). For example a higher proportion of native fish captures was observed in slackwater and riffle habitats. On the other hand, a higher proportion of non-native fish captured was associated with pool and backwater habitats.

Table 2.01. Summary of habitat use by Colorado pikeminnow along DR 82, DR 131, and DR137 (total Colorado pikeminnow captured): 2007-2009

DATE	August_07			March_08				August_08				March_09				August_09				Grand Total
REACH	82	137	82 & 137 Combined	82	131	137	82-131-137 Combined	82	131	137	82-131-137 Combined	82	131	137	82-131-137 Combined	82	131	137	82-131-137 Combined	
BACKWATER				3		8	11			2	2			19	19					32
COBBLE SHOAL	2	6	8					1	3	5	9							1	1	18
EDDY		3	3																	3
EMBAYMENT						12	12													12
POOL					12	9	21	1		2	3	21	2		23					47
RIFFLE				1	1		2	1	13	7	21									23
SAND SHOAL		3	3	3	3		6	1	1	2	4	6			6					19
RUN	1	1	2	8	5	14	27	1	2		3	2	1		3					35
SLACKWATER	2	6	8	4	1	5	10	2	5	7	14	2	2	3	7	8	1	6	15	54
Grand Total	5	19	**24**	19	22	48	**89**	7	24	25	**56**	31	5	22	**58**	8	1	7	**16***	**243**

* Five of these 16 larger Colorado pikeminnow (1 in cobble shoal and 4 in slackwater), were captured during the first half (Pass 1) of August 2009 sample collection under atypical sampling conditions (i.e., low water turbidity) and were not accounted for in the assessment of habitat selection.

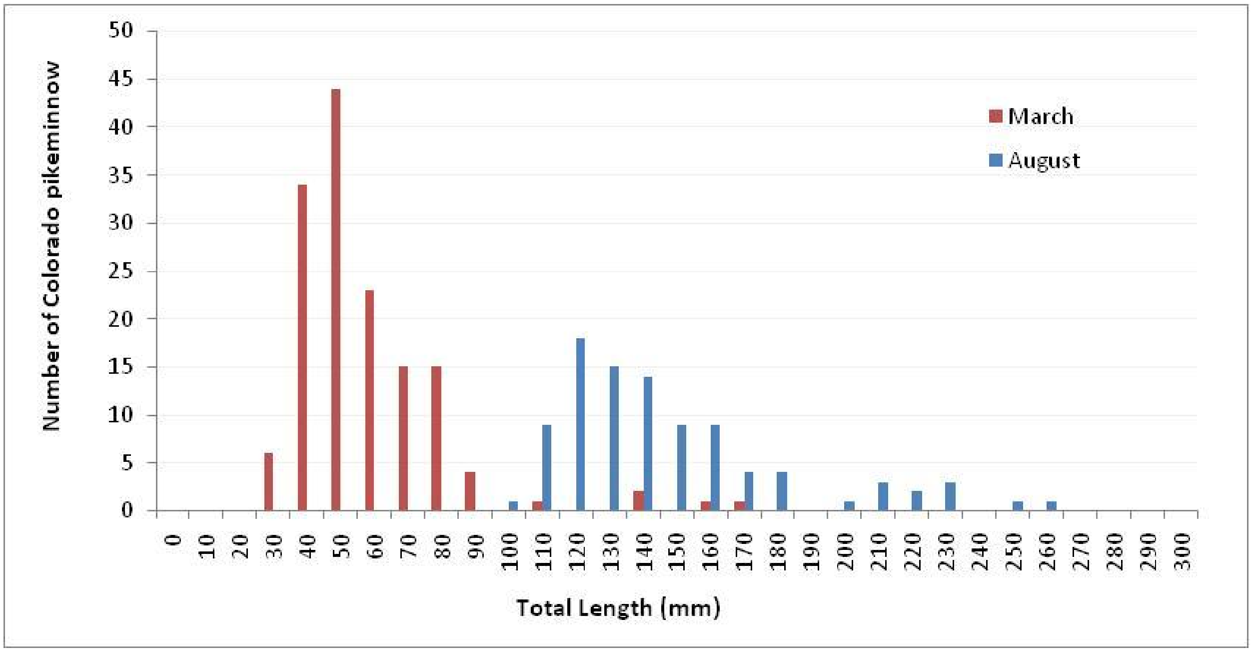


Figure 2.01. Length frequency distribution for Colorado pikeminnow captured in DR82, DR131, and DR137 during the detailed reach study (2007-2009).

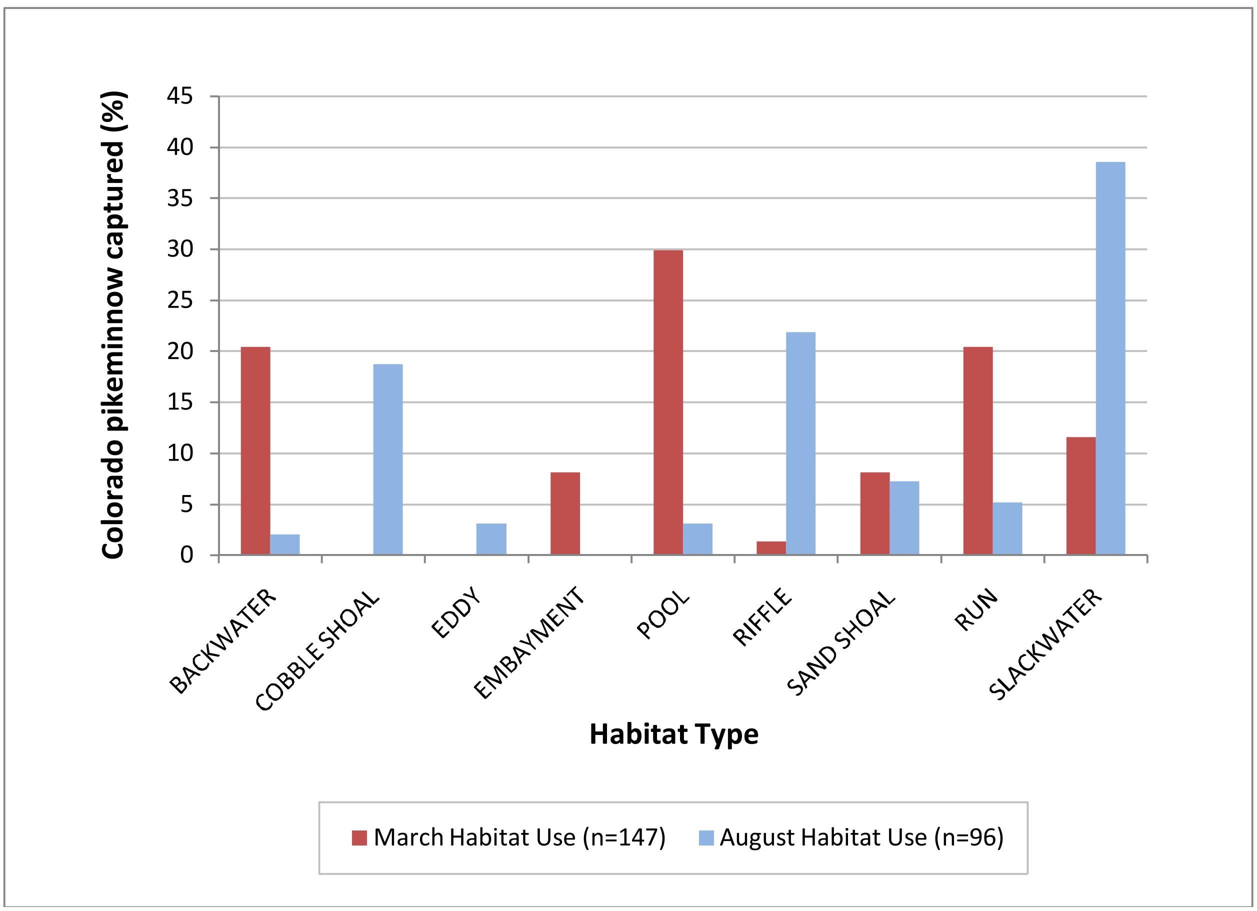


Figure 2.02. Habitat use by Colorado pikeminnow. Proportion of Colorado pikeminnow captured by habitat type (All reaches and years combined).

Table 2.02. Summary of overall fish habitat use along DR82, DR131, DR137 (Total fish captured):2007-2009

DATE	August_07			March_08				August_08				March_09				August_09				
REACH	82	137	82 & 137 Combined	82	131	137	82-131-137 Combined	82	131	137	82-131-137 Combined	82	131	137	82-131-137 Combined	82	131	137	82-131-137 Combined	Grand Total
BACKWATER	83		83	5	0	11	16	37	53	59	149			44	44	55	85	423	563	855
COBBLE SHOAL	48	12	60	0	7	26	33	65	9	16	90	12	1	1	14	127	29	42	198	395
EDDY	2	24	26			0	0	8		2	10	0			0	31		227	258	294
EMBAYMENT						19	19		6	1	7						78		78	104
ISOLATED POOL	26		26			99	99	12		2	14	0		0	0	0			0	139
PLUNGE	9	2	11							2	2									13
POOL	151		151		15	16	31	149		46	195	111	28	18	157	54	111	23	188	722
RIFFLE	18	6	24	7	9	7	23	27	40	36	103	26	19	3	48	36	99	51	186	384
SAND SHOAL	128	13	141	9	240	14	263	49	13	7	69	37	5	2	44	58	173	30	261	778
RUN	57	15	72	24	9	39	72	240	13	18	271	22	13	1	36	71	69	61	201	652
SLACKWATER	378	130	508	33	622	32	687	336	20	38	394	13	11	16	40	69	429	205	703	2332
Total	900	202	**1,102**	78	902	263	**1,243**	923	154	227	**1,304**	221	77	85	**383**	501	1,073	1,062	**2,636**	**6,668**

Table 2.03. Total fish captured by habitat type. All reaches combined (2007-2009)

HABITAT	Colorado pikeminnow	Bluehead sucker	Flannelmouth sucker	Speckled dace	Channel catfish	Red Shiner	Fathead minnow	All Natives	All Non-Natives	All fish	% USE
BACKWATER	32	42	35	271	24	239	92	380	355	855	13
COBBLE SHOAL	18	18	41	143	123	30	5	220	158	395	6
EDDY	3	27	11	221	28	3	0	262	31	294	4
EMBAYMENT	12	9	31	12	0	20	6	64	26	104	2
ISOLATED POOL	0	0	7	3	4	4	114	10	122	139	2
PLUNGE	0	0	1	6	6	0	0	7	6	13	0
POOL	47	5	32	250	153	181	35	334	369	722	11
RIFFLE	23	6	23	299	21	11	1	351	33	384	6
SAND SHOAL	19	22	51	484	152	42	1	576	195	778	12
RUN	35	28	48	305	209	19	7	416	235	652	10
SLACKWATER	54	207	277	1,156	520	87	15	1,694	622	2,332	35
Total	**243**	**364**	**557**	**3,150**	**1,240**	**636**	**276**	**4,314**	**2,152**	**6,668**	**100**

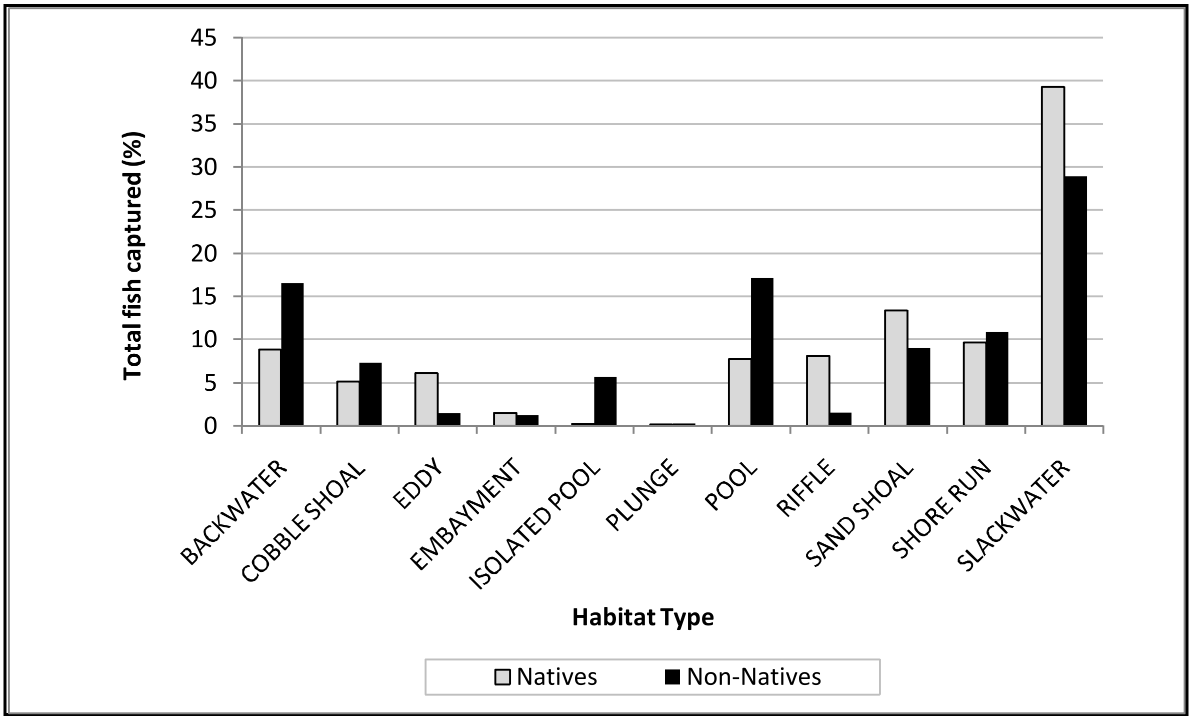


Figure 2.03. Habitat use by the complete fish assemblage. Proportion of fish captured by habitat type (All reaches and years combined).

Capture per Unit of Effort

Across all reaches, a total of 1,102, 1,304, and 2,636 fishes were captured in August of 2007, 2008, and 2009, respectively. Interestingly, the largest number of fish captured occurred in August 2009 but this was the month with lowest number of Colorado pikeminnow captured (Table 2.04). During March samples, the total number of fish captured was substantially larger in 2008 than in 2009 primarily due to the lower number of native bluehead sucker and speckled dace captured during 2009 (Table 2.04).

Of the total 1,215 habitat units sampled across all reaches and samples, habitat types sampled more frequently included slackwater, shore-run, riffle, sand shoal, and cobble shoal (Table 2.05). The frequency in which these habitat types were sampled reflects their dominance of the overall habitat observed across all reaches. Rare habitats sampled less frequently included backwater, eddy, embayment, and pool. Sampling effort, in terms of number of seine hauls, was kept relatively constant across samples. The average number of seine hauls per sampling event was 243 and the range over the course of the study was 194 in August 2007 to 267 in August 2008. The lower number of seine hauls in August 2007 was due to DR131 not being sampled that year.

Table 2.04. Number of fish captured by species during March and August 2009.

YEAR	MONTH	REACH	Colorado pikeminnow	Bluehead sucker	Speckled dace	Flannelmouth sucker	Fathead minnow	Red Shiner	Channel catfish	All Natives	All Non-Natives	All fish
2007	August	82	5	8	79	93	126	111	474	185	711	900
		131	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		137	19	8	80	22	3	15	53	129	71	202
		Combined	***24***	***16***	***159***	***115***	***129***	***126***	***527***	***314***	***782***	***1,102***
2008	March	82	19	7	21	9	8	10	3	56	21	78
		131	22	126	749	1	4	0	0	898	4	902
		137	48	8	83	5	108	11	0	144	119	263
		Combined	***89***	***141***	***853***	***15***	***120***	***21***	***3***	***1,098***	***144***	***1,243***
	August	82	7	5	330	63	0	18	496	405	514	923
		131	24		88	8	1	7	25	120	33	154
		137	25	11	105	35	3	33	5	176	41	227
		Combined	***56***	***16***	***523***	***106***	***4***	***58***	***526***	***701***	***588***	***1,304***
2009	March	82	31	0	89	9	2	82	7	129	91	221
		131	5	1	54	3	3	10	0	63	13	77
		137	22	0	32	4	4	20	0	58	24	85
		Combined	***58***	***1***	***175***	***16***	***9***	***112***	***7***	***250***	***128***	***383***
	August	82	8	1	190	20	3	91	129	219	223	501
		131	1	101	663	239	0	34	14	1,004	48	1,073
		137	7	88	587	46	11	194	34	728	239	1,062
		Combined	***16***	***190***	***1,440***	***305***	***14***	***319***	***177***	***1,951***	***510***	***2,636***
Total			**243**	**364**	**3,150**	**557**	**276**	**636**	**1,240**	**4,314**	**2,152**	**6,668**

Table 2.05. Sample frequency (number of seine hauls by habitat) during surveys along DR82, DR131, and DR137 in the San Juan River (2007-2009).

YEAR	MONTH	REACH	BACKWATER	COBBLE SHOAL	EDDY	EMBAYMENT	ISOLATED POOL	PLUNGE	POOL	RIFFLE	SAND SHOAL	RUN	SLACKWATER	TOTAL NUMBER OF SEINE HAULS
2007	August	82	3	12	1		1	1	9	5	10	15	49	106
		137	_	9	6	_	_	2	_	8	7	13	43	88
		Combined	***3***	***21***	***7***		***1***	***3***	***9***	***13***	***17***	***28***	***92***	***194***
2008	March	82	5	1						9	9	27	32	83
		131	1	3					4	5	16	18	16	63
		137	1	10	1	2	2	_	4	11	11	24	26	92
		Combined	***7***	***14***	***1***	***2***	***2***		***8***	***25***	***36***	***69***	***74***	***238***
	August	82	4	12	2		5		7	14	15	16	21	96
		131	3	11	1	3				19	4	16	27	84
		137	5	11	1	1	2	1	6	16	3	14	27	87
		Combined	***12***	***34***	***4***	***4***	***7***	***1***	***13***	***49***	***22***	***46***	***75***	***267***
2009	March	82		10	3		1		10	15	18	13	23	93
		131		9					1	14	7	28	23	82
		137	5	10	_	_	1	_	3	18	8	18	24	87
		Combined	***5***	***29***	***3***		***2***		***14***	***47***	***33***	***59***	***70***	***262***
	August	82	4	10	3		1		6	7	10	18	24	83
		131	2	7		2			5	6	12	22	31	87
		137	6	11	7	_	_	_	1	13	3	16	27	84
		Combined	***12***	***28***	***10***	***2***	***1***		***12***	***26***	***25***	***56***	***82***	***254***
Total			**39**	**126**	**25**	**8**	**13**	**4**	**56**	**160**	**133**	**258**	**393**	**1,215**

In terms of area sampled, differences in effort between March and August sampling largely reflect the size of seine used during each sampling event. As noted above, larger seines were typically used during low-flow conditions in August but smaller seines were used for high-flow conditions in March. As a result, the areas sampled in March were between 35 and 56 percent smaller than the areas sampled in August (Table 2.05).

Overall, when comparing Colorado pikeminnow CPUE across seasons and years, it is evident that CPUE was lower in August than in March (Table 2.06, Figure 2.04). Comparing pikeminnow CPUE across reaches suggests a pattern of increasing CPUE from lower (DR82) to upper (DR131 and DR 137) reaches during August 2007, March 2008, and August 2008. However, this pattern appeared to be reversed in March and August 2009 with higher Colorado pikeminnow CPUE in the lower-most reach (DR82) than in the upper reaches (DR131 and DR 137; Figure 2.04). This apparent reversal in longitudinal distribution did not appear to be related to the number and location of Colorado pikeminnow stockings across years.

A consistent seasonal or annual pattern of increasing or decreasing CPUE for the entire fish assemblage, native fish and non-native fish assemblages was not observed (Figure 2.05). The combined CPUE (all reaches combined) for the entire fish assemblage decreased from March 2008 to March 2009 but it increased through the three consecutive August months. (Table 2.06, Figure 2.05). These differences are consistent with those observed seasonally and annually for the native fish assemblage CPUE. CPUE for the non-native fish assemblage was fairly consistent across seasons and years.

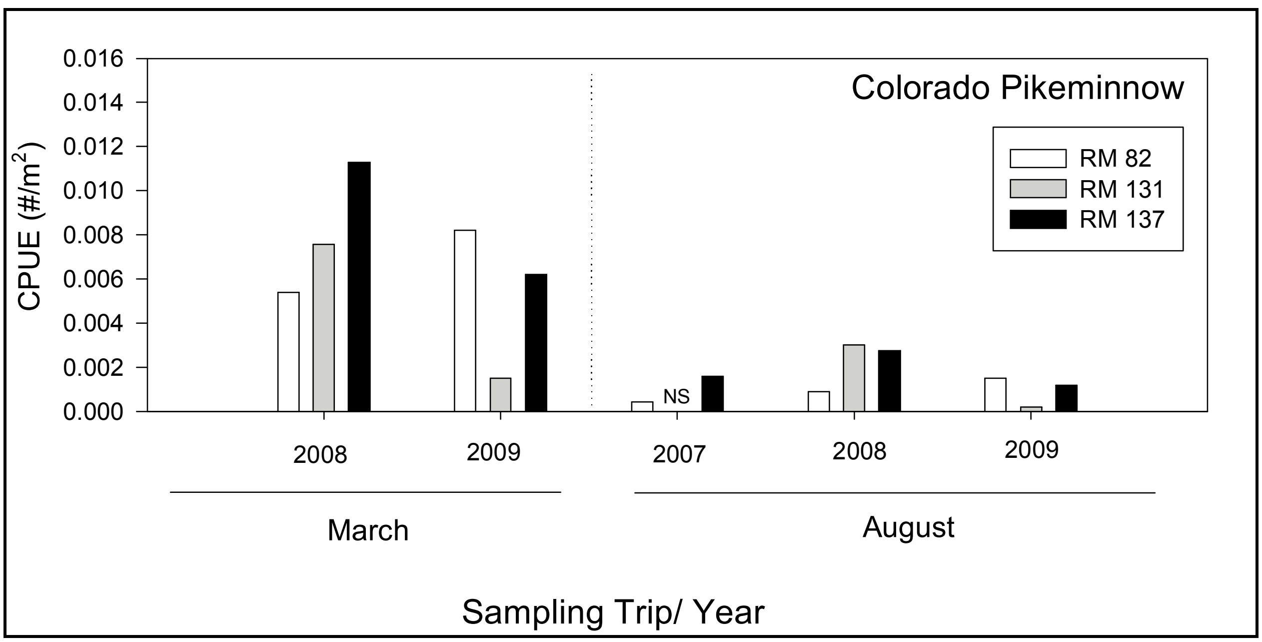


Figure 2.04. Colorado pikeminnow CPUE during surveys conducted in DR 82, DR131, and DR 137 during March and August of 2007, 2008, and 2009. NS indicates reach not sampled.

Table 2.06. CPUE Summary (number of fish/area sampled m²): 2007-2009

YEAR	MONTH	REACH	Sample Frequency (Number of seine hauls)	Area sampled (m^2)	CPUE (# fish/m^2)									
					All fish	All Natives	All Non-Natives	Colorado pikeminnow	Bluehead sucker	Speckled dace	Flannelmouth sucker	Fathead minnow	Red Shiner	Channel catfish
2007	August	82	106	11,624	0.0774	0.0159	0.0612	**0.0004**	0.0007	0.0068	0.0080	0.0108	0.0095	0.0408
		131	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		137	88	11,809	0.0171	0.0109	0.0060	**0.0016**	0.0007	0.0068	0.0019	0.0003	0.0013	0.0045
		Combined	***194***	***23,433***	***0.0470***	***0.0134***	***0.0334***	***0.0010***	***0.0007***	***0.0068***	***0.0049***	***0.0055***	***0.0054***	***0.0225***
2008	March	82	83	3,514	0.0222	0.0159	0.0060	**0.0054**	0.0020	0.0060	0.0026	0.0023	0.0028	0.0009
		131	63	2,904	0.3107	0.3093	0.0014	**0.0076**	0.0434	0.2580	0.0003	0.0014	0.0000	0.0000
		137	92	4,252	0.0619	0.0339	0.0280	**0.0113**	0.0019	0.0195	0.0012	0.0254	0.0026	0.0000
		Combined	***238***	***10,670***	***0.1165***	***0.1029***	***0.0135***	***0.0083***	***0.0132***	***0.0799***	***0.0014***	***0.0112***	***0.0020***	***0.0003***
	August	82	96	7,798	0.1184	0.0519	0.0659	**0.0009**	0.0006	0.0423	0.0081	0.0000	0.0023	0.0636
		131	84	7,970	0.0193	0.0151	0.0041	**0.0030**	0.0000	0.0110	0.0010	0.0001	0.0009	0.0031
		137	87	9,041	0.0251	0.0195	0.0045	**0.0028**	0.0012	0.0116	0.0039	0.0003	0.0037	0.0006
		Combined	***267***	***24,808***	***0.0526***	***0.0283***	***0.0237***	***0.0023***	***0.0006***	***0.0211***	***0.0043***	***0.0002***	***0.0023***	***0.0212***
2009	March	82	93	3,767	0.0587	0.0342	0.0242	**0.0082**	0.0000	0.0236	0.0024	0.0005	0.0218	0.0019
		131	82	3,368	0.0229	0.0187	0.0039	**0.0015**	0.0003	0.0160	0.0009	0.0009	0.0030	0.0000
		137	87	3,534	0.0241	0.0164	0.0068	**0.0062**	0.0000	0.0091	0.0011	0.0011	0.0057	0.0000
		Combined	***262***	***10,668***	***0.0359***	***0.0234***	***0.0120***	***0.0054***	***0.0001***	***0.0164***	***0.0015***	***0.0008***	***0.0105***	***0.0007***
	August	82	83	5,464	0.0917	0.0401	0.0408	**0.0015**	0.0002	0.0348	0.0037	0.0005	0.0167	0.0236
		131	87	5,341	0.2009	0.1880	0.0090	**0.0002**	0.0189	0.1241	0.0447	0.0000	0.0064	0.0026
		137	84	5,834	0.1820	0.1248	0.0410	**0.0012**	0.0151	0.1006	0.0079	0.0019	0.0333	0.0058
		Combined	***254***	***16,638***	***0.1584***	***0.1173***	***0.0307***	***0.0010***	***0.0114***	***0.0865***	***0.0183***	***0.0008***	***0.0192***	***0.0106***
Total			**1215**	**86,217**	**0.0773**	**0.0500**	**0.0250**	**0.0028**	**0.0042**	**0.0365**	**0.0065**	**0.0032**	**0.0074**	**0.0144**

Among the native fishes captured, speckled dace was the dominant species (Table 2.06, Figure 2.06). In general, as observed for the native fish assemblage, flannelmouth sucker, bluehead sucker, and speckled dace CPUE was higher in March 2008 than in March 2009 but increased in August from 2007 to 2009 (Figure 2.06). In general, channel catfish dominated the overall non-native fish assemblage CPUE in August; CPUE for red shiner and fathead minnow dominated during March (Figure 2.07).

Colorado Pikeminnow Population Estimate

Sufficient Colorado pikeminnow were recaptured in five of the 14 paired reach samples to make mark-recapture population estimates. Four of the population estimates were very similar, ranging from 52 to 59 fish/reach (Table 2.07). The March 2009 population estimate was lower than the others (34 fish/reach). Wide confidence limits in all cases suggest none of the differences were significant (Table 2.07). These data suggest that we were capturing 30-40% of the Colorado pikeminnow found in these complex reaches.

Habitat Selection Analysis

Although young Colorado pikeminnow were captured in a wide range of habitat types, their use of habitats was non-random based on analyses of habitat selection for each year, month (March, August), and reach (Table 2.08).

Colorado pikeminnow captures along all reaches in March 2008 suggested selection (in decreasing order) for embayment, pool, and backwater habitats. Selection against particular habitats was evident for cobble shoal, riffle, slackwater, and shoal habitats (Table 2.09). Similarly, Colorado pikeminnow selection for backwater and pool habitats and selection against cobble shoal, riffle, and slackwater habitats was evident in March 2009. Selection for or against sand shoal was not evident in March 2009, but there was evidence of selection against run habitat during this month. The pattern of habitat selection based on the pooled data from March of 2008 and 2009 was consistent with the results based on March 2008 data (Table 2.09).

Habitat selection by Colorado pikeminnow in August was more variable than in March (Table 2.10). The August 2007 assessment suggested selection for eddy and cobble shoal. In August 2008 selection for riffle and against run was indicated. In August 2009 there was evidence of selection for slackwater and against run habitat. The assessment based on pooled data from all August sampling suggested selection for riffle and against run habitat.

Based on all captures from 2007 to 2009, Colorado pikeminnow in both size classes appeared to select specific habitat types. The smaller pikeminnow selected for pools, embayments, and backwaters and selected against cobble shoal, riffle and slackwater habitats. In contrast, larger fish appeared to select for riffles and against run habitat (Table 2.11).

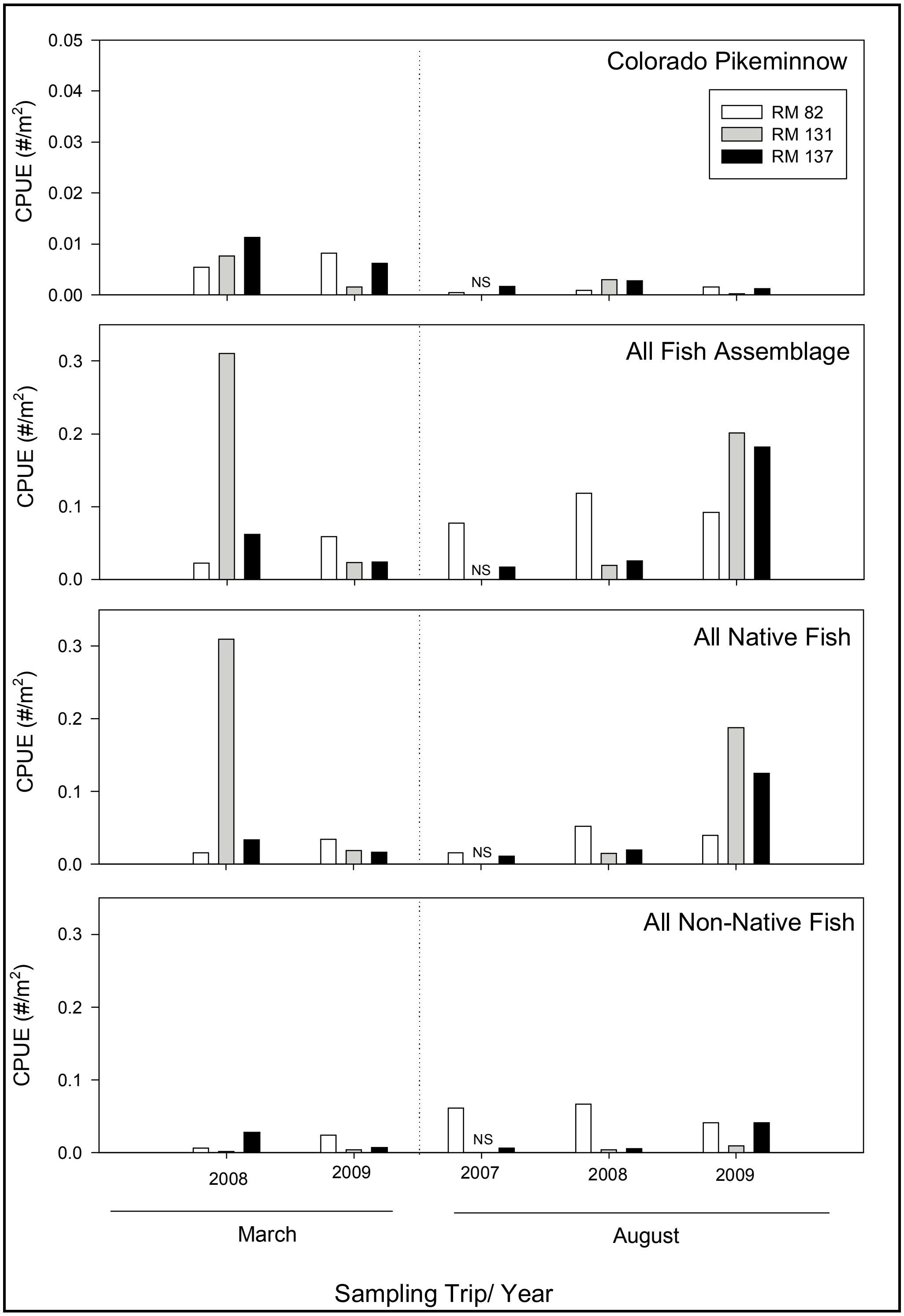


Figure 2.05. CPUE for Colorado pikeminnow, all fishes , all native fishes, and all nonnative fishes during surveys conducted along DR 82, DR131, and DR 137 during March and August of 2007, 2008, and 2009. NS indicates reach not sampled.

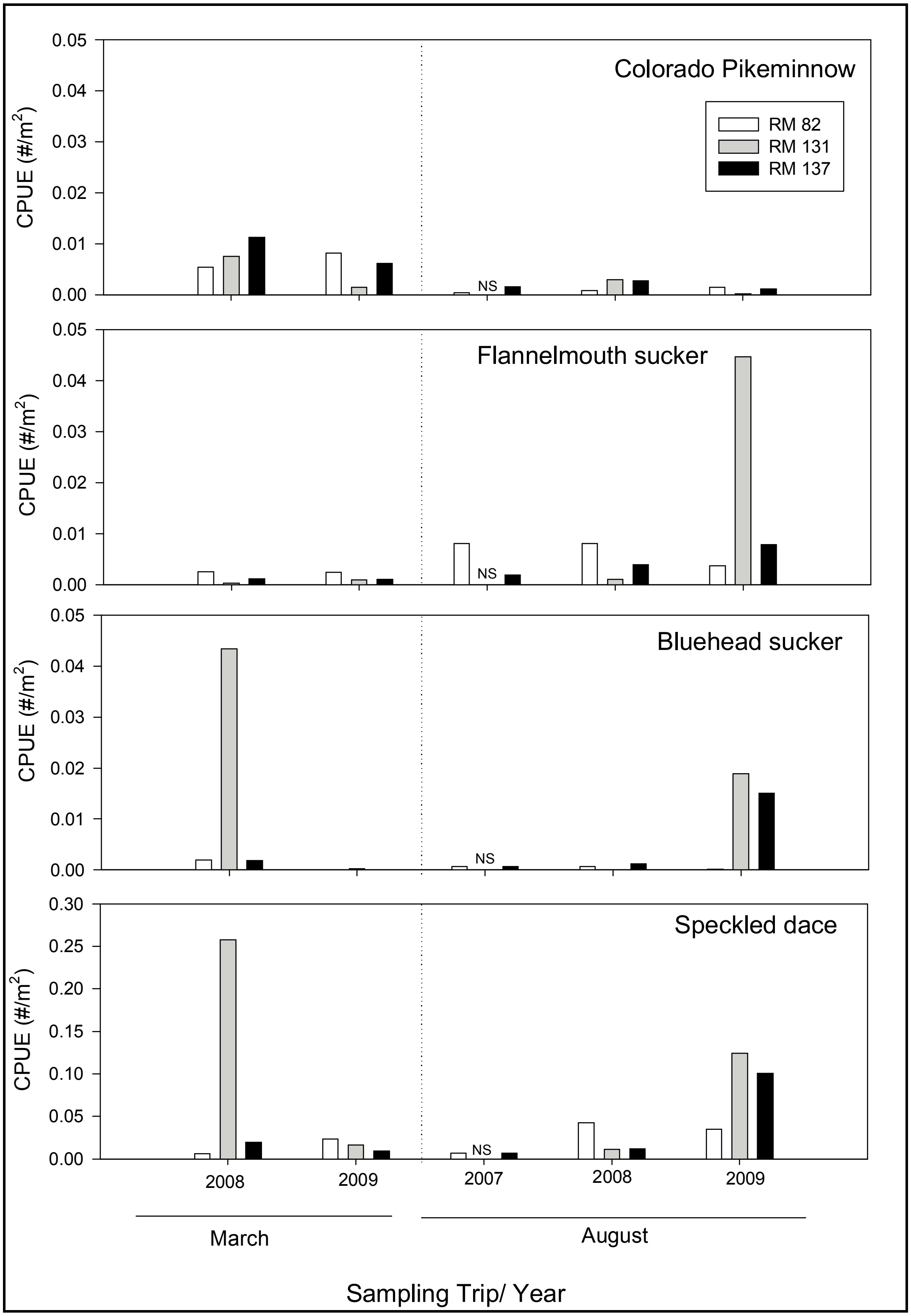


Figure 2.06. CPUE for Colorado pikeminnow, flannelmouth sucker, bluehead sucker, and speckled dace during surveys conducted in DR 82, DR131, and DR 137 during March and August of 2007, 2008, and 2009. NS indicates reach not sampled.

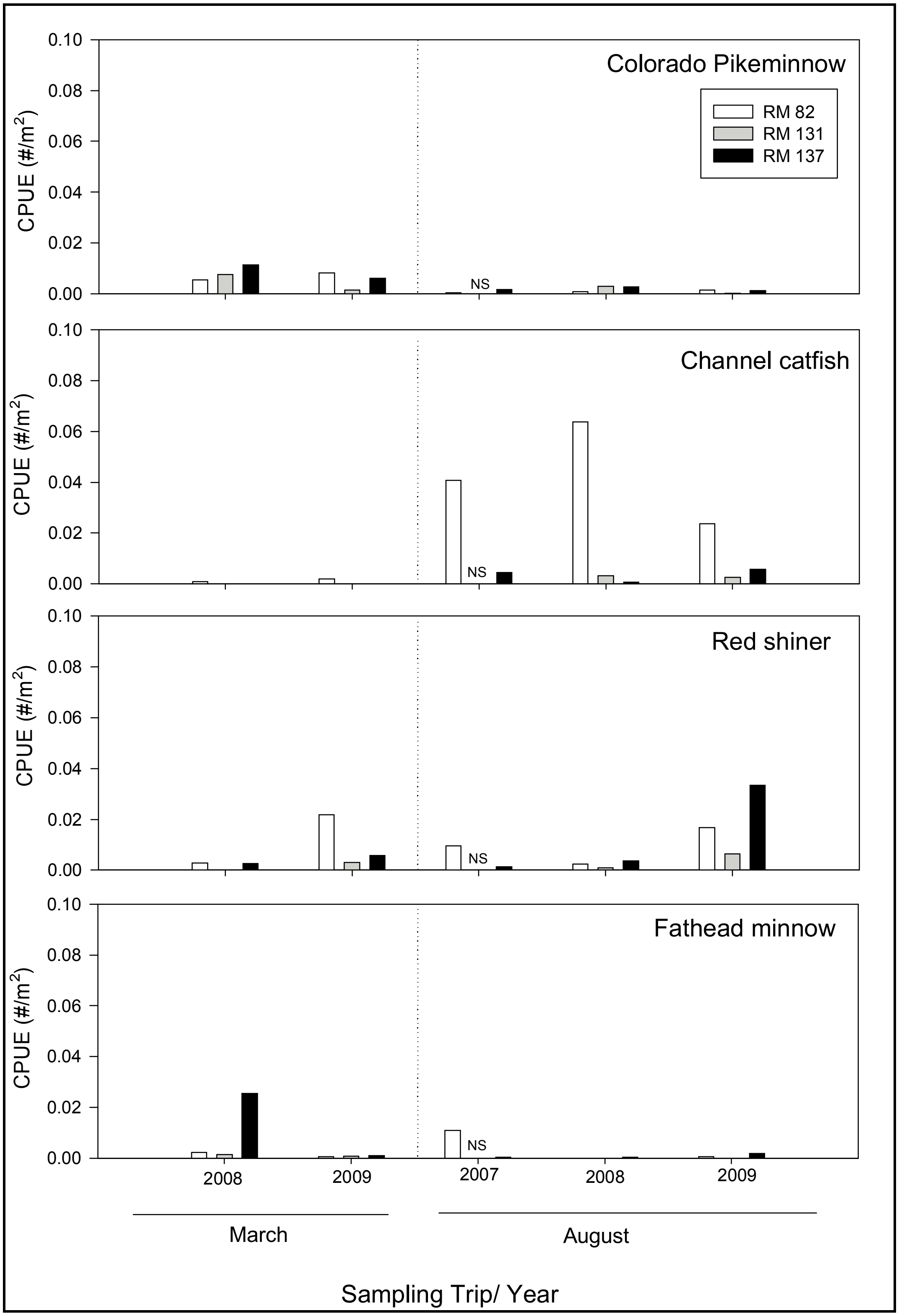


Figure 2.07. CPUE for Colorado pikeminnow, channel catfish, red shiner, and fathead minnow during surveys conducted in DR 82, DR131, and DR 137 during March and August of 2007, 2008, and 2009. NS indicates reach not sampled.

Table 2.07. Summary of population estimates for Colorado pikeminnow based on mark-recapture data collected during detailed reach fish surveys along DR82, DR131, and DR137 of the San Juan River: 2007-2009.

DETAILED REACH	DR82	DR131	DR137
		AUGUST_2007	
Marked Pass 1 (M)	2	NS	11
Recaptured Pass 2 (R)	0		1
Total Captured Pass 2 (C)	3		8
Population Estimate (N)	NA		**53**
Variance			630
Standard Deviation			25
95 % CI			4-102
		MARCH_2008	
Marked Pass 1 (M)	8	17	43
Recaptured Pass 2 (R)	1	1	0
Total Captured Pass 2 (C)	11	5	5
Population Estimate (N)	NA	**53**	NA
Variance		576	
Standard Deviation		24	
95 % CI		6-100	
		AUGUST_2008	
Marked Pass 1 (M)	3	9	14
Recaptured Pass 2 (R)	0	2	2
Total Captured Pass 2 (C)	4	15	11
Population Estimate (N)	NA	**52**	**59**
Variance		404	540
Standard Deviation		20	23
95 % CI		13-92	13-105
		March_2009	
Marked Pass 1 (M)	13	0	9
Recaptured Pass 2 (R)	1	0	3
Total Captured Pass 2 (C)	18	5	13
Population Estimate (N)	NA	NA	**34**
Variance			105
Standard Deviation			10
95 % CI			14-54

Population estimates for reaches where recaptures accounted for at least 10 percent of the total catch in the second sample were calculated using the Lincoln-Petersen method.
NA: Not enough fish were marked and/or recaptured to estimate population size. NS: Not sampled

Table 2.08. Summary of Colorado pikeminnow habitat selection by year, month, and reach (2007-2009)*.

Year	Month	Reach	n	Pearson Chi^2	p-value	Log-likelihood Chi^2	p- value
2007	August	82	5	NA	NA	NA	NA
		137	19	15.2	0.02	14.57	0.02
		Combined	***24***	***19.09***	***0.02***	***16.59***	***0.055***
2008	March	82	19	6.45	0.26	5.76	0.33
		131	22	106.13	0	44.64	0
		137	48	172.18	0	103.18	0
		Combined	***89***	***296.7***	***0***	***141.72***	***0***
	August	82	7	NA	NA	NA	NA
		131	24	16.14	0.02	15.21	0.03
		137	25	13.27	0.21	16.97	0.07
		Combined	***56***	***23***	***0.01***	***24.8***	***0***
2009	March	82	31	154.92	0	81.99	0
		131	5	NA	NA	NA	NA
		137	22	298.56	0	103.51	0
		Combined	***58***	***544.87***	***0***	***196.56***	***0***
	August	82	8	NA	NA	NA	NA
		131	1	NA	NA	NA	NA
		137	7	NA	NA	NA	NA
		Combined	***16***	***28.42***	***0.0008***	***30.71***	***0.0003***

* Significant ($p<0.05$) Chi^2 values suggest selection for particular habitat types occur. Non-significant values indicate no selection.

NA: Selection analysis not conducted due to small sample size (n).

Table 2.09. Summary of habitat selection ratios for Colorado pikeminnow captured in March 2008-2009 *.

Month/Year Reach HABITAT	March_08 82-131- 137 RATIO (n=89)	March_09 82-131- 137 RATIO (n=58)	March_08 & 09 82-131- 137 RATIO (n=147)
BACKWATER	3.99	19.22	8.5
COBBLE SHOAL	0	0	0
EDDY			
EMBAYMENT	11.7	NS	14.16
ISOLATED POOL			
POOL	7.97	9.9	8.6
RIFFLE	0.18	0	0.09
SAND SHOAL	0.43		0.58
RUN		0.22	
SLACKWATER	0.4	0.5	0.4

*Only significant selection ratios (p<0.05) are shown.
Ratio values greater than one indicate selection for, ratios below one indicate selection against, and ratios equal to one indicate no selection.
NS= Habitat not sampled

Table 2.10. Summary of habitat selection ratios for Colorado pikeminnow captured in August 2007, 2008, and 2009 *.

Month/Year Reach HABITAT	August_07 82 & 137 RATIO (n=24)	August_08 82-131- 137 RATIO (n=56)	August_09 82-131- 137 RATIO (n=11)	August_07-08-09 82-131- 137 RATIO (n=91)
BACKWATER				
COBBLE SHOAL	2.4			
EDDY	4.3			
EMBAYMENT	NS			
ISOLATED POOL				
PLUNGE POOL			NS	
RIFFLE		2.1		1.88
SAND SHOAL				
RUN		0.3	0**	0.28
SLACKWATER			2.76	

*Only significant selection ratios (p<0.05) are shown.
Ratio values greater than one indicate selection for, ratios below one indicate selection against, and ratios equal to one indicate no selection.
** Ratio is marginally significant (p=0.06).
NS= Habitat not sampled

Table 2.11. Summary of habitat selection ratios for Colorado pikeminnow by size. Based on all captures: 2007-2009.

COLORADO PIKEMINNOW HABITAT	TL <100 mm Ratio (n=142)	TL> 100 mm Ratio (n=93)
BACKWATER	10.72	
COBBLE SHOAL	0.05	
EDDY		
EMBAYMENT	11.21	
ISOLATED POOL		
PLUNGE		
POOL	12.21	
RIFFLE	0.11	1.7
SAND SHOAL		
RUN		0.34
SLACKWATER	0.3	
Pearson Chi^2 *	877 (p=0.00)	21.64 (p=0.017)
Log-likelihood Chi^2 *	353 (p=0.00)	24.74 (p=0.006)

* Significant (p<0.05) Chi^2 values suggest selection for particular habitat types occur.
Only significant selection ratios (p<0.05) are shown.
Ratio values greater than one indicate selection for, ratios below one indicate selection against, and ratios equal to one indicate no selection.

The entire fish assemblage, all native fishes, all non-native fishes, and most single native and non-native fish species also showed some degree of habitat selection. Based on the combined 2008 and 2009 March data from all reaches, the selection for embayment by Colorado pikeminnow was shared with flannelmouth sucker and fathead minnow (Table 2.12), and selection for pool habitat was shared by red shiner and channel catfish. Colorado pikeminnow selection for backwater habitat also overlapped with red shiner. Although Colorado pikeminnow captures during both August surveys suggested selection for riffles, no other fish species selected for this habitat type and most native and non-native species appeared to select against it (Table 2.13). Summaries of habitat selection ratios for all species based on 2009 data are included in the Appendix (Tables A1 and A2).

Habitat Availability

Over the course of the study, more than 1.8 million m^2 were mapped within the complex study reaches (Table 2.14). Of the total area mapped, the dominant habitat types observed across all reaches and samples were run and riffle. Less common habitats included slackwater, sand shoal, and cobble shoal. Low water velocity habitats such as backwater, eddy, and pool accounted for only a small fraction of the total mapped area.

The proportion sampled of the total area mapped along all reaches during August 2007, March 2008, August 2008, March 2009, and August 2009 was 14%, 2%, 5%, 4% and 7% respectively (Table 2.15). Roughly, 30 to 40 percent of mapped backwater, eddy, pool, slackwater, embayment, and isolated pool habitat were sampled.

Table 2.12. Summary of habitat selection ratios: March 2008 and 2009 Combined - DR82, DR131, and DR137*.

SPECIES/ FISH GROUP	Colorado pikeminnow	All fish	All Natives	All Non-Natives	Bluehead sucker	Flannelmouth sucker	Speckled dace	Red Shiner	Fathead minnow	Channel catfish
HABITAT	**RATIO (n=147)**	**RATIO (n=1626)**	**RATIO (n=1348)**	**RATIO (n=272)**	**RATIO (n=142)**	**RATIO (n=31)**	**RATIO (n=1028)**	**RATIO (n=133)**	**RATIO (n=129)**	**RATIO (n=10)**
BACKWATER	8.40	1.54		3.98			0.04	6.88		
COBBLE SHOAL	0.00	0.29	0.32	0.15	0.07		0.40	0.00	0.31	
EDDY		0.00	0.00				0.00			
EMBAYMENT	14.16	2.03	1.80	3.19		11.19	0.00		6.72	
ISOLATED POOL		6.45	0.00	38.58			0.00		81.35	
POOL	8.60	3.33	1.96	9.94				17.96		14.39
RIFFLE	0.09	0.29	0.34	0.07	0.05		0.41	0.15	0.00	
SAND SHOAL	0.58	1.35	1.57	0.29	0.15		1.93	0.54	0.00	
RUN		0.25	0.26	0.22	0.24		0.17	0.20	0.20	
SLACKWATER	0.43	1.67	1.98	0.19	3.35	1.69	2.02	0.22	0.12	
Pearson Chi^2	694 (p=0.00)	1460.77 (p=0.00)	819 (p=0.00)	4611.8 (p=0.00)	286 (p=0.00)	27.46 (p=0.00)	732.7 (p=0.00)	1518 (p=0.00)	7974 (p=0.00)	65.6 (p=0.00)
Log-likelihood Chi^2	314 (p=0.00)	1241.4 (p=0.00)	879 (p=0.00)	1085.8 (p=0.00)	255 (p=0.00)	15.97 (0.06)	805.1 (p=0.00)	494 (p=0.00)	846.7 (p=0.00)	23.7 (p=0.00)

* Significant ($p<0.05$) Chi^2 values suggest selection for particular habitat types occur.

Only significant selection ratios ($p<0.05$) are shown.

Ratio values greater than one indicate selection for, ratios below one indicate selection against, and ratios equal to one indicate no selection.
NA: Not calculated due to small sample size. NS: Habitat not sampled.

Table 2.13. Summary of habitat selection ratios: August 2007, 2008 and 2009 Combined - DR 82, DR131, and DR137*.

SPECIES/ FISH GROUP	Colorado pikeminnow	All fish	All Natives	All Non-Natives	Bluehead sucker	Flannelmouth sucker	Speckled dace	Red Shiner	Fathead minnow	Channel catfish
HABITAT	**RATIO (n=91)**	**RATIO (n=5042)**	**RATIO (n=2966)**	**RATIO (n=1880)**	**RATIO (n=222)**	**RATIO (n=526)**	**RATIO (n=2122)**	**RATIO (n=503)**	**RATIO (n=147)**	**RATIO (n=1230)**
BACKWATER		8.624	6.436	9.572	10.348	3.639	6.959	23.596	32.743	
COBBLE SHOAL		0.500	0.432	0.593	0.554	0.551	0.348	0.432	0.049	0.724
EDDY		2.887	4.373		6.021		5.156		0.000	
EMBAYMENT		2.078	2.078		4.997	6.795		4.901		0.000
ISOLATED POOL		1.493		2.302		2.504	0.266		19.197	
PLUNGE										
POOL		4.921	3.791	6.797		2.650	4.489	9.053	9.167	5.591
RIFFLE	1.88	0.523	0.804	0.134	0.190	0.320		0.134	0.057	0.144
SAND SHOAL		1.161	1.173	1.216			1.206		0.085	1.525
RUN	0.28	0.516	0.522	0.557	0.409	0.382	0.581	0.114	0.000	0.805
SLACKWATER		0.844	0.878	0.858		1.326	0.753	0.417	0.199	1.117
Pearson Chi^2	22.71 (p=0.001)	8058 (p=0.00)	3123 (p=0.00)	4214 (p=0.00)	538 (p=0.00)	355 (p=0.00)	2941 (p=0.00)	5683 (p=0.00)	3291 (p=0.00)	734 (p=0.00)
Log-likelihood Chi^2	25.74 (p=0.004)	3891 (p=0.00)	1771 (p=0.00)	1928 (p=0.00)	245 (p=0.00)	259 (p=0.00)	1581 (p=0.00)	1575 (p=0.00)	779 (p=0.00)	512 (p=0.00)

* Significant ($p<0.05$) Chi^2 values suggest selection for particular habitat types occur.

Only significant selection ratios ($p<0.05$) are shown.

Ratio values greater than one indicate selection for, ratios below one indicate selection against, and ratios equal to one indicate no selection. NA: Not calculated due to small sample size. NS: Habitat not sampled.

Table 2.14. Summary of area mapped by habitat type during surveys along DR 82, DR131, and DR137 in the San Juan River (2007-2009).

DATE	August_07				March_08					August_08				
REACH	82 (m^2)	137 (m^2)	Combined (m^2)	Combined (%) *	82	131	137	Combined (m^2)	Combined (%) *	82	131	137	Combined (m^2)	Combined (%) *
BACKWATER	93	174	***267***	0	797	90	195	***1,082***	0	665	46	453	***1,164***	0
COBBLE SHOAL	5,630	4,334	***9,964***	6	276	2,137	2,422	***4,835***	1	5,231	5,229	6,731	***17,191***	4
EDDY	103	267	***370***	0	693	881	285	***1,859***	0	148	102	148	***398***	0
EMBAYMENT	60	159	***219***	0	0	44	1,306	***1,350***	0	0	335	0	***335***	0
ISOLATED POOL	72	63	***135***	0	0	0	84	***84***	0	719	38	606	***1,363***	0
PLUNGE		36	***36***	0	0	0	0	***0***	0	0	0	18	***18***	0
POOL	734		***734***	0	0	772	349	***1,121***	0	1,075	34	1,036	***2,145***	0
RIFFLE	14,009	14,849	***28,858***	17	33,173	32,768	58,105	***124,046***	19	25,728	17,418	30,171	***73,317***	15
SAND SHOAL	5,138	2,569	***7,707***	4	1,620	5,815	4,035	***11,470***	2	7,712	2,781	2,137	***12,630***	3
RUN	57,544	53,944	***111,488***	65	199,036	140,242	132,940	***472,218***	74	143,884	92,434	114,693	***351,011***	71
SLACKWATER	7,828	4,383	***12,211***	7	8,333	3,949	10,298	***22,580***	4	13,334	7,007	11,027	***31,368***	6
Total	**91,211**	**80,778**	**171,989**	**100**	**243,928**	**186,698**	**210,019**	**640,645**	**100**	**198,496**	**125,424**	**167,020**	**490,940**	**100**

DATE	March_08					August_09					Total	
REACH	82	131	137	Combined (m^2)	Combined (%) *	82	131	137	Combined (m^2)	Combined (%) *	(m^2)	(%)
BACKWATER	133	148	**553**	*834*	0	445	158	**418**	***1,022***	0	**4,369**	0
COBBLE SHOAL	2,173	2,037	**3,732**	*7,942*	3	4,596	3,036	**8,255**	***15,888***	7	**55,820**	3
EDDY	170	445	**102**	*717*	0	83		**227**	***311***	0	**3,654**	0
EMBAYMENT	23			*23*	0	9	69	**38**	***115***	0	**2,042**	0
ISOLATED POOL	45		**68**	*112*	0	121			***121***	0	**1,815**	0
PLUNGE		46		*0*	460				***0***	0	**54**	0
POOL	579	12,692	**51**	*676*	0	471	114	**58**	***643***	0	**5,319**	0
RIFFLE	13,816	3,605	**12,187**	*38,695*	14	11,276	8,119	**9,551**	***28,946***	12	**293,862**	16
SAND SHOAL	5,568	75,251	**4,055**	*13,227*	5	6,061	8,700	**3,326**	***18,087***	7	**63,121**	3
RUN	70,904	2,510	**49,405**	*195,560*	73	59,520	62,913	**39,492**	***161,925***	67	**1,292,203**	71
SLACKWATER	4,710	96,735	**3,656**	*10,876*	4	4,511	4,803	**5,054**	***14,369***	6	**91,404**	5
Total	**98,119**		**73,808**	**268,662**	**100**	**87,094**	**87,912**	**66,421**	**241,426**	**100**	**1,813,662**	**100**

* Proportion of habitat mapped in relation to the total area (all reaches combined)

Table 2.15. Summary of area sampled by habitat type during surveys along DR 82, DR131, and DR137 in the San Juan River (2007-2009).

DATE	August_07				March_08					August_08				
REACH	82 (m^2)	137 (m^2)	Combined (m^2)	Combined (%) *	82	131	137	Combined (m^2)	Combined (%) *	82	131	137	Combined (m^2)	Combined (%) *
BACKWATER	118	NS	***118***	44	193	36	102	***331***	31	168	102	227	***497***	43
COBBLE SHOAL	1,784	1,491	***3,276***	33	41	137	410	***587***	12	1,185	1,088	1,159	***3,432***	20
EDDY	68	613	***681***	184	NS	NS	25	***25***	1	84	73	57	***214***	54
EMBAYMENT	NS	NS	***NS***	NS	NS	NS	123	***123***	9	NS	353	61	***414***	123
ISOLATED POOL	6	NS	***6***	4	NS	NS	73	***73***	87	187		140	***327***	24
PLUNGE	13	126	***139***	383	NS	NS	NS	***NS***	NS	NS	NS	64	***64***	356
POOL	401	NS	***401***	55	NS	156	160	***316***	28	245		406	***651***	30
RIFFLE	519	1,254	***1,773***	6	416	302	611	***1,329***	1	974	1,748	1,822	***4,544***	6
SAND SHOAL	965	971	***1,936***	25	393	834	448	***1,675***	15	1,219	253	287	***1,759***	14
RUN	2,162	1,674	***3,836***	33	1,208	778	1,226	***3,212***	7	1,523	1,778	1,740	***5,041***	14
SLACKWATER	5,588	5,679	***11,268***	92	1,264	661	1,074	***2,999***	13	2,212	2,575	3,080	***7,867***	25
Total	**11,624**	**11,809**	**23,433**	**14**	**3,514**	**2,904**	**4,252**	**10,670**	**2**	**7,798**	**7,970**	**9,041**	**24,808**	**5**

DATE	March_09					August_09					Total	
REACH	82	131	137	Combined (m^2)	Combined (%) *	82	131	137	Combined (m^2)	Combined (%) *	(m^2)	(%) *
BACKWATER	NS	NS	182	***182***	22	133	73	366	***571***	56	**1,699**	**39**
COBBLE SHOAL	676	381	485	***1,542***	19	689	545	1,019	***2,253***	14	**11,090**	**20**
EDDY	69	NS	NS	***69***	10	82		334	***416***	134	**1,404**	**38**
EMBAYMENT				***NS***	0	NS	113	NS	***113***	98	**649**	**32**
ISOLATED POOL	32		96	***128***	114	12			***12***	10	**546**	**30**
PLUNGE											**203**	**375**
POOL	301	18	107	***426***	63	203	126	15	***344***	54	**2,138**	**40**
RIFFLE	569	596	680	***1,844***	5	375	203	808	***1,386***	5	**10,876**	**4**
SAND SHOAL	709	273	327	***1,308***	10	655	586	286	***1,527***	8	**8,205**	**13**
RUN	501	1,193	768	***2,463***	1	1,599	1,956	1,138	***4,693***	3	**19,245**	**5**
SLACKWATER	910	907	889	***2,706***	25	1,715	1,739	1,869	***5,323***	37	**30,162**	**33**
Total	**3,767**	**3,368**	**3,534**	**10,668**	**4**	**5,464**	**5,341**	**5,834**	**16,638**	**7**	**86,217**	**10**

* Numbers in parenthesis indicate the proportion of habitat sampled in relation to the area mapped.

Table 2.16. Proportional Habitat Availability: percent area sampled by habitat type based on total area sampled along DR 82, DR131, and DR137 in the San Juan River (2007-2009).

DATE	August_07			March_08				August_08				March_09				August_09				Total
REACH	82	137	82 & 137 Combined	82	131	137	82-131-137 Combined	82	131	137	82-131-137 Combined	82	131	137	82-131-137 Combined	82	131	137	82-131-137 Combined	
BACKWATER	1.0	0.0	0.5	5.5	1.2	2.4	3.1	2.2	1.3	2.5	2.0	0.0	0.0	5.1	1.7	2.4	1.4	6.3	3.4	2.0
COBBLE SHOAL	15.4	12.6	14.0	1.2	4.7	9.7	5.5	15.2	13.7	12.8	13.8	17.9	11.3	13.7	14.5	12.6	10.2	17.5	13.5	12.9
EDDY	0.6	5.2	2.9	0.0	0.0	0.6	0.2	1.1	0.9	0.6	0.9	1.8	0.0	0.0	0.6	1.5	0.0	5.7	2.5	1.6
EMBAYMENT	0.0	0.0	0.0	0.0	0.0	2.9	1.2	0.0	4.4	0.7	1.7	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.7	0.8
ISOLATED POOL	0.0	0.0	0.0	0.0	0.0	1.7	0.7	2.4	0.0	1.5	1.3	0.9	0.0	2.7	1.2	0.2	0.0	0.0	0.1	0.6
PLUNGE	0.1	1.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
POOL	3.5	0.0	1.7	0.0	5.4	3.8	3.0	3.1	0.0	4.5	2.6	8.0	0.5	3.0	4.0	3.7	2.4	0.3	2.1	2.5
RIFFLE	4.5	10.6	7.6	11.8	10.4	14.4	12.5	12.5	21.9	20.2	18.3	15.1	17.7	19.2	17.3	6.9	3.8	13.8	8.3	12.6
SAND SHOAL	8.3	8.2	8.3	11.2	28.7	10.5	15.7	15.6	3.2	3.2	7.1	18.8	8.1	9.2	12.3	12.0	11.0	4.9	9.2	9.5
RUN	18.6	14.2	16.4	34.4	26.8	28.8	30.1	19.5	22.3	19.2	20.3	13.3	35.4	21.7	23.1	29.3	36.6	19.5	28.2	22.3
SLACKWATER	48.1	48.1	48.1	36.0	22.8	25.3	28.1	28.4	32.3	34.1	31.7	24.2	26.9	25.2	25.4	31.4	32.6	32.0	32.0	35.0

A considerable area of mapped cobble shoal (20%) and sand shoal (13%) were also sampled. Habitats sampled in lower proportions include riffle and run; these habitats were typically too swift, too deep, or presented debris that precluded effective seining. Percentages > 100 (e.g., total plunge habitat sampled- 374%) are the result of replicate sampling within rare habitats types and/or due to the total area sampled (i.e., seine haul area) being larger than the mapped area.

In terms of proportional habitat availability used for the habitat selection analysis, the percentages allocated to each habitat type were based on the actual habitat sampled and not the area mapped. On this basis, slackwater accounted for the largest proportion of habitat sampled followed by run, riffle, cobble shoal, and sand shoal. . Low water velocity habitats including backwater, eddy, embayment, isolated pool, and pool, accounted for less than 8% of the total area sampled across all reaches and samples (Table 2.16).

Other SJRIP Studies

We reviewed other SJRIP studies for use in determining habitat selection. The general criteria to determine if the data could be used were that fish sampling locations and habitats needed to be known and most or all habitats were represented in the sampling. Larval fish studies did not meet these criteria because they primarily target low velocity habitats and not all habitats were sampled. Data from non-native removal and adult monitoring studies could not be used because the exact location and specific type of habitat are not known. However, because the non-native removal studies collected GPS locations when Colorado pikeminnow were netted, habitat association in the localized area of capture was analyzed and will be discussed in a later section.

The small-bodied monitoring program conducted by New Mexico Game and Fish Department met the general criteria for habitat selection analysis. Overall 34,968 m^2 encompassing 11 habitat types were sampled by the small-bodied monitoring program from 2007 to 2009 (New Mexico Department of Fish and Game, unpublished data). Runs and shoals were the habitat types sampled more extensively during these efforts (Table 2.17). Riffles, backwaters, and eddies, represented approximately 27% of the total area sampled. Pool and slackwater made up approximately 7% of the sample area with the remaining 2 % encompassing embayment, isolated pool, plunge and chute habitats.

A total of 31 Colorado pikeminnow with TL > 100 mm were captured during the small bodied sampling efforts in 2007 (Paroz et al. 2008). Significant ratios indicating selection for particular habitats were estimated for riffle-eddy, pool and debris pile. Habitat selection was also evident for the 28 Colorado pikeminnow with TL < 100 mm captured during small-bodied monitoring efforts in 2007. Significant ratios for the smaller Colorado pikeminnow indicated selection for backwater, slackwater, and overhanging vegetation habitats and selection against run and shoal habitat (Bliesner et al. 2008).

Small-bodied sampling in 2008 captured 10 Colorado pikeminnow (TL> 100 mm) from run (7 pikeminnow), backwater (2 pikeminnow), and plunge (1 pikeminnow) habitats. No Colorado pikeminnow < 100 mm TL were captured. The small sample size in 2008 precluded the assessment of habitat selection and an assessment of selection based on the combined 2007 and 2008 data did not provide evidence of habitat selection (Bliesner et al. (2009).

Table 2.17. **Summary of area sampled by habitat type, Colorado pikeminnow captures, and tests of No Selection based on small-bodied monitoring sampling in August-October 2007, 2008, and 2009**

Habitat	Area (m^2)	Percent of total area (%)	Age-1 Pikeminnow >100mm (n)	Age-0 Pikeminnow <100mm (n)	Age-0 Pikeminnow <100mm (Ratio)
BACKWATER	2,744	7.8	6	23	**10.85**
EDDY	3,014	8.6	6	0	
EMBAYMENT	275	0.8	0	0	
ISOLATED POOL	138	0.4	0	0	
PLUNGE	251	0.7	1	0	
POOL	1,040	3.0	2	0	
RIFFLE	3,583	10.2	1	1	
RUN	16,384	46.9	29	1	**0.08**
SLACKWATER	1,257	3.6	1	1	
SHOAL	6,169	17.6	6	1	
CHUTE	112	0.3	0	0	
TOTAL	34,968	100	**52****	**27****	
Pearson Chi^2 *			9.28 (p=0.5)	224 (p=0.00)	
Log-likelihood Chi^2 *			11.55 (p=0.3)	99 (p=0.00)	

* Significant (p<0.05) Chi^2 values suggest selection for particular habitat types occur. Non-significant values indicate no selection.

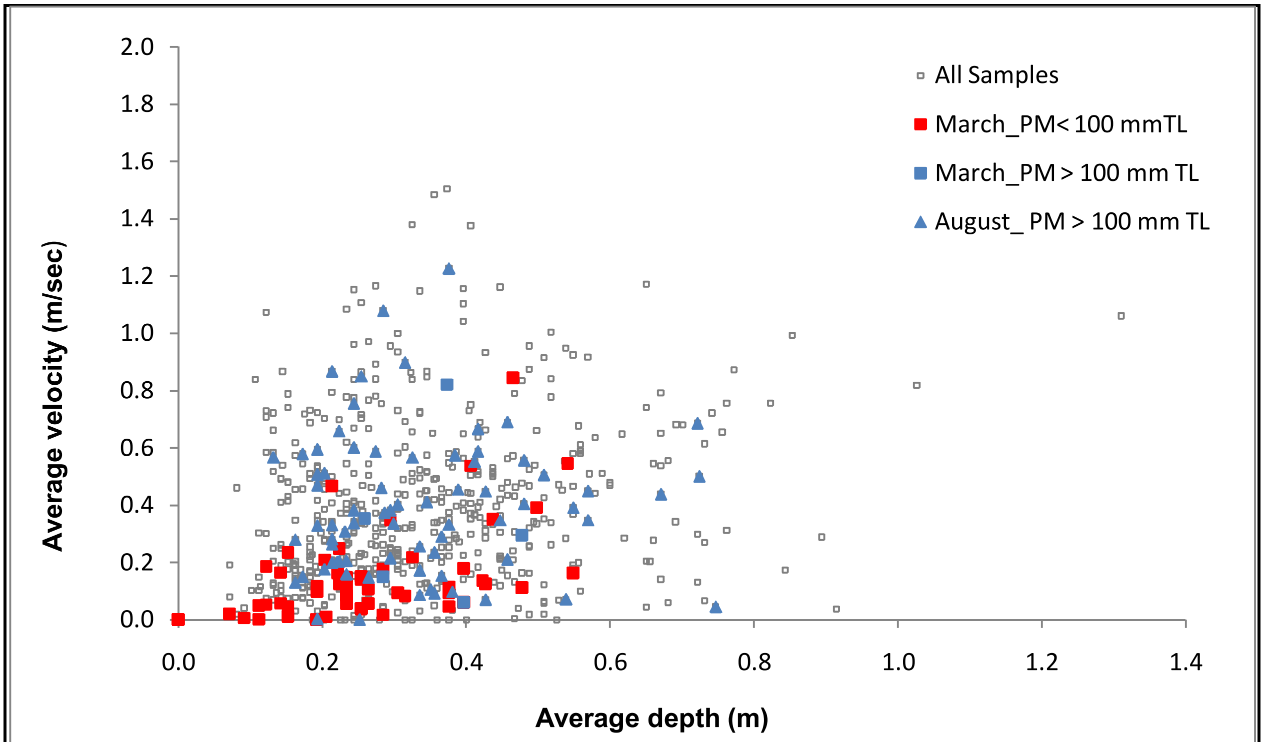
** Colorado pikeminnow captures totaled 53 fish with TL> 100 mm and 28 fish with TL<28mm. One fish from each size class was reported as captured in overhanging vegetation habitat and therefore were not taken into account for this selection test.

In 2009, small-bodied sampling captured 12 Colorado pikeminnow with TL > 100 mm (New Mexico Department of Fish and Game, unpublished data). Of these captures, 6 Colorado pikeminnow occurred in run, 3 in shoal, 1 in backwater, 1 in eddy, and 1 in slackwater habitats. Habitat selection analyses were conducted by combining the habitat use and availability data from 2007, 2008, and 2009. No selection was evident for Colorado pikeminnow with TL > 100mm. However, the analysis conducted for smaller Colorado pikeminnow indicated selection for backwater and selection against run habitat (Table 2.17). Only the selection for backwater by these smaller Colorado pikeminnow is consistent with results based on the detailed reach assessment (Table 2.11).

Physical Characteristics

A depth-velocity plot for all sites sampled and those associated with Colorado pikeminnow captures indicated that smaller Colorado pikeminnow typically occurred in sites with lower water velocity than in sites where larger Colorado pikeminnow were captured (Figure 2.08). On average, sites associated with small Colorado pikeminnow captures were also shallower than in sites with larger Colorado pikeminnow. The average depth and velocity associated with small Colorado pikeminnow captures were 0.12m and 0.26 m/sec, respectively. The average depth in sites with larger Colorado pikeminnow was 0.37 m and the average velocity was 0.34 m/sec.

The average depth in backwaters where smaller Colorado pikeminnow were captured was 0.12 m versus 0.25 m where larger Colorado pikeminnow occurred. The average backwater depth across all sites samples was 0.16 m (Table 2.18). Similarly, shallower slackwaters with lower water velocity were associated with captures of smaller Colorado pikeminnow. On the other hand, faster and slightly deeper run, riffle, and shoal habitats were associated with captures of larger Colorado pikeminnow. Smaller Colorado pikeminnow selected for sand/silt and against cobble/gravel whereas larger Colorado pikeminnow selected for cobble/gravel and against sand/silt substrate (Table 2.19).



TL	PM < 100 mm TL	PM >100 mm TL
Average depth (m)	0.12	0.37
Average velocity (m/sec)	0.26	0.34

Figure 2.08. Scatter plot of mean velocity and depth for all samples and for those with Colorado pikeminnow. Red markers indicate captures on Colorado pikeminnow with TL < 100 mm. Blue markers indicate captures of Colorado pikeminnow with TL > 100 mm.

Table 2.18. Average depth and velocity by habitat type

HABITAT	Average depth (m)			Average Velocity (m/sec)		
	All sites	Sites with PM <100mm TL	Sites with PM >100mm TL	All sites	Sites with PM <100mm TL	Sites with PM >100mm TL
BACKWATER	0.16	0.12	0.25	0.01	0.01	0.00
COBBLE SHOAL	0.23	0.16	0.26	0.34	0.13	0.28
EDDY	0.49		0.74	0.04		0.20
EMBAYMENT	0.13	0.22		0.08	0.09	
POOL	0.30	0.34	0.34	0.09	0.10	0.06
RIFFLE	0.27	0.21	0.23	0.72	0.19	0.67
SAND SHOAL	0.22	0.18	0.28	0.24	0.10	0.29
RUN	0.42	0.32	0.38	0.49	0.23	0.55
SLACKWATER	0.40	0.29	0.41	0.32	0.18	0.32

Table 2.19. Summary of substrate selection ratios for Colorado pikeminnow by size. Based on detailed habitat fish surveys conducted in 2007, 2008, and 2009.

COLORADO PIKEMINNOW HABITAT	TL < 100 mm Ratio (n=142)	TL > 100 mm Ratio (n=98)
SAND/SILT	1.7	0.82
COBBLE/GRAVEL	0.05	1.25
Pearson Chi^2	94.59 ($p<0.00$)	4.51 ($p<0.05$)
Log-likelihood Chi^2	129.69 ($p<0.00$)	4.45 ($p<0.05$)

* Significant ($p<0.05$) Chi^2 values suggest selection for particular habitat types occur.
Only significant selection ratios ($p<0.05$) are shown.
Ratio values greater than one indicate selection for, ratios below one indicate selection against, and ratios equal to one indicate no selection.

DISCUSSION

The 2009 results combined with those from fish and habitat surveys in detailed reaches conducted in 2007 and 2008 (Bliesner et al. 2009) suggest that young Colorado pikeminnow select for specific habitat types. Small pikeminnow appear to select for low water velocity habitats including embayment, pool, and backwaters but select against riffle, cobble shoal, and slackwater. Alternatively, larger Colorado pikeminnow in appear to select for riffle and against run habitat. Although there is some variability in the habitats selected by young Colorado pikeminnow across years, the larger cumulative sample sizes allowed for a better assessment of habitat selection and the comparison of selection by Colorado pikeminnow in two different size classes.

Relatively high water velocities in riffle habitat lead us to question the selection for riffle habitat by the larger Colorado pikeminnow. However, it is possible that Colorado pikeminnow may have been captured in adjacent habitats when riffle was the target habitat. This is consistent with the assessment of habitat associations indicating that Colorado pikeminnow are more likely to be captured in habitat associations that include riffle habitat. The discussion of habitat associations (below) will provide more insight into the selection for particular habitat types.

We noted consistencies and discrepancies between habitat selection analyses based on small-bodied monitoring and detailed reach data. Both datasets support the finding of selection for backwater habitat by the smaller Colorado pikeminnow and the selection against run habitat by larger Colorado pikeminnow. However, although the small-bodied monitoring data suggest that Colorado pikeminnow in the small size class also select against run habitat, this is not supported by the detailed reach assessment. These differences in habitat selection assessments based on the two datasets seem to be largely due to differences in sample sizes and the area sampled by habitat type. For example, run and slackwater habitat accounted for 22 and 35 % of the total habitat sampled during the detail reach study. On the other hand, of the total habitat sampled by the small-bodied monitoring program, 47 % was run habitat and < 4 % was slackwater.

As noted in Bliesner et al. (2009), the larval study captured a number of Colorado pikeminnow with TL> 100 mm in backwaters and other low velocity habitats, typical habitats for Colorado pikeminnow in this size class (Golden et al. 2006), but since not all habitat types were sampled it is difficult to determine if those data support the habitat selection from other studies.

Overall, results from the detailed reach survey support findings from previous research indicating Colorado pikeminnow with TL> 100 mm typically use habitats with some current, whereas smaller fish tend to use slow-water habitat types such as backwaters (Golden et al. 2006, Robertson and Holden 2007). The observed differences in habitat selection by Colorado pikeminnow in the two size classes are consistent with shifts in habitat use documented for other species (Gido and Propst 1999, Mullen and Burton 1995). For Colorado pikeminnow, differences in habitat use across age classes could be associated with shifts in diet composition. Franssen et al. (2007) noted that age-0 Colorado pikeminnow feed mainly on insects and may require shifting to piscivory by age-1 for optimal growth and survival. Although previous research has highlighted the importance of low water velocity habitat for small Colorado pikeminnow, the detailed reach fish survey has provided more insight into other types of low water velocity habitats that are used by small Colorado pikeminnow and differences in habitat selection between this size class and larger fish.

In terms of habitat selection overlap by Colorado pikeminnow and other native and non-native fishes, the combined results from the detailed reach surveys in March 2008 and 2009 suggest that small Colorado pikeminnow, flannelmouth sucker, and fathead minnow selected for embayment habitat. Backwater habitat was selected for by both small Colorado pikeminnow and red-shiner, and selected against by speckled dace. Channel catfish and red shiner also overlapped with small Colorado pikeminnow in terms of selection for pool habitat. Further, the analysis of habitat selection based on the combined detailed reach surveys in August 2007-2009 suggested Colorado pikeminnow was the only species selecting for riffle habitat. All other species appeared to select against this habitat type.

Similar to the larger Colorado pikeminnow typically captured in August surveys, all other native and non-native species also appeared to select against run habitat. Interestingly, as observed for Colorado pikeminnow, a shift in habitat selection by speckled dace from March to August surveys was evident with speckled dace selecting for habitats with higher water velocities (i.e., shoal and slackwater) in March and selecting for habitats with low water velocities in August (i.e., backwater, eddy, pool). We believe this is due to the collection of predominantly age-1 dace during March, and predominantly age-0 dace during August, and, similar to Colorado pikeminnow, the younger (smaller) fish prefer lower velocity habitats, but they can utilize higher velocity areas as they age.

More generally, the comprehensive results of detailed reach surveys in March and August reveal overlap in habitat selection by native and non-native fish assemblages. In March, both native and non-native fish communities appear to select for embayment and pool habitat and select against higher water velocity habitats including cobble shoal, riffle, and run. On the other hand, both fish assemblages appeared to select for backwater, pool, and sand shoal habitats, and against cobble shoal, riffle, run and slackwater habitats. These results support findings from previous studies that have documented overlaps in resources used by native and non-native fishes in the San Juan River. For example, the food web dynamics study of Gido et al. (2006) in the San Juan River confirmed a high degree of overlap in diet composition and suggested that most native and non-native species fed on macroinvertebrates (particularly chironomids) in low-velocity habitats. Gido and Propst (1999) also documented high levels of habitat overlap between native and non-native fishes in secondary channels of the San Juan River, particularly among juvenile and larval fishes. These noted patterns of habitat selection and overlap highlight the potential for negative interspecies interactions (e.g., competition) between native and non-native fishes.

As noted in previous reports (Bliesner et al. 2008, 2009), despite efforts to sample representative areas of the habitats mapped, the selection of sampling habitats during the detailed reach fish survey was typically not proportional to their occurrence for various reasons. For example, sampling run and riffle habitat was very limited due to waters that were too swift or too deep. Samples from some areas were not collected because depth, vegetation, and/or debris also prevented effective seining. However, given that the majority of habitats mapped were sampled, it is unlikely that limited sampling in dominant habitat types (particularly along run and riffle) biased the results of our habitat selection analyses. More importantly, results of habitat mapped and sampled highlight the lack of low water velocity habitats that are used by small Colorado pikeminnow (e.g., backwater, pool).

Consistent with the analysis of habitat selection, the physical characteristics data show that small Colorado pikeminnow tend toward shallower and lower velocity habitats. Larger fish use a broader range of habitats that are of higher and more varied velocity and depth. Also, smaller Colorado pikeminnow appeared to select for fine substrate but larger substrate appeared to be important only for fish in the larger size class.

CHAPTER 3: HABITAT ASSOCIATION OF COLORADO PIKEMINNOW AND RAZORBACK SUCKER

INTRODUCTION

A key hypothesis considered at the outset of the detailed reach study was that the endangered fish are responding not just to a specific habitat where they were captured, but a combination of habitats in the vicinity of capture. The habitat association studies were devised to test that hypothesis.

The approach was developed for the detailed reach study, but as more endangered fish were being captured by other studies, a process was devised to look at habitat association on a somewhat larger scale using GPS data collected at the time of capture. The data analysis process is the same for both analyses, and the SJRIP habitat GIS (Bliesner, et al. 2009) was used in both cases for integrating sampling and capture data.

The habitat data collection for the past 12 years has focused on autumn base flows. No habitat data have been collected during high flow periods since 2005. During the review of monitoring protocol in 2009 it was evident that an assessment of habitat availability for larval razorback through the spring runoff period was important. The habitat data for all the sampling locations collected by the larval sampling program may be used as a surrogate for backwater habitat availability as the backwaters tend to be sampled in proportion to their availability. These data were used to assess conditions that may be important to larval razorback sucker and to take a first look at backwater persistence over a range of flows.

The specific objectives of the habitat association studies were: (1) Determine if combinations of habitats are important to young Colorado pikeminnow and razorback sucker, (2) determine habitats within 0.1 and 1.0 mile reaches associated with capture locations of larger (>150 mm) Colorado pikeminnow and razorback sucker, and (3) examine habitat use and availability for larval razorback sucker, including habitat persistence during the typical period of use.

METHODS

Detailed Reach

In 2008 and 2009, the seine haul area of each sample collected in the detailed reach study was recorded in the field and digitized. These digitized boundaries were intersected with the habitat mapping boundaries recorded at the same time as the fish sampling to determine that habitats within the seine haul area. Using digitized habitat and seine haul location datasets, buffer distances of from 5 to 20 m around each seine haul site were set and habitat types within those buffers identified (Figure 3.01). Combinations of habitats (habitat associations) within each buffer zone were then examined in relation to the capture of Colorado pikeminnow. The average availability of each combination for sites with and without Colorado pikeminnow capture was determined and the ratios of availability for each category (with and without Colorado pikeminnow) computed. When ratios are > 1.0, preference is indicated. Significant differences between samples with and without Colorado pikeminnow were determined using a two-tailed t-

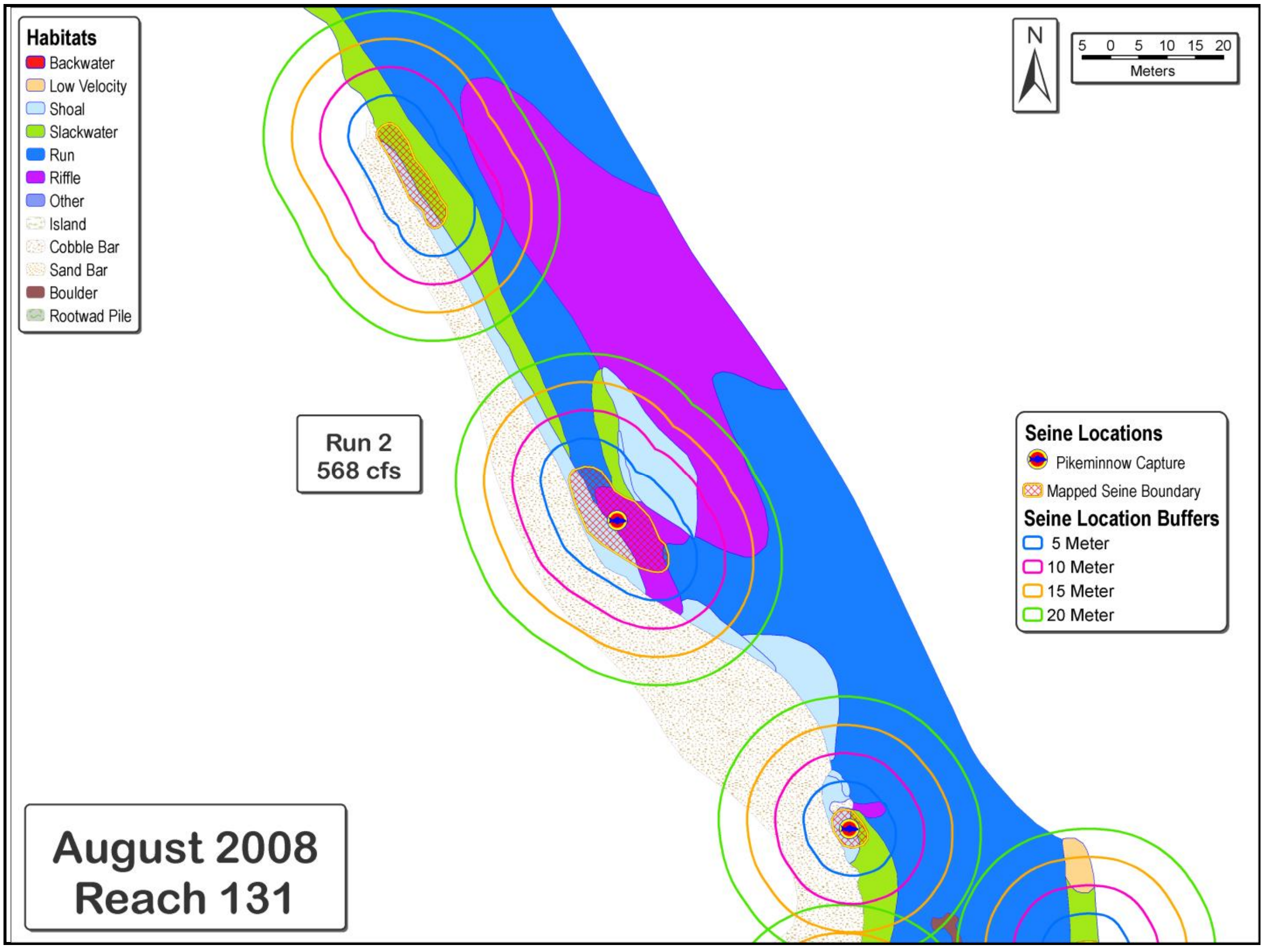


Figure 3.01. Graphical representation of seined areas, buffers and intersection with habitat mapping used in habitat association analysis

test for non-equal variance. P-values of 0.05 and less are considered significant. P-values between 0.05 and 0.10 are considered marginally significant.

Large Bodied and Non-native Removal

The GPS location data for Colorado pikeminnow capture collected in 2009 in the non-native removal and large bodied monitoring programs provide the opportunity to examine capture location on a resolution finer than 1 mile for electrofishing data. Although the accuracy of the GPS data and the nature of electrofishing do not allow specific habitat use data, it is possible to refine the analysis to 0.1 mile segments. An analysis similar to that described above for the detailed reach fish sampling locations was performed to examine the potential relationship between habitat complexity (number of habitats per 0.01 river mile) and capture of Colorado pikeminnow by electrofishing during the non-native removal program. The abundance of individual habitats types and habitat classes were also examined. GPS locations and dates of Colorado pikeminnow captures were obtained from the non-native removal program (Davis, Pers. Com. 2009, 2010) and the large-bodied monitoring program (Ryden, Pers. Com. 2009, 2010). The locations were tabulated to the nearest 0.01 mile. Habitat abundance and complexity for each 0.01 mile from the 2007 river-wide habitat survey (latest survey for which data were available) was computed by using a 220 m buffer around each 0.01 river mile mark in the SJRIP GIS. This buffer allows for possible GPS location error and fish movement that might be outside the 0.01 mile range. The abundance of individual habitats and habitat complexity of the 0.01 river mile segments for which Colorado pikeminnow were captured was compared to those for which there were no captures using a two-tailed student t-test for non-equal variance to test the hypothesis that the mean habitat complexity for the two cases are different. The analysis covered RM 68 to RM 166.6 for the combined dataset. GPS positions in the canyon are less reliable due signal interference from the canyon walls, thus limiting the lower end of the range.

The GPS dataset is very difficult to normalize for effort since the river reaches are not sampled uniformly and sometimes only one of the boats on a trip had a functioning GPS receiver. The upper river tended to be sampled more intensely so the habitat association results are biased towards conditions in the upper river. The multiple pass sampling trips in the non-native removal program also tend to displace fish down-river with inadequate time between sampling passes for the fish to redistribute to their preferred habitat conditions. To allow a look at habitat association without these influences the endangered fish capture data from the large-bodied sampling trip in the fall of 2009 were analyzed against the habitat availability within the river mile in which they were captured to determine large scale habitat association. Only sampled river miles were included in this analysis, comparing habitat availability in the river miles with endangered fish captures to habitat availability in river miles with no captures to identify habitat conditions that may be important to the endangered fishes. The analytical procedures described above were used to determine significance.

The 2009 results are also compared to those from 2008.

Larval Fish Study

Habitats sampled and habitats in which larval razorback sucker were captured by the larval fish study during 2007, 2008 and 2009 (Brandenburg, Pers. Com. 2008, 2009) were analyzed to assess habitat use of larval razorback sucker. The sampled habitat data were also used to assess habitat persistence. Utilizing GPS coordinates in the sampling data and the SJRIP GIS, habitats sampled in each successive trip were located and sites sampled repeatedly identified. When a backwater was sampled again in a subsequent trip, it was assumed to have persisted. If it did not show up in a subsequent trip dataset, it was assumed to either not be available or to be of such deteriorated condition that it was not selected for sampling. This is only an indication of persistence as not all available backwaters are sampled each trip.

RESULTS

Detailed Reach Analysis

The seined area typically extends beyond the target habitat, especially for small habitats. On average about 69% of the seined area consisted of target habitat in 2009, ranging from 40% to 100% by habitat type (Table 3.01) and comparable to the results in 2008 (Table 3.02). An analysis of the habitats that are significantly related to capture within the seine hauls was completed that considered all habitats sampled. The seine haul boundary was used as the offset boundary for 5, 10, 15 and 20 m buffers to look at habitat associations that might also be important to Colorado pikeminnow capture.

Table 3.01. Target habitats and their average portion of the total seine haul area for March and August 2009 samples.

Target Habitat	Count		Percent in Seine Haul	
	Mar-09	Aug-09	Mar-09	Aug-09
Backwater	5	11	62%	87%
Cobble Shoal	29	28	79%	49%
Eddy	3	10	100%	40%
Embayment		2		60%
Isolated Pool	2	1	100%	100%
Pool	14	12	66%	71%
Riffle	47	26	62%	79%
Run	5		90%	
Sand Shoal	32	25	65%	56%
Shore Run	54	56	88%	77%
Slackwater	70	82	64%	62%
Total/average	261	253	72%	66%

Table 3.02. Target habitats and their average portion of the total seine haul area for March and August 2008 samples.

Target Habitat	Count		Percent in Seine Haul	
	Mar 08	Aug 08	Mar 08	Aug 08
Backwater	7	12	93%	75%
Cobble shoal	14	34	65%	67%
Eddy	1	4	46%	80%
Embayment	3	4	52%	57%
Isolated Pool	2	7	100%	100%
Plunge pool	0	1	n/a	26%
Pool	8	13	99%	83%
Riffle	27	49	64%	65%
San shoal	34	22	72%	74%
Shore run	70	46	76%	84%
Slackwater	71	74	81%	75%
Total	237	266	76%	74%

The results of the habitat association study differed between the March and August samples. In March 2009, pools and sand shoals in the buffer areas were significantly related with Colorado pikeminnow capture with pools having the highest ratios (Table 3.03). The combinations of pools with sand shoals and pools with riffles were also significant in some buffer distances, but the ratios were typically not large at distances beyond 5 m from the seine haul. Young Colorado pikeminnow were less likely to be found were runs, slackwaters and cobble shoals were within the seine haul. This is in contrast to the results in 2008 that placed more importance on backwaters and embayments and indicated significance of five combinations of habitats

(Bliesner, et al. 2009). The difference is likely due to the large difference in flows during sampling (>3500 cfs in 2008, <1,000 cfs in 2009).

When 2008 and 2009 were analyzed together, backwaters and pools were both significant, with pools having a higher selection ratio than backwaters (Table 3.04). The combinations of backwaters with runs and pools with sand shoals were also important, with higher selection ratios than for backwaters or pools taken alone within the seine haul boundary.

Although the two individual habitats and several combinations show significance in all the buffer distances, the ratios typically diminish with distance from the seine haul and selection ratios for the associations are smaller than those for single habitats beyond 5 m. In both years, the lower velocity habitats are most important and the range of importance away from the seined area is small (≤5 m beyond the seine haul). Ranking the importance as indicated by the magnitude of the selection ratio, the combination of pools and sand shoals has the greatest importance followed by backwaters adjacent to runs, then pools, then backwaters.

In August 2009, only slackwaters were positively correlated with Colorado pikeminnow capture. The habitats combinations listed below were significantly correlated with no capture (Table 3.05).

- Embayment
- Root wad pile
- Run + cobble shoal
- Run + riffle
- Run + riffle + slackwater
- Run + slackwater + root wad pile

The low number of captures and the sampling conditions (clear water) contributed to the difference between 2008 and 2009. In 2008, riffles were more important than slack waters and several combinations were important, particularly at some distance from the capture location (Bliesner, et al. 2009).

When 2008 and 2009 were combined, both riffles and slackwaters showed significance and the combinations of a number of habitats that are associated with riffles were also important (Table 3.06). The selection ratios more than double for habitat combinations over any single habitat within the seine haul area and the ratios continue to be larger for the combinations than the individual habitats out to 20 meters from the seine haul. This indicates that these larger fish are ranging more widely and using a wider variety of habitats than the smaller fish in March. They were also using higher velocity habitats and those habitats associated with riffles (slackwaters and cobble shoals).

For both March and August sampling, captures tended to group in specific areas of the detailed reaches. Across all years sampled, the areas used are similar (Figures 3.02 – 3.05). The exception is between March 2008 and 2009 in DR 82. When flows are adequate to provide a small amount of flow through the small secondary channel on the north, it provides a number of pool habitats that are used by the <100 mm Colorado pikeminnow in 2009. At higher flows, the secondary channel carries too much water and becomes a run (2008). At flows below about 600 cfs it dries up. In general, the fish tended to be in the most complex areas of the complex reaches that had the combination of habitats they needed over the range of flows sampled, although the location and size of these habitats may change within the area as flows change.

Table 3.03. Portion of samples with and without Colorado pikeminnow captures that contain certain habitats and the significance of the difference for March 2009 samples.

Distance (m) from Seined Boundary	Colorado Pikeminnow Captured	Back-water	Pool	Sand Shoal	Run	Slack-water	Cobble Shoal	Back water + Run	Back water + Sand Shoal	Pool + Run	Pool + Riffle	Pool + Slack-water	Pool + Sand Shoal	Back-water + Run + Slack water	Pool + run + Slack water
Seined area	no	1.7%	**2.9%**	**32.2%**	**60.3%**	39.3%	**28.9%**	0.4%	1.3%	0.0%	1.3%	0.0%	*1.3%*	0.4%	0.0%
	yes	13.0%	**34.8%**	**69.6%**	**34.8%**	26.1%	**8.7%**	8.7%	8.7%	0.0%	8.7%	0.0%	*17.4%*	0.0%	0.0%
	ratio yes/no	7.79	**11.88**	**2.16**	**0.58**	0.66	**0.30**	20.78	6.93	n/a	6.93	n/a	*13.86*	0.00	n/a
	p-value	0.130	**0.005**	**0.001**	**0.024**	0.191	**0.005**	0.183	0.231	n/a	0.231	n/a	*0.059*	0.318	n/a
5	no	4.6%	**4.2%**	**46.4%**	**79.5%**	**54.4%**	**46.9%**	2.9%	31.4%	0.4%	*2.5%*	4.2%	31.4%	2.9%	0.8%
	yes	17.4%	**34.8%**	**95.7%**	**47.8%**	**30.4%**	**17.4%**	13.0%	47.8%	0.0%	*17.4%*	4.3%	47.8%	4.3%	0.0%
	ratio yes/no	3.78	**8.31**	**2.06**	**0.60**	**0.56**	**0.37**	4.45	1.52	0.00	*6.93*	1.04	1.52	1.48	0.00
	p-value	0.132	**0.007**	**0.000**	**0.008**	**0.028**	**0.002**	0.177	0.149	0.318	*0.081*	0.971	0.149	0.754	0.158
10	no	6.3%	**6.3%**	**56.1%**	**91.2%**	**64.0%**	**54.0%**	5.0%	48.1%	0.4%	*5.0%*	**2.5%**	***5.9%***	4.6%	**1.7%**
	yes	17.4%	**34.8%**	**95.7%**	**52.2%**	**30.4%**	**21.7%**	13.0%	52.2%	0.0%	*21.7%*	**0.0%**	***34.8%***	4.3%	**0.0%**
	ratio yes/no	2.77	**5.54**	**1.71**	**0.57**	**0.48**	**0.40**	2.60	1.08	0.00	*4.33*	**0.00**	***5.94***	0.94	**0.00**
	p-value	0.19	**0.011**	**0.000**	**0.001**	**0.003**	**0.002**	0.284	0.718	0.318	*0.073*	**0.014**	***0.010***	0.956	**0.045**
15	no	8.4%	**7.1%**	**62.8%**	**93.3%**	**69.5%**	**59.0%**	7.1%	7.1%	0.8%	*5.0%*	3.3%	**7.1%**	6.7%	2.5%
	yes	17.4%	**39.1%**	**95.7%**	**52.2%**	**39.1%**	**30.4%**	13.0%	13.0%	0.0%	*21.7%*	8.7%	**39.1%**	4.3%	4.3%
	ratio yes/no	2.08	**5.50**	**1.52**	**0.56**	**0.56**	**0.52**	1.83	1.83	0.00	*4.33*	2.60	**5.50**	0.65	1.73
	p-value	0.29	**0.006**	**0.000**	**0.001**	**0.010**	**0.010**	0.429	0.429	0.158	*0.073*	0.391	**0.006**	0.617	0.684
20	no	*9.2%*	**7.9%**	**69.0%**	**95.4%**	**75.3%**	**65.3%**	8.8%	*8.4%*	0.8%	**7.5%**	4.2%	**7.9%**	8.4%	3.8%
	yes	*17.4%*	**39.1%**	**95.7%**	**52.2%**	**39.1%**	**34.8%**	13.0%	*13.0%*	0.0%	**30.4%**	8.7%	**39.1%**	4.3%	4.3%
	ratio yes/no	*1.89*	**4.92**	**1.39**	**0.55**	**0.52**	**0.53**	1.48	*1.56*	0.00	**4.04**	2.08	**4.92**	0.52	1.15
	p-value	*0.33*	**0.007**	**0.000**	**0.001**	**0.002**	**0.008**	0.571	*0.533*	0.158	**0.031**	0.470	**0.007**	0.399	0.899

Key:

2.00	Significantly ($p \leq 0.05$) correlated with Colorado pikeminnow captures
2.00	Marginally (P>.05, <0.10) correlated with Colorado pikeminnow captures
2.00	Significantly correlated with no Colorado pikeminnow capture

Table 3.04. Portion of samples with and without Colorado pikeminnow captures that contain certain habitats and the significance of the difference for March 2008 and 2009 samples combined.

Distance (m) from Seined Boundary	Colorado Pikeminnow Captured	Back-water	Pool	Sand Shoal	Run	Slack-water	Cobble Shoal	Back water + Run	Back water + Sand Shoal	Pool + Run	Pool + Riffle	Pool + Slack-water	Pool + Sand Shoal	Back-water + Run + Slack water	Pool + run + Slack water
Seined area	no	2.7%	2.7%	29.3%	57.1%	44.0%	22.3%	0.9%	0.9%	0.0%	0.9%	0.2%	0.7%	0.7%	0.0%
	yes	14.3%	23.2%	37.5%	50.0%	33.9%	12.5%	8.9%	5.4%	0.0%	5.4%	1.8%	8.9%	0.0%	0.0%
	ratio yes/no	5.27	8.57	1.28	0.88	0.77	0.56	9.89	5.93	n/a	5.93	7.91	13.18	0.00	n/a
	p-value	0.019	0.001	0.240	0.323	0.143	0.047	0.043	0.152	n/a	0.152	0.390	0.037	0.083	n/a
5	no	5.4%	3.8%	42.7%	77.9%	58.0%	38.8%	3.8%	3.2%	0.7%	2.5%	0.9%	2.5%	3.2%	0.5%
	yes	17.9%	26.8%	55.4%	60.7%	42.9%	21.4%	12.5%	10.7%	5.4%	8.9%	7.1%	17.9%	5.4%	5.4%
	ratio yes/no	3.30	6.98	1.30	0.78	0.74	0.55	3.26	3.39	7.91	3.60	7.91	7.19	1.70	11.87
	p-value	0.022	0.000	0.078	0.015	0.036	0.005	0.062	0.081	0.132	0.105	0.080	0.005	0.488	0.114
10	no	7.7%	5.4%	50.8%	89.4%	69.5%	44.9%	6.8%	4.5%	2.7%	4.1%	2.5%	3.8%	5.6%	1.6%
	yes	23.2%	28.6%	57.1%	71.4%	48.2%	28.6%	21.4%	12.5%	10.7%	10.7%	8.9%	19.6%	16.1%	8.9%
	ratio yes/no	3.02	5.27	1.13	0.80	0.69	0.64	3.16	2.77	3.96	2.64	3.60	5.12	2.85	5.65
	p-value	0.010	0.000	0.373	0.006	0.004	0.015	0.012	0.085	0.064	0.125	0.105	0.005	0.044	0.064
15	no	10.4%	6.8%	56.7%	92.6%	73.8%	50.8%	9.7%	5.9%	4.5%	5.2%	3.8%	5.0%	8.6%	3.4%
	yes	23.2%	32.1%	58.9%	73.2%	53.6%	33.9%	21.4%	12.5%	14.3%	17.9%	14.3%	21.4%	16.1%	12.5%
	ratio yes/no	2.24	4.75	1.04	0.79	0.73	0.67	2.21	2.13	3.16	3.44	3.72	4.31	1.87	3.69
	p-value	0.033	0.000	0.748	0.002	0.005	0.016	0.044	0.154	0.047	0.019	0.034	0.005	0.149	0.049
20	no	11.1%	7.2%	60.7%	95.3%	79.2%	55.8%	10.8%	6.5%	5.2%	0.9%	4.5%	5.4%	9.9%	4.3%
	yes	25.0%	32.1%	60.7%	76.8%	58.9%	42.9%	23.2%	12.5%	16.1%	1.8%	16.1%	23.2%	17.9%	14.3%
	ratio yes/no	2.26	4.45	1.00	0.81	0.74	0.77	2.14	1.91	3.10	1.98	3.56	4.28	1.80	3.33
	p-value	0.024	0.000	0.999	0.002	0.005	0.073	0.039	0.201	0.036	0.633	0.026	0.003	0.144	0.042

Key:
- **2.00** Significantly (p≤0.05)correlated with Colorado pikeminnow captures
- *2.00* Marginally (P>.05, <0.10) correlated with Colorado pikeminnow captures
- **2.00** Significantly correlated with no Colorado pikeminnow capture

Table 3.05. **Portion of samples with and without Colorado pikeminnow captures that contain certain habitats and the significance of the difference for August 2009 samples.**

Distance (m) from Seined Boundary	Colorado Pikeminnow Captured	Riffle	Slack-water	Embay-ment	Rood Wad	Cobble Shoal	Slack-water + Cobble Shoal	Run + Cobble Shoal	Run + Slack-water + Cobble Shoal	Run + Riffle	Run + Riffle + Slack-water	Run + Slack-water + Root Wad	Riffle + Cobble Shoal	Riffle + Slack-water	Riffle + Slack-water + Cobble Shoal	Riffle + Cobble Bar + Cobble Shoal
Seined area	no	29%	53%	2%	14%	38%	19%	*26%*	13%	17%	10%	6%	10%	15%	5%	2%
	yes	18%	100%	0%	0%	27%	27%	*9%*	9%	0%	0%	0%	9%	18%	9%	9%
	ratio yes/no	0.63	1.89	0.00	0.00	0.72	1.43	*0.35*	0.69	0.00	0.00	0.00	0.92	1.22	2.00	3.67
	p-value	0.410	0.000	0.014	0.000	0.472	0.576	*0.100*	0.667	0.000	0.000	0.000	0.931	0.795	0.631	0.486
5	no	43%	65%	3%	29%	57%	36%	45%	31%	31%	25%	21%	28%	31%	19%	23%
	yes	45%	100%	0%	27%	55%	55%	27%	27%	9%	9%	9%	27%	45%	27%	18%
	ratio yes/no	1.06	1.53	0.00	0.94	0.96	1.52	0.61	0.87	0.29	0.36	0.44	0.97	1.47	1.43	0.80
	p-value	0.880	0.000	0.004	0.911	0.900	0.272	0.255	0.779	0.038	0.116	0.245	0.955	0.387	0.576	0.723
10	no	48%	71%	4%	38%	64%	43%	*54%*	38%	39%	30%	*29%*	36%	36%	26%	31%
	yes	45%	100%	0%	36%	55%	55%	*27%*	27%	18%	18%	*9%*	27%	45%	27%	18%
	ratio yes/no	0.96	1.41	0.00	0.97	0.86	1.26	*0.51*	0.72	0.46	0.61	*0.31*	0.76	1.26	1.05	0.59
	p-value	0.900	0.000	0.003	0.938	0.583	0.502	*0.094*	0.472	0.122	0.376	*0.060*	0.560	0.566	0.933	0.344
15	no	54%	77%	7%	41%	71%	54%	63%	48%	46%	38%	36%	45%	44%	36%	37%
	yes	45%	100%	0%	36%	64%	64%	36%	36%	18%	18%	9%	36%	45%	36%	27%
	ratio yes/no	0.85	1.29	0.00	0.88	0.89	1.18	0.58	0.77	0.39	0.48	0.25	0.81	1.03	1.00	0.73
	p-value	0.617	0.000	0.000	0.756	0.622	0.537	0.117	0.488	0.047	0.143	0.016	0.606	0.940	1.000	0.506
20	no	55%	76%	6%	43%	71%	54%	62%	48%	47%	38%	36%	45%	45%	37%	38%
	yes	55%	100%	0%	36%	55%	55%	27%	27%	27%	27%	9%	36%	55%	36%	27%
	ratio yes/no	1.00	1.31	0.00	0.85	0.77	1.01	0.44	0.56	0.58	0.72	0.26	0.80	1.22	0.99	0.72
	p-value	1.000	0.000	0.000	0.698	0.325	0.980	0.033	0.172	0.206	0.472	0.017	0.571	0.550	0.979	0.472

Key:		
	2.00	Significantly (p≤0.05)correlated with Colorado pikeminnow captures
	2.00	Marginally (P>.05, <0.10) correlated with Colorado pikeminnow captures
	2.00	Significantly correlated with no Colorado pikeminnow capture
	2.00	Marginally correlated with Colorado pikeminnow captures

Table 3.06. Portion of samples with and without Colorado pikeminnow captures that contain certain habitats and the significance of the difference for August 2008 and 2009 samples combined.

Distance (m) from Seined Boundary	Colorado Pikeminnow Captured	Riffle	Slack-water	Embay-ment	Rood Wad	Cobble Shoal	Slack-water + Cobble Shoal	Run + Cobble Shoal	Run + Slack-water + Cobble Shoal	Run + Riffle	Run + Riffle + Slack-water	Run + Slack-water + Root Wad	Riffle + Cobble Shoal	Riffle + Slack-water	Riffle + Slack-water + Cobble Shoal	Riffle + Cobble Bar + Cobble Shoal
Seined area	no	29%	**52%**	2%	11%	**36%**	**19%**	23%	12%	17%	10%	5%	**9%**	*15%*	**5%**	**4%**
	yes	38%	**73%**	2%	9%	**54%**	**39%**	25%	20%	21%	16%	2%	**23%**	*27%*	**16%**	**14%**
	ratio yes/no	1.31	**1.41**	0.83	0.81	**1.51**	**2.12**	1.10	1.69	1.26	1.59	0.38	**2.45**	*1.80*	**3.24**	**3.49**
	p-value	0.202	**0.001**	0.847	0.617	**0.013**	**0.003**	0.701	0.155	0.451	0.253	0.151	**0.022**	*0.059*	**0.032**	**0.038**
5	no	**43.0%**	**64.4%**	2.4%	24.6%	**52.7%**	**33.7%**	40.6%	29.2%	33.0%	26.1%	16.8%	**25.9%**	*30.7%*	*17.9%*	**21.2%**
	yes	**57.1%**	**78.6%**	3.6%	26.8%	**71.4%**	**55.4%**	50.0%	37.5%	39.3%	28.6%	16.1%	**42.9%**	*42.9%*	*30.4%*	**37.5%**
	ratio yes/no	**1.33**	**1.22**	1.50	1.09	**1.36**	**1.64**	1.23	1.29	1.19	1.09	0.95	**1.65**	*1.40*	*1.69*	**1.77**
	p-value	**0.049**	**0.020**	0.647	0.732	**0.005**	**0.003**	0.191	0.228	0.372	0.706	0.883	**0.018**	*0.087*	*0.058*	**0.019**
10	no	**49%**	**72%**	3%	32%	*60%*	**43%**	51%	38%	41%	34%	26%	**33%**	**39%**	**26%**	**27%**
	yes	**63%**	**86%**	4%	30%	*71%*	**63%**	57%	50%	48%	43%	20%	**48%**	**55%**	**43%**	**45%**
	ratio yes/no	**1.29**	**1.18**	1.18	0.94	*1.19*	**1.45**	1.13	1.30	1.16	1.26	0.76	**1.44**	**1.42**	**1.64**	**1.63**
	p-value	**0.049**	**0.011**	0.835	0.757	*0.084*	**0.007**	0.369	0.109	0.347	0.218	0.294	**0.041**	**0.023**	**0.019**	**0.017**
15	no	**54%**	**77%**	5%	38%	66%	**51%**	58%	*46%*	48%	*42%*	**33%**	**41%**	**47%**	**34%**	**34%**
	yes	**70%**	**91%**	4%	32%	73%	**70%**	61%	*59%*	55%	*54%*	**21%**	**57%**	**64%**	**54%**	**50%**
	ratio yes/no	**1.28**	**1.18**	0.79	0.84	1.11	**1.37**	1.05	*1.28*	1.17	*1.29*	**0.64**	**1.40**	**1.38**	**1.56**	**1.48**
	p-value	**0.024**	**0.002**	0.720	0.366	0.253	**0.006**	0.709	*0.070*	0.273	*0.099*	**0.051**	**0.024**	**0.012**	**0.008**	**0.025**
20	no	**57%**	**79%**	5%	42%	67%	**54%**	60%	**49%**	51%	**45%**	37%	*44%*	**50%**	**37%**	**37%**
	yes	**73%**	**95%**	4%	36%	71%	**71%**	64%	**64%**	64%	**64%**	27%	*57%*	**71%**	**57%**	**52%**
	ratio yes/no	**1.28**	**1.20**	0.79	0.84	1.06	**1.33**	1.07	**1.30**	1.26	**1.42**	0.72	*1.30*	**1.44**	**1.53**	**1.41**
	p-value	**0.015**	**0.000**	0.720	0.338	0.513	**0.008**	0.559	**0.034**	0.057	**0.007**	0.109	*0.064*	**0.001**	**0.006**	**0.037**

Key:

	2.00	Significantly (p≤0.05)correlated with Colorado pikeminnow captures
	2.00	Marginally (P>.05, <0.10) correlated with Colorado pikeminnow captures
	2.00	Significantly correlated with no Colorado pikeminnow capture

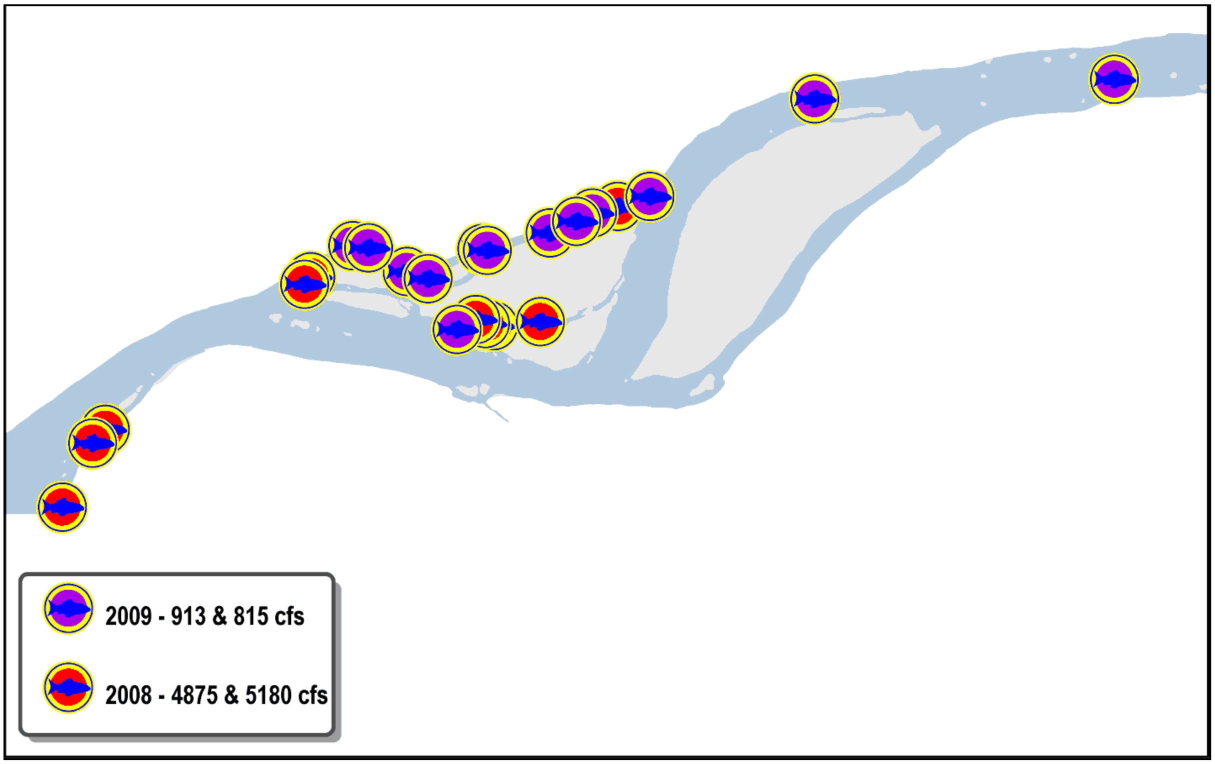


Figure 3.02. Colorado pikeminnow capture locations in DR 82, March 2008 and 2009.

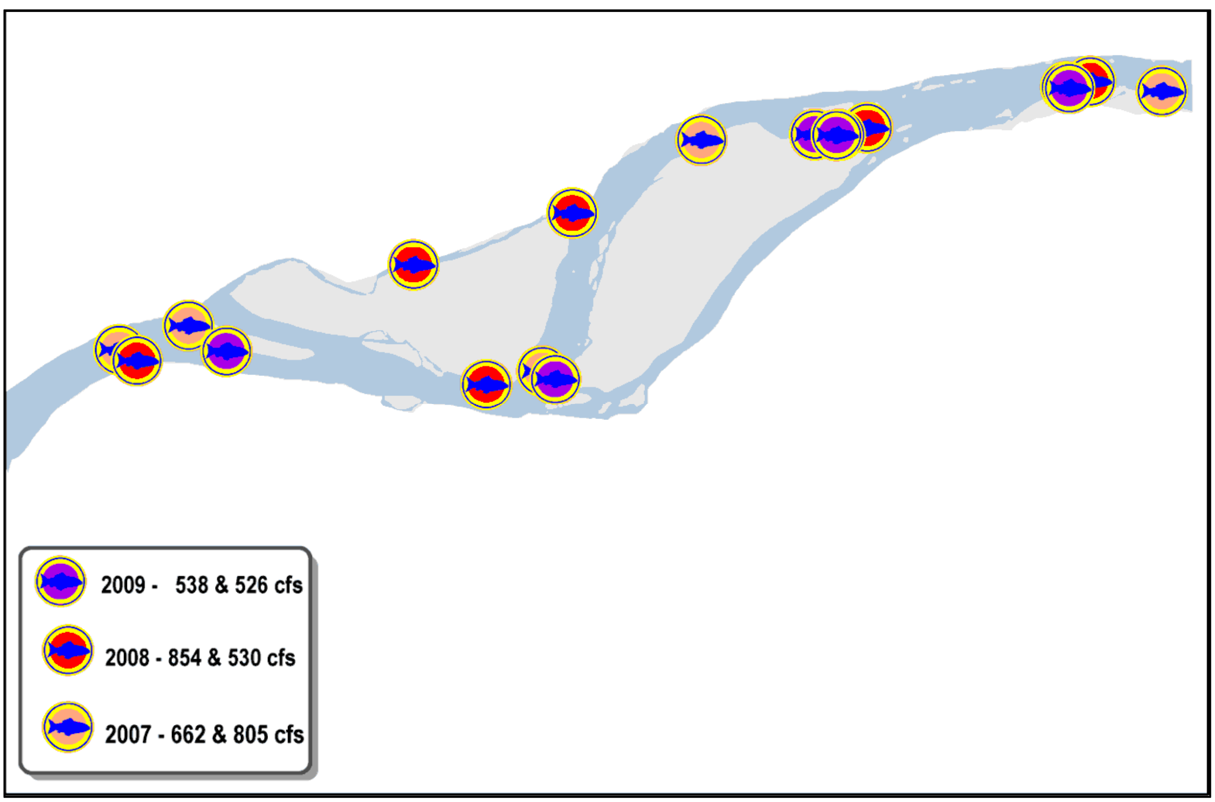


Figure 3.03. Colorado pikeminnow capture locations in DR 82, August 2007 - 2009

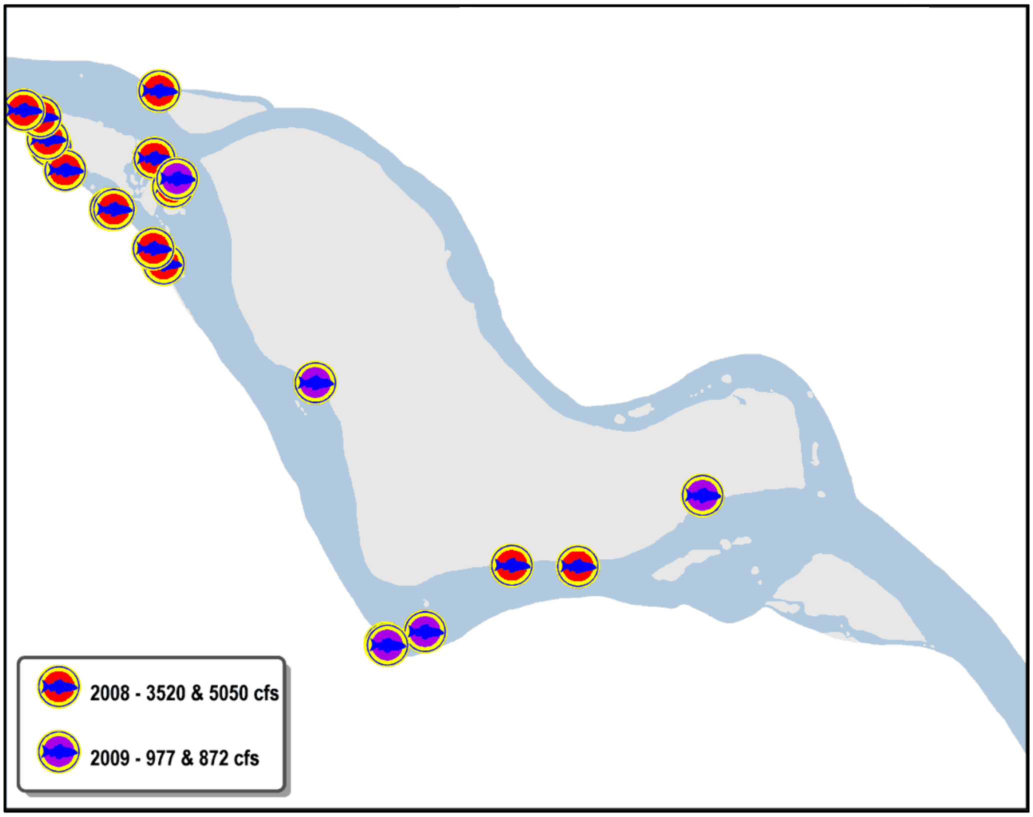


Figure 3.04. Colorado pikeminnow capture locations in DR 137, March 2008 and 2009.

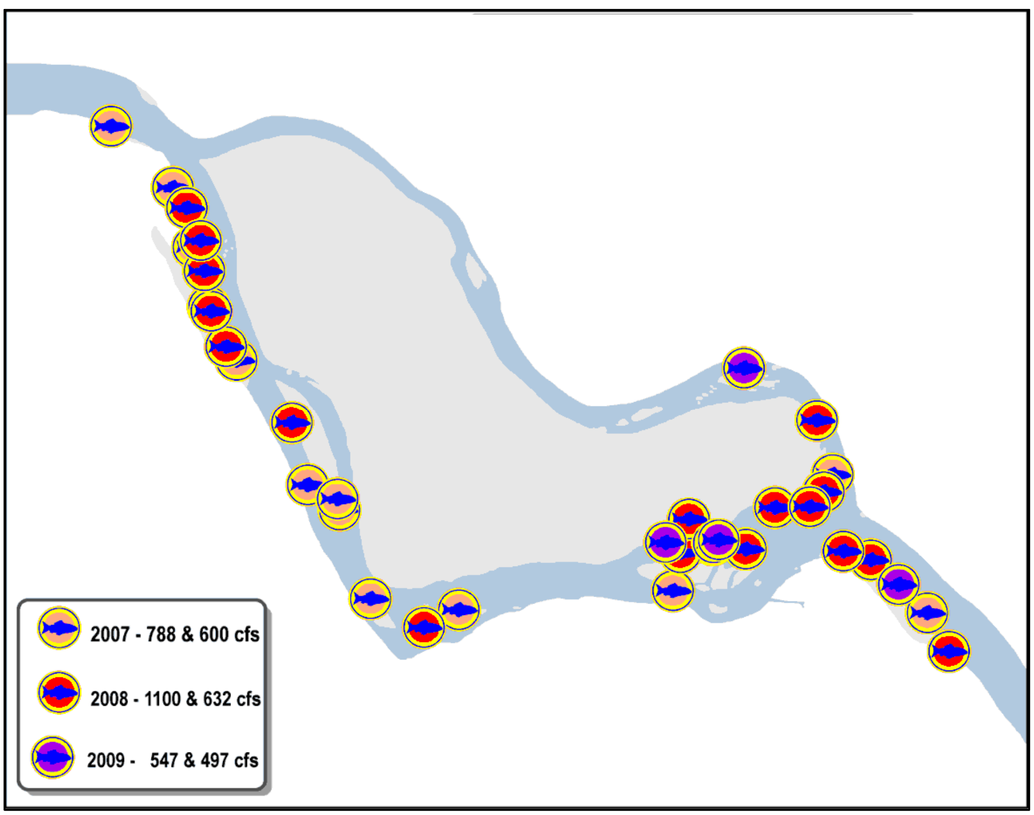


Figure 3.05. Colorado pikeminnow capture locations in DR 82, August 2007 - 2009.

Non-Native Removal and Large-Bodied Monitoring Razorback Sucker and Colorado Pikeminnow Habitat Association

The combined dataset for non-native removal and large-bodied monitoring had 470 razorback sucker and 1,205 Colorado pikeminnow captures with GPS locations, approximately 2.7 times the captures in 2008. They were located in nearly twice as many 0.1 mile reaches as in 2008 and the habitat associations that were significant are somewhat different.

In 2008, razorback sucker captures were associated with reaches that had greater abundance of Islands, cobble type habitat and isolated pools (Table 3.07), although the ratio for cobble types is not much greater than 1.0. In 2009, reaches with greater abundance of pools and riffles were associated with razorback sucker and reaches with sand shoals or boulders were less likely to have captures (Table 3.08).

Colorado pikeminnow captures in 2008 were significantly associated only with islands and then not strongly so (Table 3.07). In 2009, with 2.7 times as many captures, Colorado pikeminnow were significantly associated with riffle and cobble type habitats and marginally associated with habitat complexity (total number of habitats) and richness (number of different habitat types) within the 0.1 mile reaches (Table 3.08). Tributaries were indicated as significant, but were in such low abundance the association may not be meaningful. Colorado pikeminnow were less likely to be found in reaches with high abundance of sand type habitats.

Table 3.07. Habitat associations for razorback sucker (ZYRTEX) and Colorado pikeminnow (PTYLUC) captures by non-native removal and large-bodied monitoring studies resolved to 0.1 mile river reaches, 2008

Habitat	Adult Monitoring				Non-Native Removal			
	Habitats per 0.1 mi		Ratio with / without	T-test p- value	Habitats per 0.1 mi		Ratio with / without	T-test p-value
	With PTYLUC	W/O PTYLUC			With PTYLUC	W/O PTYLUC		
Cobble shoal	**1.03**	**0.91**	**1.14**	**0.00**	1.05	0.92	1.14	0.14
Cobble shoal/run	*0.13*	*0.09*	*1.44*	*0.09*	0.12	0.10	1.15	0.59
Isolated Pool	**0.12**	**0.04**	**2.81**	**0.03**	0.08	0.05	1.57	0.20
Overhanging Vegetation	*0.19*	*0.16*	*1.20*	*0.06*	0.21	0.19	1.15	0.48
Island	**0.72**	**0.56**	**1.29**	**0.00**	*0.69*	*0.58*	*1.19*	*0.06*
Cobble types	**1.94**	**1.85**	**1.05**	**0.01**	2.02	1.88	1.08	0.34
Total Fish Captured	178				447			
Total 0.1 mile reaches	119	1075			267	698		

Table 3.08. Habitat associations for razorback sucker (ZYRTEX) and Colorado pikeminnow (PTYLUC) captures by non-native removal and large-bodied monitoring studies resolved to 0.1 mile river reaches, 2009

Habitat	Habitats per 0.1 mi		Ratio with / without	T-test p- value	Habitats per 0.1 mi		Ratio with / without	T-test p-value
	With XYRTEX	W/O XYRTEX			With PTYLUC	W/O PTYLUC		
Pool	**0.09**	**0.04**	**2.17**	**0.025**	0.06	0.05	1.06	0.849
Sand shoal	**0.59**	**0.77**	**0.78**	**0.006**	0.64	0.80	0.80	0.006
Riffle	0.78	0.72	1.09	0.381	**0.80**	**0.68**	**1.19**	**0.046**
Riffle/chute	0.07	0.05	1.34	0.380	**0.08**	**0.04**	**1.81**	**0.043**
Rootwad pile	**0.16**	**0.34**	**0.48**	**0.000**	*0.25*	*0.34*	*0.73*	*0.066*
Sand bar	**0.70**	**0.85**	**0.83**	**0.049**	0.80	0.83	0.97	0.666
Tributary	0.01	0.001	9.48	0.127	**0.01**	**0.00**	**n/a**	**0.045**
Island	0.68	0.60	1.14	0.171	0.65	0.59	1.10	0.253
Pocket water	0.01	0.03	0.50	0.205	0.02	0.02	0.79	0.628
Boulders	**0.03**	**0.11**	**0.23**	**0.028**	0.05	0.12	0.46	0.217
Cobble types	0.70	0.57	1.24	0.465	2.09	1.81	1.16	0.034
Sand types	0.68	0.67	1.02	0.102	*1.86*	*2.07*	*0.90*	*0.081*
All riffle types	**0.65**	**0.40**	**1.61**	**0.025**	**2.03**	**1.73**	**1.17**	**0.016**
Complexity (wet types)	6.11	6.11	1.00	0.999	*6.34*	*5.91*	*1.07*	*0.090*
Richness (hab. types/0.1 mi)	6.06	4.70	1.29	0.906	*6.21*	*5.86*	*1.06*	*0.058*
Total Fish Captured	470				1,205			
Total 0.1 mile reaches	237	749			461	525		

The fall adult monitoring habitat associations within sampled river miles were quite different from the 0.1 mile combined results for both razorback sucker and Colorado pikeminnow. The abundance of 13 habitat types or combinations plus all complexity measurements (complexity, richness and diversity) were significantly associated with razorback sucker captures, with selection ratios as high as 4.05 (Table 3.09). The abundance of 14 habitat types or combinations in addition to all the complexity measurements are significant for Colorado pikeminnow, with selection ratios as high as 12 (Table 3.09). The habitat associations differed from razorback sucker in the absence of sand type habitats.

Since this relationship is based on the ratio of the number of habitats per mile with and without captures, the large number of associations just means that both species are more likely to be captured where habitat is complex (high numbers of habitat polygons mapped). Both Colorado pikeminnow and razorback sucker appeared to have an affinity for river miles with high island counts and overhanging vegetation (ratios of 12.75 and 11.91, respectively, for Colorado pikeminnow versus 3.24 and 2.65 for razorback sucker). Cobble and riffle habitats were important to both species.

Table 3.09. Habitat associations for razorback sucker (ZYRTEX) and Colorado Pikeminnow (PTYLUC) captures in sampled miles only from the large-bodied monitoring program resolved to 1.0 river mile, 2009

Habitat	Average per mile		Ratio	Tstat	Average per mile		Ratio	Tstat
	With XYRTEC	Without XYRTEC	with / without		With PTYLUC	Without PTYLUC	with / without	
Pool	0.68	0.17	4.05	0.031	0.44	0.00	n/a	0.000
Sand shoal	5.65	3.72	1.52	0.025				
cobble shoal	8.65	3.67	2.36	0.000	6.43	1.13	5.67	0.000
Sand shoal/run	3.65	2.02	1.81	0.009				
Cobble shoal/run	0.70	0.33	2.11	0.044	0.54	0.13	4.03	0.004
Run					5.36	3.40	1.58	0.002
Run/riffle	3.81	2.65	1.44	0.027	3.40	1.27	2.68	0.002
Riffle	6.54	3.02	2.17	0.000	4.86	1.33	3.65	0.001
Riffle/chute	0.49	0.18	2.65	0.044	*0.34*	*0.13*	*2.53*	*0.095*
Overhanging vegetation	2.16	0.82	2.65	0.016	1.59	0.13	11.91	0.000
Cobble bar	*6.14*	*4.37*	*1.40*	*0.056*	5.83	1.13	5.14	0.000
Rootwad pile					1.90	0.33	5.70	0.003
Island	2.54	0.78	3.24	0.000	1.70	0.13	12.75	0.000
Run types	10.41	7.72	1.35	0.028	9.41	4.80	1.96	0.000
Riffle types	15.00	9.63	1.56	0.004	12.75	5.73	2.22	0.007
Cobble types	15.49	8.37	1.85	0.001	12.79	2.40	5.33	0.000
Vegetation types					7.65	3.27	2.34	0.004
Total mapped features	67.41	47.50	1.42	0.007	59.58	32.33	1.84	0.002
Richness (habitat types)	11.22	9.12	1.23	0.002	10.43	7.33	1.42	0.005
Complexity (total wet habitats)	47.62	33.05	1.44	0.003	40.84	27.33	1.49	0.009
Diversity (Shannon-Weiner Index)	2.08	1.91	1.09	0.028	2.06	1.56	1.32	0.008
2009 captures	76				369			
Sampled River Miles	37	60			80	15	5.33	

Larval Razorback Sucker Habitat Association

In the May and June sampling periods for larval fish, up to nine habitat types were sampled in 2007 – 2009 (pers. com. Brandenburg, 2009; Table 3.10). Larval razorback sucker were captured in two to six of these habitat types over this period, but over 90% of the total larval razorback suckers captured were in backwaters each year.

Among the three years, the portion of samples that had some type of cover (debris, inundated vegetation or overhanging vegetation) ranged from 41% in 2009 to 80% in 2008 (Table 3.11). During the same period the portion of samples with razorback sucker larvae with cover ranged from 54% in 2007 to 81% in 2008. Only in 2009 was the proportion higher in samples with razorback sucker than in all samples. Even then, the difference was not significant. It appears that cover is in greater abundance at higher flow (2008), but it is not a significant factor in use by larval razorback sucker.

Depth in samples with larval razorback sucker captures was significantly greater, both in 2009 and in all years combined when all samples were included in the analysis (Table 3.12).

Table 3.10. Larval samples by habitat during the May and June sampling periods with and without larval razorback suckers, 2007-2009.

Habitat	2007			2008			2009		
	Sampled	With XerTex	Total XerTex	Sampled	With XerTex	Total XerTex	Sampled	With XerTex	Total XerTex
Backwater	60	23	181	87	26	123	63	24	249
Cobble shoal				1	0	0			
Eddy	1	0	0						
Embayment	12	1	1	2	0	0	9	2	4
Isolated pool							3	3	13
Shore run	3	1	5	1	0	0			
Mixed habitat	1	0	0						
Pocket water	2	0	0				3	1	1
Pool	30	2	10	8	0	0	28	3	4
Sand shoal	6	0	0	2	0	0	1	0	0
Slackwater	7	1	1	19	0	0	2	1	1
Tributary				1	1	3			
Total	***122***	***28***	***198***	***121***	***27***	***126***	***109***	***34***	***272***
Average Flow-cfs	4,390			8,054			2,665		
Max flow - cfs	6,710			9,690			4,920		
min flow - cfs	3,120			4,470			1,020		

Table 3.11. Samples with and without cover and with and larval razorback suckers (XerTex), 2007 - 2009

Cover	2007			2008			2009		
	Sampled	With XerTex	Total XerTex	Sampled	With XerTex	Total XerTex	Sampled	With XerTex	Total XerTex
Debris	19	4	10	9	0	0	17	5	7
Inundated Veg	61	17	93	80	22	101	21	8	126
Overhanging Veg	8	1	3	8	1	1	7	5	83
None	34	6	92	24	4	24	64	16	56
Total	122	28	198	121	27	126	109	34	272
percent w/cover	72%	79%	54%	80%	85%	81%	41%	53%	79%
Average Flow-cfs	4,390			8,054			2,665		
Max flow - cfs	6,710			9,690			4,920		
min flow - cfs	3,120			4,470			1,020		

Table 3.12. Average maximum depth in samples with and without razorback sucker larvae, 2007-2009.

Period	Metric	With Razorback	Without Razorback	T-Stat
2009	mean max depth, m	0.620	0.461	0.006
	95% confidence, m	0.093	0.057	
2007-2009	mean max depth, m	0.577	0.388	4.75E-07
	95% confidence, m	0.063	0.029	

When only backwaters were included in the analysis there was no significant difference. It appears that deeper habitats are more likely to have larval razorbacks, but that may be biased by the importance of backwaters, which tended to have greater maximum depths that other habitats sampled and are where most of the larval razorback suckers are found.

Backwater persistence through the April – September larval sampling period was assessed for the first time in 2009. Backwater habitats from five sampling periods over a range of flows from 564 cfs to 4,660 cfs (Figure 3.06) were examined for persistence. Larval razorback sucker were only captured during the May and June sampling trips. A total of 38 backwaters were sampled in May, of which only two were still available in June (Table 3.13). None of the backwaters sampled in May persisted until July. This is the period with the greatest change in flow, changing from 4,660 cfs at sampling in May to a peak of 6,760 cfs, returning to 1,020 cfs during the June sampling trip. Following runoff, the backwaters were more persistent with up to 43% persisting at least one month. Even in the later period only 4% persisted for two months and no backwaters persisted more than three months.

Of the two backwaters that persisted from May to June, one had larval razorback sucker in May but not in June. Only one sample location river-wide had larval razorback suckers in May and June (n=52 and 2, respectively). It was located at RM 3.3. It was a backwater in May, but an isolated pool in June. No razorback sucker remained in that habitat (or any habitat sampled) in July.

This assessment is only an approximation of persistence. Not all backwaters were measured, so it is possible that some sampled in the first sampling were simply missed the second and third trips. However, at the very least all habitats that had fish would have been sampled in subsequent trips if they were still available and in suitable condition. Even though this study has limitations it is apparent that backwater persistence is very low in the San Juan River from razorback sucker spawning through early summer as well as being generally low in abundance.

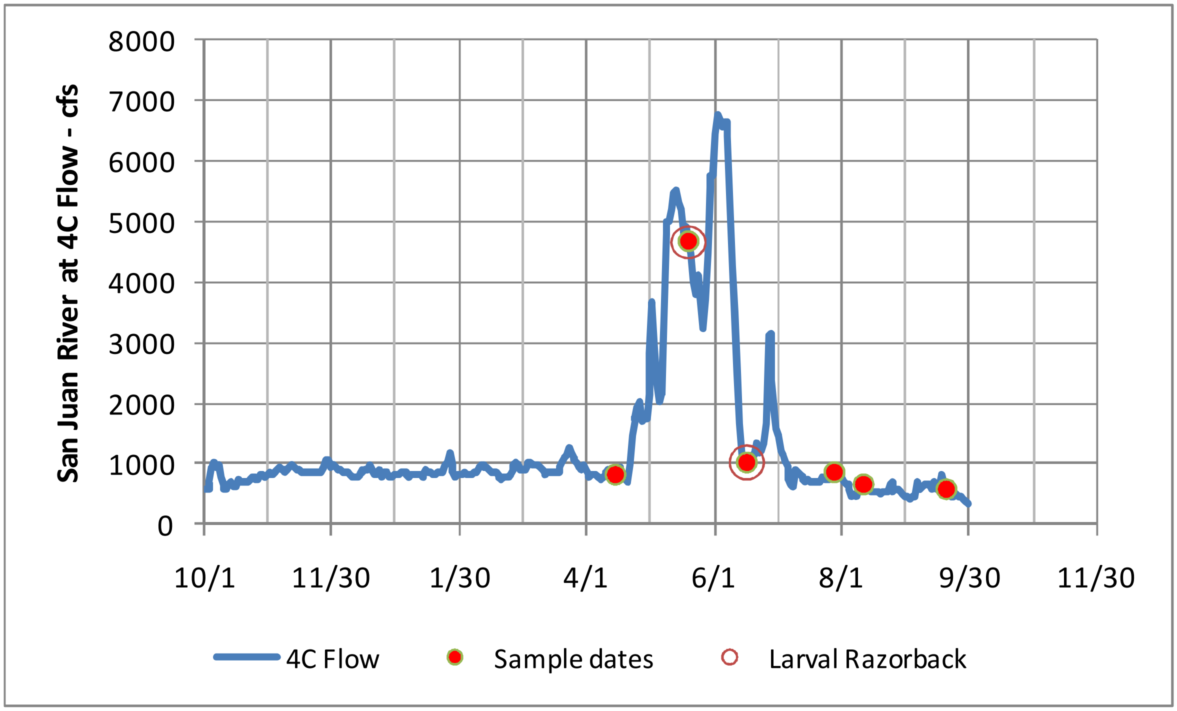


Figure 3.06. 2009 San Juan River Flow at Four Corners, New Mexico and Larval fish sampling dates.

Table 3.13. Summary of 2009 larval sampling results showing backwater habitat persistence.

Trip	Mean Date	Samples	Back-waters Sampled	BW % of Samples	4C flow cfs	sites w/RZ	RZ captures	Backwaters first sampled and remaining by trip 1	2	3	4	5
1	4/15/09	56	31	55%	827	0		31				
2	5/20/09	55	38	69%	4660	21	238	8	38			
3	6/17/09	54	26	48%	1020	13	34	1	2	26		
4	7/29/09	61	28	46%	854	0		0	0	9	28	
5	8/12/09	66	36	55%	646	0				3	12	36
6	9/20/09	47	24	51%	564	0				0	1	3

DISCUSSION

Detailed Reach Habitat Association

Combinations of certain habitats within the proximity of Colorado pikeminnow captures appear to be important. The relationship between Colorado pikeminnow captures and combinations of low velocity habitats adjacent to moderate velocity habitats is significant, but diminishes beyond about 5 m outside the seined area. The habitat associations in March when the Colorado pikeminnow are smaller are with lower velocity habitats. The conclusions from the habitat association study are similar to those from the target habitat selection study, but show that combinations of habitats may be even more important than single habitats in describing locations selected by young Colorado pikeminnow.

In August, the older Colorado pikeminnow are associated with different habitats than in March. They use more habitats and range further. The habitats used have a greater range of velocity and are significantly related to cobble substrate. These conclusions support those of the habitat selection study and add the importance of habitat combinations in describing areas that may be most important for this age of Colorado pikeminnow.

The results of the detailed reach study indicate the importance of collecting habitat data simultaneously with fish capture data for small-bodied fish. The habitats they use change markedly with only a few hundred cfs change in flow and are easily changed by storm events that lead to fine sediment deposition. The original hypothesis was that a more detailed scale of sampling was needed to describe habitat availability and selection and allow integration of fish capture and habitat mapping. Although increased detail does improve the description of available habitat and is helpful for integrating fish and habitat data, it is not nearly as important as mapping habitat and collecting fish at the same time. The larger scale standard habitat mapping is adequate to determine habitat availability and particularly trends in habitat availability. If habitat use by small-bodied fish is desired, the habitat must be mapped (or at least identified) at the time of sampling.

Non-Native Removal and Large-Bodied Monitoring Razorback Sucker and Colorado Pikeminnow Habitat Association

The GPS location datasets for both Colorado pikeminnow and razorback sucker demonstrate that habitat is typically more complex (more habitat polygons mapped) where these fish are captured than in locations where they are not. Both species are more likely to be present in the vicinity of riffle habitats and less likely to be found where there is an abundance of sand type habitats. All though the associations are significant, the selection for these conditions is not particularly strong using this dataset.

The GPS location data set is difficult to normalize for effort to provide a uniform look at habitat use throughout the range of the endangered fishes. The multiple pass non-native removal trips displace fish down-river and possibly re-sample prior to their redistribution to more preferred locations. The effort and the number of captures in the upper reaches are also much greater. The results are therefore biased toward the habitat in the upper reaches and are influenced by displacement induced by the sampling method.

In 2009 a river-mile scale analysis was introduced using the large-bodied monitoring data from the sampled miles. This data set represents more uniform effort and can be analyzed in the lower canyon reaches where the GPS data become inaccurate. The conclusions from this analysis are generally the same as for the GPS study, but the associations with complexity are stronger for both species. The two endangered fishes are more likely to be found in river miles with more mapped habitats, particularly those associated with cobble, riffles and islands.

One caution for both data sets is that the results are based on fish that are stocked in the upper reaches of the river and the simpler river reaches typically occur lower in the system. This could create bias toward more complex reaches. For example, Colorado pikeminnow were only absent from one sampled river mile above RM 68 and from 15 miles total. The one sampled mile in the upper river where they were not present (RM 160) was above average in complexity.

The strength of either of these analyses diminishes as more fish are captured as the results are based on presence-absence. With higher abundance an analysis that considers density may be necessary.

Since the last river-wide habitat mapping occurred in 2007 the actual habitat availability could be different than described by the mapping. The results here should be considered a general indication of the importance of habitat complexity to larger bodied Colorado pikeminnow and razorback sucker. It would be advisable to repeat the analysis with habitat and fish capture data from the same year when the habitat is again mapped river-wide.

Larval Razorback Sucker Habitat Association

The larval fish data indicated the importance of backwaters for larval razorback sucker since 90% or more of the captures were in backwaters in each of the three years. Cover was not found to be important as captures were as likely in habitats with cover as without. Habitats with larval razorback sucker captures had significantly deeper maximum depths than those without, but that may be biased by the high percentage of backwaters in the sites with captures. Backwaters tended to have deeper maximum depths than other habitats sampled. When depth was analyzed for backwaters only, there was no significant difference in depth between samples with captures and those without.

Backwater habitat persistence from the time of first capture was found to be very low. Only 2 out of 38 backwaters sampled in May persisted until the next sampling in June and no backwater persisted more than three months. Only one habitat had larval razorback sucker captures in both May and June (n=52 and 2, respectively) and it had changed from a backwater to an isolated pool. It is also located very low in the river (RM 3.3). Low backwater abundance in the system and poor persistence may be one reason the retention of larval razorback sucker is low in the San Juan River.

The persistence results are based on sampled backwaters and not all backwaters are sampled. To more accurately measure persistence it would be necessary to attempt to sample the same habitats each time if they are available and of suitable quality to sample. It would also be helpful to map the habitats sampled so the change with time could be assessed. The data presently collected by the larval sampling study is adequate to describe changes in condition other than size.

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APPENDIX A

Table A1. Summary of habitat selection ratios: March 2009 - RM 82, 131, and 137 (combined)*.

SPECIES/ FISH GROUP	Colorado pikeminnow	All fish	All Natives	All Non-Natives	Bluehead sucker	Flannelmouth sucker	Speckled dace	Red Shiner	Fathead minnow	Channel catfish
HABITAT	RATIO (n=58)	RATIO (n=383)	RATIO (n=250)	RATIO (n=128)	RATIO (n=1)	RATIO (n=16)	RATIO (n=175)	RATIO (n=112)	RATIO (n=9)	RATIO (n=7)
BACKWATER	19.22	6.72	4.69	10.10				9.95		
COBBLE SHOAL	0.00	0.25	0.39	0.00			0.50	0.00		
EDDY										
EMBAYMENT	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
ISOLATED POOL		0.00								
POOL	9.93	10.27	6.70	17.23			6.01	17.45		
RIFFLE	0.00	0.72		0.14			1.42	0.15		
SAND SHOAL										
RUN	0.22	0.40	0.60	0.03			0.72	0.04		
SLACKWATER	0.48	0.41	0.55	0.12			0.50	0.07		
Pearson Chi^2	545 (p=0.00)	1637 (p=0.00)	424 (p=0.00)	1617 (p=0.00)	NA	6.95 (p=0.54)	206.6 (p=0.00)	1444 (p=0.00)	NA	NA
Log-likelihood Chi^2	196.6 (p=0.00)	688 (p=0.00)	225 (p=0.00)	558 (p=0.00)	NA	6.86 (0.55)	118.99 (p=0.00)	497 (p=0.00)	NA	NA

* Significant ($p<0.05$) Chi^2 values suggest selection for particular habitat types occur.

Only significant selection ratios ($p<0.05$) are shown.

Ratio values greater than one indicate selection for, ratios below one indicate selection against, and ratios equal to one indicate no selection. NA: Not calculated due to small sample size. NS: Habitat not sampled.

Table A2. Summary of habitat selection ratios: August 2009 - DR 82, DR131, and DR137 (combined)*.

SPECIES/ FISH GROUP	Colorado pikeminnow	All fish	All Natives	All Non-Natives	Bluehead sucker	Flannelmouth sucker	Speckled dace	Red Shiner	Fathead minnow	Channel catfish
HABITAT	RATIO (n=11)	RATIO (n=2636)	RATIO (n=1951)	RATIO (n=510)	RATIO (n=190)	RATIO (n=305)	RATIO (n=1440)	RATIO (n=319)	RATIO (n=14)	RATIO (n=177)
BACKWATER		6.220	3.806	11.249	6.437	2.578	3.762	17.071	20.801	0.000
COBBLE SHOAL		0.555	0.394		0.505	0.218	0.415	0.602		2.211
EDDY		3.919	5.069		5.479		5.866	0.251		2.036
EMBAYMENT		4.364	3.326	5.783	6.985	13.054				
ISOLATED POOL										
PLINGE	NS									
POOL		3.446	3.293	3.600			4.328	4.543	6.902	
RIFFLE		0.847		0.235	0.126	0.118	1.425	0.151		0.407
SAND SHOAL			1.229			0.607	1.407	0.649		
RUN	0.00**	0.270	0.293	0.278	0.205	0.198	0.327	0.089	0.000	0.641
SLACKWATER	2.76	0.834		0.490		1.968	0.727	0.225		
Pearson Chi^2	19.42 (p=0.01)	4054 (p=0.00)	2003 (p=0.00)	2137 (p=0.00)	390 (p=0.00)	525 (p=0.00)	1889 (p=0.00)	3230 (p=0.00)	209 (p=0.00)	60 (p=0.00)
Log-likelihood Chi^2	22.38 (p=0.004)	2421 (p=0.00)	1409 (p=0.00)	873 (p=0.00)	233 (p=0.00)	338 (p=0.00)	1210 (p=0.00)	1070 (p=0.00)	65 (p=0.00)	60 (p=0.00)

* Significant ($p<0.05$) Chi^2 values suggest selection for particular habitat types occur.

Only significant selection ratios ($p<0.05$) are shown.

Ratio values greater than one indicate selection for, ratios below one indicate selection against, and ratios equal to one indicate no selection.
NA: Not calculated due to small sample size. NS: Habitat not sampled.
** Marginally significant (p=0.06).