COLORADO RIVER RECOVERY PROGRAM
FY 2018 ANNUAL PROJECT REPORT

RECOVERY PROGRAM
PROJECT NUMBER: 138

I. Project Title: Annual fall monitoring of young-of-year Colorado pikeminnow and small-bodied native fishes

II. Bureau of Reclamation Agreement Number(s): R14AP00007
Project/Grant Period: Start date (Mo/Day/Yr): 05/01/2014
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Reporting period end date: 09/30/2018
Is this the final report? Yes _____ No __X__

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IV. Abstract:

Monitoring of young-of-year (YOY) Colorado pikeminnow (*Ptychocheilus lucius*) is an ongoing project initiated in 1986 in the upper Colorado River basin as part of the Interagency Standardized Monitoring Program (USFWS 1987) to evaluate recruitment success of age-0 endangered fishes. In 2018, 78 young-of-year Colorado pikeminnow were encountered on the lower Colorado River (Reach 1), 57 on the lower Green River (Reach 3), and five on the middle Green River (Reach 4). Catch rates were the sixth highest on record in Reach 1, thirteenth lowest on record in Reach 3, and eighth lowest on record in Reach 4. Specifically for Green River reaches, summer base flows were consistent due to Flaming Gorge Dam (FGD) releases, with far more days in the desired range for pikeminnow recruitment (i.e., 1,700–3,000 cfs for Reach 4; 1,700–3,800 cfs for Reach 3) than 2017 (poor recruitment) and 2015 (extremely productive year). Limited larval transport in 2018 relative to 2015 may explain poor YOY recruitment in the Green River in 2018. Regardless, experimental FGD releases should continue in order to collect additional data for a more comprehensive evaluation of base flow regime manipulation.

V. Study Schedule:

1986–On going. It is anticipated that this study will continue indefinitely and will be a component of studies designed to evaluate a variety of management actions.

VI. Relationship to RIPRAP:

GENERAL RECOVERY PROGRAM SUPPORT ACTION PLAN

V.	Monitor populations and habitat and conduct research to support recovery actions (research, monitoring, and data management).
V.A.	Measure and document population and habitat parameters to determine status and biological response to recovery actions.
V.B.2.	Conduct appropriate studies to provide needed life history information.

GREEN RIVER ACTION PLAN: MAINSTEM

V.	Monitor populations and habitat and conduct research to support recovery actions (research, monitoring, and data management).
V.A.	Conduct research to acquire life history information and enhance scientific techniques required to complete recovery actions.

COLORADO RIVER ACTION PLAN: MAINSTEM

V.	Monitor populations and habitat and conduct research to support recovery actions (research, monitoring, and data management).
V.A.	Conduct research to acquire life history information and enhance scientific techniques required to complete recovery actions

VII. Accomplishment of FY 2018 Tasks and Deliverables, Discussion of Initial Findings and Shortcomings:

Task 1. Seining the middle Green River

Middle Green River (Reach 4):

Annual monitoring for young-of-year (YOY) Colorado pikeminnow (*Ptychocheilus lucius*) began 18 September 2018 and was completed on 26 September 2018. Beginning at Split Mountain boat ramp (river mile [RM] 319.3) and concluding at Sand Wash (RM 215.3), we sampled 57 backwater habitats that met Interagency Standardized Monitoring Program (ISMP; USFWS 1987) criteria: 21 primary, 20 secondary, and 16 tertiary. Tertiary backwaters originated and carried over from Recovery Program project #144 (discontinued) and were only sampled in reach four, in an effort to obtain additional information on low-velocity habitat use by native YOY and other small-bodied fishes.

These tertiary backwaters are not included in the ISMP protocol (USFWS 1987), but additional sampling in these habitats can provide useful information without the constraints of the ISMP methodology. A total of 4,760 m^2 of suitable habitat was seined in 2018 (primary and secondary backwaters only), which was 1,020 m^2 more area than 2017 (Breen et al. 2017). A total 7.6% of the available habitat was sampled from primary and secondary backwaters in 2018. An additional 2,069 m^2 of habitat was sampled from tertiary backwaters.

Discharge for the middle Green River is measured at USGS gage #09261000, located near Jensen, Utah. Peak spring discharge reached 12,100 cubic feet per second (cfs) on 30 May 2018, which is below the mean annual peak flow for the period of record (Figure 1). Mean daily discharge remained below 3,000 cfs beginning on 23 June 2018 (Figure 1). From 1 July 2018 until ISMP sampling was initiated on 18 September 2018, mean daily discharge averaged 2,283 cfs (range = 1,890–2,450 cfs; provisional values) with extremely stable flows for the entire months of August and September (Figure 2). Likewise, mean daily discharge for the sample period was very stable with an average of 2,212 cfs (range = 2,170–2,240 cfs; provisional values). Main channel temperatures averaged 18.5 ºC (range = 15.0–21.8 ºC), whereas mean backwater temperatures were 19.0 ºC (range = 13.4–24.1 ºC) during the sampling period, with both metrics being substantially warmer than 2017 (Breen et al. 2017). Turbidity measurements (cm visibility; mean ± SD) obtained in main channel and backwater habitats were 34.3 ± 13.2 cm (range = 14–60 cm) and 25.5 ± 13.1 cm (5–60), respectively, representing much better water clarity in both habitat types during ISMP sampling compared to 2017 (Breen et al. 2017).

We captured five YOY Colorado pikeminnow (mean total length [TL] ± SE = 60.4 ± 5.2 mm) from primary and secondary backwaters, representing the seventh lowest total on record (Table 1). One additional YOY pikeminnow (TL = 82 mm) was captured from a tertiary backwater. Catch-per-unit-effort (CPUE; fish/100 m^2) for YOY pikeminnow (0.105 fish/100 m^2) was well below the 5- (1.26 fish/100 m^2), 15- (0.97 fish/100 m^2), and 29-year averages (1.81 fish/100 m^2), and represented the eighth lowest catch rate on record (Table 1). In 2018, YOY pikeminnow were larger than the 5- (45.3 mm), 15- (47.8 mm), and 29-year (45.6 mm) averages (Table 1).

Other native species are only reported for captures within primary backwaters to be consistent with previous data summaries (Table 2); this included 19 bluehead sucker (*Catostomus discobulus*), three flannelmouth sucker (*C. latipinnis*), and one speckled dace (*Rhinichthys osculus*; TL = 59 mm). One juvenile roundtail chub (*Gila robusta*; TL = 135 mm) was also captured from a primary backwater. Secondary and tertiary backwaters accounted for an additional 24 bluehead sucker (average TL for 43 total captures = 51.0 mm) and 21 flannelmouth sucker (average TL for 24 total captures = 77.0 mm), comprising 56% and 88% of total captures, respectively (Figure 3). Additionally, tertiary backwaters accounted for 30% and 31% of total bluehead and flannelmouth sucker captures, respectively (Figure 3), demonstrating the value in sampling a third backwater in each sub-reach.

Also to match past data summaries, nonnative species captured during ISMP sampling are only reported for the first seine haul within primary backwaters. Samples continue to be dominated by small-bodied nonnative cyprinids, mainly fathead minnow (*Pimephales promelas*), red shiner (*Cyprinella lutrensis*), and sand shiner (*Notropis stramineus*; 99.4% of the total catch; Table 3). We collected a total of 9,953 nonnative fish comprised of seven species in the first seine haul of primary backwaters, which is higher than last year (Breen et al. 2017) and the eighth highest total in 32 years of sampling (Table 3). In addition, we collected 31 channel catfish (*Ictalurus punctatus*), one black bullhead (*Ameiurus melas*), one brook stickleback (*Culaea inconstans*), and one smallmouth bass (*Micropterus dolomieu*; TL = 253 mm) from additional seine hauls in primary, secondary, and tertiary backwaters.

Task 2. Seining the lower Green River and the Colorado River

Lower Green River (Reach 3):

Utah Division of Wildlife Resources began sampling for ISMP in Reach 3 on 18 September 2018 and concluded on 21 September 2018. Crews sampled 120 river miles, in accordance with ISMP protocols, from Green River State Park (RM 120) to the confluence with the Colorado River (RM 0). Altogether, we sampled 55 backwater habitats that met ISMP criteria, yielding the fourth lowest area sampled (1,642 m²) since the inception of the project. During sampling in 2018, many habitats encountered were small, shallow and bedded with deep silt. Although we took no formal measurements of total habitat within Reach 3, crews sampled most of what was available.

Discharge on the lower Green River is measured at USGS gage #09315000 at Green River, Utah (Figure 4). At this location, the Green River peaked at 12,700 cfs on 2 June 2018. The river reached base flow (≤ 3,800 cfs) on 19 June 2018. During ISMP sampling in 2018, flows averaged 2,020 cfs, considerably lower than flows for those same dates in 2017 (3,045 cfs; Breen et al. 2017), the pre-dam period average (2,479 cfs, 1894-1962) and the post-dam period average (2,799 cfs, 1962-2017). Main channel temperatures averaged 22.4 °C (range = 20-24 °C), while habitat temperatures averaged 22.9 °C (range = 18.5-26 °C) in 2018. Main channel and habitat temperatures were substantially warmer in 2018 than 2017 (Breen et al. 2017). Main channel turbidity (mm visibility; mean ± SD) was lower in 2018 (254 ± 25 mm) than 2017 (Breen et al. 2017). Habitat turbidity in 2018 (205 ± 54 mm) was also lower than 2017.

Researchers encountered 57 YOY Colorado pikeminnow in reach 3 during ISMP sampling in 2018 (Table 4). This represents an increase from 2017 (25 fish; Breen et al. 2017) but is below the 5-, 15- and 30-year averages (190, 187 and 404 fish, respectively). Catch rates on the lower Green River ranked 13th lowest since the inception of ISMP. Colorado pikeminnow CPUE in 2018 was 3.42 fish per 100 m², higher than CPUE in 2017, however, lower than the 5-, 15-, and 30-year averages (10.52, 8.39 and 12.02 fish per 100 m² respectively). Of 34 habitats sampled in Reach 3, 32% contained

pikeminnow. Mean Colorado pikeminnow total length was 48.2 mm (range = 32-70 mm), which is higher than that from 2017 and the 5-, 15-, and 30-year averages (34.6, 42.8, 39.6 and 40.1 mm, respectively).

In addition to pikeminnow, researchers encountered flannelmouth sucker (n=2) and speckled dace (n=2) within Reach 3 (Table 5). All native species were identified, measured for total length and released. Crews identified and enumerated nonnative species on the first seine haul within primary habitats only (Table 6). Channel catfish (n=6), green sunfish (*Lepomis cyanellus*; n=1) and gizzard shad (*Dorosoma cepedianum*; n=1) were encountered. However, the majority of nonnative fishes encountered in 2018 were small-bodied cyprinids: fathead minnow (n=431), red shiner (n=1,185) and sand shiner (n=648).

Lower Colorado River (Reach 1):

Sampling on the lower Colorado River (Reach 1), began on 11 September 2018 and ended on 14 September 2018. All sampling followed ISMP protocols from Cisco boat ramp (RM 110.5) to the confluence with the Green River (RM 0). Crews sampled 52 backwater habitats that met ISMP criteria, consisting of 969 m^2 of rearing habitat. The amount of habitat sampled in 2018 ranks the lowest in 33 years of ISMP sampling.

Discharge on the lower Colorado River is measured at USGS gage #09180500 near Cisco, Utah (Figure 5). The Colorado River peaked on 14 May 2018 at 8,170 cfs. Recommended base flows to benefit pikeminnow YOY recruitment (i.e., Bestgen and Hill 2016) have not been described for the Colorado River, however, for comparison purposes flows reached 3,800 cfs on 15 June 2018; low flows were maintained through ISMP sampling. Mean discharge for the period of study was 2,195 cfs, considerably lower than the average for the period of record (3,908 cfs; 1913-2017). Average main channel temperature was 21.8 °C (range = 19.5-24 °C), and average habitat temperature was 22.5 °C (range = 19.5-25.5 °C) in 2018; both metrics were similar to 2017 (Breen et al. 2017). Main channel turbidity (mm visibility; mean ± SD) was higher in 2018 (242 ± 37 mm) than 2017 (Breen et al. 2017). Habitat turbidity in 2018 (262 ± 81 mm) was similar to 2017.

Crews captured 78 YOY Colorado pikeminnow in 2018 (Table 7). Catch-per-unit-effort in 2018 was the sixth highest on record (8.05 fish/100 m^2) and slightly higher than the 30-year average (7.0 fish/100 m^2). Mean total length for 2018 was 44.8 mm (range = 28-87 mm).

In addition to young-of-year pikeminnow, crews encountered 29 chub (*Gila* spp.) that were too small to identify to species, two bluehead sucker, and five flannelmouth sucker (Table 8). The majority (>99%, Table 9) of nonnative fishes encountered in 2018 belonged to three species, all small-bodied cyprinids: fathead minnow (n=528), red shiner (n=1,348) and sand shiner (n=1,270). Other nonnative fish included black bullhead (n=1), channel catfish (n=8), mosquitofish (*Gambusia* spp.; n=37), gizzard shad (n=126), and

smallmouth bass (n=1).

Task 4. Nursery habitat pilot study

Utah Division of Wildlife Resources completed a nursery habitat evaluation pilot study from 17-23 August 2018. For the purposes of this study, researchers defined nursery habitat as any near channel environment characterized by a maximum depth greater than 50 mm, an area larger than 30 m^2 and either very low or zero- velocity current. Crews sampled two discrete 10-mile reaches on the Colorado River (Moab, RM 65-55 and Little Bridge, RM 30-20) and one reach on the Green River (Mineral Bottom, RM 46-56). Habitat measurements were recorded for all nursery habitats encountered within each reach. Additionally, crews completed multiple seine hauls, where possible, within each habitat and recorded the total length of all fish encountered.

Total nursery habitat availability was estimated using Collector, a Global Positioning System application developed by Esri. Total available habitat varied considerably between sites. Little Bridge contained the greatest amount of available nursery habitat at 26,494 m^2, while Mineral Bottom contained the least (13,846 m^2). The Moab reach was intermediate with 18,825 m^2 of available habitat.

Mean discharge on the Colorado River, measured at gage #09180500 near Cisco, Utah was 2,610 cfs during the period of study. Mean discharge on the Green River was 2,000 cfs, measured at gage #09315000 at Green River, Utah. Mean main channel temperatures were similar between Green and Colorado River sites (23.6 and 24.8 °C, respectively); however, turbidity differed substantially (48 and 411 mm, respectively). Researchers enumerated 47 YOY pikeminnow at the Little Bridge site (CPUE = 16.2 fish/100 m^2) and 43 at the Moab site (CPUE = 14.1 fish/100 m^2). At the Mineral Bottom site, 55 YOY pikeminnow were encountered (CPUE = 13.0 fish/100 m^2). Mean pikeminnow total length was 37.0 mm (range = 20-68 mm).

VIII. Additional noteworthy observations:

Summer base flows on the Green River maintained within a certain range likely contribute to successful fall recruitment (Bestgen and Hill 2016). More specifically, analysis of available data obtained from 1979–2012 demonstrates that larger Colorado pikeminnow year-class production occurs in Reach 3 when mean August–September base flow levels were 1,700–3,800 cfs and in Reach 4 with mean August–September flows between 1,700–3,000 cfs (Bestgen and Hill 2016). In Reach 4, August–September flows were similar to 2015 (Breen et al. 2015) when Flaming Gorge Dam (FGD) experimental releases were implemented consistently throughout the summer and into fall. Unlike 2017 when mean daily discharge only remained below 3,000 cfs for 45 days until sampling was initiated (Breen et al. 2017), we observed 87 days below this level in 2018. This represents 28 more days within this range than observed in 2015, which was a very successful year for YOY pikeminnow recruitment in all reaches (Breen et al. 2015). Discharge for Reach 3 on the lower Green River reached the target base flow range on 19

June 2018 and remained within this range until ISMP sampling was initiated. Similar to Reach 4, discharge was within the target range for 85 days in 2018 (note that discharge has not yet been reported by USGS for six days in September), considerably more days compared to last year and 2015 (Breen et al. 2015, 2017). For comparison, CPUE was above average in the lower Colorado River, which experienced base flows from 1,700–3,800 cfs for 83 days in 2018. Limited age-0 recruitment in Green River reaches may be explained by lower densities of drifting larval pikeminnow and diminished larval transport from adult spawning reaches (Bestgen and Jones 2018). For example, spring peak flows decreased quickly in the Yampa River resulting in a much lower mean July–August discharge of 125 cfs compared to 664 cfs in 2015; only about 50% of larvae were captured in 2018 relative to 2015 (personal communication, K. Bestgen, Colorado State University). Moreover, the flow-corrected transport abundance was approximately 10 times greater in 2015 than in 2018 (Bestgen and Jones 2018). It is also worth noting that above average Colorado pikeminnow year class abundance can only be expected in 63% of years where August–September Green River discharge is within the desired ranges described above (Bestgen and Hill 2016).

Although lower than average CPUE for Colorado pikeminnow YOY was observed for both Green River reaches in 2018 despite adequate target base flows, water temperatures were warmer and likely led to higher growth rates (i.e., larger fish collected in 2018) than previous years, potentially bolstering survival of age-0 pikeminnow (Breen et al. 2011).

Utah Division of Wildlife Resources encountered a substantial number of young-of-year Colorado pikeminnow during several seining efforts not associated with ISMP sampling during the 2018 field season. Crews completed a single seining pass on both the Green (RM 120 – 0) and Colorado (RM 65-0) rivers in late July as part of Project 160 (Gibson and Caldwell 2018). Researchers encountered 157 and 244 YOY pikeminnow on the Green and Colorado rivers, respectively. These efforts yielded high catch rates (CPUE = 13.09 and 18.9 fish/100 m^2, respectively). Additionally, on 10 August 2018, UDWR and federal cooperators completed a short sampling effort on the Green River focused on capturing YOY pikeminnow for augmentation of hatchery brood stock for the Southwestern Native Aquatic Resources Recovery Center in Dexter, New Mexico. Researchers encountered 372 YOY pikeminnow between RM 63-59 (UDWR, unpublished data). Although no formal measurement of effort was recorded, if haul area is estimated at 24 m^2 (consistent with ISMP figures in 2018) CPUE can be estimated at 37.8 fish/100 m^2. Although catch rates for these efforts were higher than 2018 ISMP sampling, these data are collected through sampling designed for other objectives and are not standardized to the ISMP protocols.

Filamentous algae (*Cladophora* spp.) was widespread throughout Reach 1 and to a lesser degree Reach 3 during the 2018 field season. Crews had difficulty effectively seining a number of backwaters due to algal growth within the low velocity habitats on both rivers. It is likely that low flow conditions coupled with above average temperatures and below average turbidity promoted growth and proliferation of this organism.

IX. Recommendations:

- In light of 2015 (reaches 3 and 4) and 2016 (reach 3) fall recruitment success under recommended flow targets, and poor recruitment in 2017 with higher base flows, the Recovery Program should strive to reach Green River base flow targets suggested by Bestgen and Hill (2016), so that we can accumulate several years of comparable environmental data for a better understanding of adequate flows necessary for successful recruitment of Colorado pikeminnow. Furthermore, it is crucial that such activities occur as soon as possible and for several years to bolster current population declines, given that Colorado pikeminnow take 5-8 years to reach reproductive maturity.

- Continue to monitor annual relative abundance of post-larval Colorado pikeminnow in the middle and lower Green River and the lower Colorado River to assess long-term trends in annual fall recruitment.

- Pending recommendations to be provided in the forthcoming Project #158 Interim Report, determine whether sampling tertiary backwaters in the middle Green River (carry-over from discontinued project #144) to evaluate native fish response to nonnative removal is a necessary component of this project. However, continue with collection of this information under this project until a replacement exists given that valuable insights have been obtained each year.

- Develop a method of quantifying changes in habitat availability and quality over time. The Recovery Program should explore the use of experimental releases from Flaming Gorge dam and the Aspinall Unit to restore nursery habitat on the lower Green and Colorado rivers and the use of remote sensing technologies to track habitat change over time.

- The Recovery Program should determine optimal base flows for recruitment of YOY Colorado pikeminnow on the lower Colorado River (Reach 1). Similar work has been done for Reaches 3 and 4 on the Green River (Bestgen and Hill 2016). The establishment of this metric may aid in increasing our understanding of the complex relationship between recruitment success and flow in the upper Colorado River basin.

X. Project Status:

On track and ongoing

XI. FY 2018 Budget Status

A. Funds Provided: $82,897
B. Funds Expended: $82,897
C. Difference: $0

D. Percent of the FY 2018 work completed, and projected costs to complete: 100%
E. Recovery Program funds spent for publication charges: $0

XII. Status of Data Submission:

Data is formatted, has been QA/QC checked, and will be submitted to the USFWS by January 2019.

XIII. Signed: Matthew J. Breen & Christopher M. Michaud 11/08/2018

Principal Investigators Date

XIV. Literature Cited

Bestgen, K.R. and A.A. Hill. 2016. Reproduction, abundance, and recruitment dynamics of young Colorado pikeminnow in the Green and Yampa rivers, Utah and Colorado, 1979-2012. Final report to the Upper Colorado River Endangered Fish Recovery Program, Project FW 51 BW-Synth, Denver, CO. Department of Fish, Wildlife, and Conservation Biology, Colorado State University, Fort Collins. Larval Fish Laboratory Contribution 183.

Bestgen, K.R. and T. Jones. 2018. Interagency standardized monitoring program (ISMP) assessment of endangered fish reproduction in relation to Flaming Gorge operations in the middle Green and lower Yampa rivers–Yampa and middle Green River assessment of Colorado pikeminnow and razorback sucker larvae. Project #22f annual report to the Upper Colorado River Endangered Fish Recovery Program. Denver, CO.

Breen, M.J., M. Swasey, P. Badame, K. Creighton. 2011. Upper Colorado River basin young-of-year Colorado pikeminnow *(Ptychocheilus lucius)* monitoring: summary report 1986-2009. Final report of Utah Division of Wildlife Resources to Upper Colorado River Endangered Fish Recovery Program. Denver, CO.

Breen, M.J., R.C. Schelly, and C.M. Michaud. 2015. Annual fall monitoring of young of year Colorado pikeminnow and small-bodied native fishes. Annual report of Utah Division of Wildlife Resources to Upper Colorado River Endangered Fish Recovery Program. Denver, CO.

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Gibson, C. and J. Caldwell. 2018. Assessment of stocked razorback sucker reproduction in the lower Green and lower Colorado rivers. Annual report of Utah Division of Wildlife Resources to Upper Colorado River Endangered Fish Recovery Program. Denver, CO.

USFWS. 1987. Interagency standardized monitoring protocol handbook. U.S. Fish and Wildlife Service. Grand Junction, CO.

Table 1. Total Abundance, mean total length (TL), and mean catch-per-unit-effort (CPUE; fish/100 m^2) for young-of-year (YOY) Colorado pikeminnow collected during ISMP monitoring from 1990–2018 in the middle Green River (Reach 4). To be consistent with previous years, this table only contains individuals captured in primary and secondary backwaters of each sub-reach.

Year	Total Abundance	TL (mm)	Range (mm)	Total Area Sampled (m^2)	CPUE (Fish/100m^2)
1990	341	45.4	28 – 80	5,093	6.695
1991	524	38.2	21 – 65	5,077	10.321
1992	183	43.1	26 – 133	4,697	3.896
1993	305	36.4	21 – 59	3,960	7.702
1994	15	67.2	60 – 80	4,356	0.344
1995	75	34.5	21 – 48	3,792	1.978
1996	79	39.4	25 – 60	3,912	2.019
1997	22	36	28 – 49	3,734	0.589
1998	73	38.5	22 – 61	4,986	1.464
1999	12	33.7	25 – 45	3,897	0.308
2000	31	50.9	37 – 76	3,798	0.816
2001	8	46.9	36 – 67	4,496	0.178
2002	0	–	–	5,202	0
2003	2	52	52 – 52	4,696	0.043
2004	60	43.8	31 – 63	4,686	1.280
2005	8	48.6	35 – 60	4,190	0.191
2006	5	45.8	36 – 50	7,490	0.067
2007	3	73.3	69 – 76	5,782	0.052
2008	18	43.9	36 – 56	4,994	0.360
2009	325	43.7	22 – 71	7,503	4.332
2010*	454	37.9	24 – 58	–	–
2011	0	–	–	7,852	0
2012	2	53.5	39–68	7,805	0.026
2013	97	51.7	35–82	6,735**	1.366**
2014	45	36.3	25–67	3,118	1.443
2015	202	37.5	25–64	4,389	4.602
2016	6	40.3	33–54	4,308	0.139
2017	1	52	–	3,740***	0.027
2018	5	60.4	46–76	4,760	0.105

**Four YOY Colorado pikeminnow were not included because they were not measured; area measurements were incomplete, therefore CPUE calculations were not possible.*

***Total area does not include one backwater excluded due to lack of measurements. Five pikeminnow collected in this backwater were included in total abundance, but not CPUE.*

****The first seine haul of a secondary backwater was excluded because seine haul length was not recorded; pikeminnow were absent from this seine haul.*

Table 2. Native fish captures during young-of-year (YOY) monitoring from 1986–2018 in the middle Green River (Reach 4). Colorado Pikeminnow abundance reflects captures from primary and secondary backwaters sampled in each sub-reach; abundance of other native species reflects captures from primary backwaters only. In some years, species other than Colorado Pikeminnow were only enumerated during the first seine haul within primary backwaters. Species collected include YOY Colorado Pikeminnow (CS YOY; 10–99 mm), juvenile pikeminnow (CS JUV; 100–399 mm), unidentified *Gila* spp. (CH), Razorback Sucker (RZ), Roundtail Chub (RT), Flannelmouth Sucker (FM), Bluehead Sucker (BH), and Speckled Dace (SD).

Year	CS YOY	CS JUV	CH	RZ	RT	FM	BH	SD
1986	492	0	32	0	0	47*	47*	132
1987	209	10	19	0	0	67	277	2
1988	885	36	5	0	0	120	1	6
1989	62	0	41	0	0	16	80	3
1990	341	47	22	0	0	0	9	2
1991	524	0	7	0	0	0	0	0
1992	183	0	4	0	1	2	115	11
1993	305	0	40	0	0	54	80	7
1994	15	0	13	0	0	38	32	10
1995	75	0	6	0	0	20	62	33
1996	79	0	6	0	1	31	53	7
1997	22	0	42	0	0	12	73	8
1998	73	0	63	1	0	25	49	6
1999	12	0	43	0	0	18	20	16
2000	31	0	3	1	0	6	12	2
2001	8	0	23	0	0	78	0	0
2002	0	0	3	0	0	3	0	0
2003	2	0	2	0	0	4	2	0
2004	60	0	12	0	0	16	2	1
2005	8	2	13	0	0	7	3	2
2006	5	0	0	0	0	5	0	0
2007	3	1	2	0	0	10	11	0
2008	18	0	0	0	1	12	6	0
2009	325	0	0	0	13	57	36	1
2010	454	1	0	0	0	2	38	1
2011	0	3	0	0	1	57	35	0
2012	2	0	0	0	1	11	1	0
2013	97	0	0	0	0	1	1	0
2014	45	0	0	3	0	8	6	0
2015	202	0	4	0	0	6	25	0
2016	6	1	3	0	0	7	6	1
2017	1	1	8	0	0	5	5	0
2018	5	0	0	0	0	3	19	1

**Suckers not identified to species, thus half of suckers were applied to bluehead and half to flannelmouth.*

Table 3. Total abundance of nonnative fish collected during young-of-year monitoring in the middle Green River (Reach 4) from 1987–2018. Only fish enumerated in primary backwater first seine hauls are included. Species collected include Black Bullhead (BB), Black Crappie (BC), Bluegill (BG), Channel Catfish (CC), Common Carp (CP), Fathead Minnow (FH), Green Sunfish (GS), Gizzard Shad (GZ), Northern Pike (NP), Red Shiner (RS), Smallmouth Bass (SM), Sand Shiner (SS), Walleye (WE), and White Sucker (WS).

YEAR	BB	BC	BG	CC	CP	FH	GS	GZ	NP	RS	SM	SS	WE	WS
1987	0	0	0	1	3	873	8	0	0	9,757	0	462	0	0
1988	2	0	0	7	2	620	13	0	0	4,072	0	159	0	0
1989	0	0	0	7	43	865	22	0	0	4,025	0	284	0	0
1990	0	0	0	1	4	1,386	0	0	0	5,395	0	87	0	0
1991	0	0	0	14	5	1	1	0	0	64	0	0	0	0
1992	1	0	0	3	15	1,653	5	0	0	3,178	0	440	0	0
1993	0	0	0	17	13	1,512	3	0	0	4,677	0	49	0	0
1994	0	1	0	0	0	2,757	1	0	0	28,903	0	1,890	0	0
1995	0	0	0	0	6	1,304	1	0	0	3,229	1	188	0	0
1996	0	0	0	0	5	486	8	0	0	2,871	0	1,265	0	0
1997	0	4	0	0	11	1,067	3	0	0	1,010	1	1,152	0	3
1998	7	11	0	3	8	1,569	17	0	1	2,400	0	474	0	1
1999	3	3	0	0	23	407	68	0	0	1,832	0	533	0	0
2000	2	3	0	0	12	1,436	15	0	0	10,860	0	8,072	0	0
2001	1	10	0	6	0	371	0	0	0	4,512	0	283	0	0
2002	0	5	1	0	1	1,303	39	0	0	11,516	0	1,059	0	1
2003	0	1	0	0	48	89	0	0	0	3,847	0	49	0	0
2004	0	1	0	4	1	337	8	0	0	5,524	0	1,207	0	5
2005	0	18	0	1	1	204	0	0	0	3,654	0	552	0	0
2006	0	7	3	0	98	1,431	1	5	0	19,365	0	2,060	0	3
2007	9	0	0	10	16	327	0	3	0	5,754	6	3,940	0	13
2008	1	16	0	3	40	155	102	0	0	1,121	5	821	0	7
2009	0	4	0	0	17	108	1	2	0	2,101	1	417	0	5
2010	1	0	0	1	38	231	15	0	0	3,596	0	959	0	8
2011	5	3	0	0	13	867	14	0	0	1,682	2	301	0	0
2012	0	0	0	6	1	189	0	22	0	2,379	1	583	0	0
2013	0	4	0	1	1	323	21	1	0	6,102	23	4,018	1	55
2014	0	0	0	4	31	471	2	6	0	924	3	466	0	36
2015	0	0	0	0	12	518	41	0	0	2,354	0	966	0	6
2016	0	17	0	2	31	348	0	0	0	2,293	9	882	0	10
2017	0	2	0	0	9	327	4	7	0	3,070	2	2,495	0	9
2018	0	0	0	0	1	440	1	12	0	4,123	0	5,326	0	50

Table 4. The lower Green River (Reach 3) total numbers, lengths and mean catch-per-unit-effort (CPUE; fish/100 m^2), by year for young-of-year Colorado Pikeminnow caught during ISMP monitoring conducted from 1986—2018.

Reach 3 Year	YOY Colorado Pikeminnow Caught	Mean Length (mm)	Length Range (mm)	Total Area Sampled (m^2)	CPUE (fish/100m^2)
1986	813	28.63		1964	41.40
1987	849	36.32		2831.8	29.98
1988	2892	39.41		3076.4	94.01
1989	1494	38.79		4261.8	35.06
1990	418	41.82		6516.6	6.41
1991	186	38.81		2822.2	6.59
1992	122	40.62		5181.6	2.35
1993	1616	37.36		4435.4	36.43
1994	354	37.36	14-74	3797.8	9.32
1995	56	49.98	23-99	2548	2.20
1996	410	24.94	13-45	2888.6	14.19
1997	39	41.4	19-75	2709.8	1.44
1998	252	33.1	19-40	3050.2	8.26
1999	384	32.1	18-68	4055.8	9.47
2000	705	26.8	15-38	5760	12.24
2001	17	37.9	21-88	5962	0.29
2002	22	43.2	30-68	4644.5	0.47
2003	124	64.9	22-90	4005.8	3.10
2004	80	60.1	30-96	1974	4.05
2005	63	46	26-84	2937.6	2.14
2006	331	31.2	23-41	4936	6.71
2007	686	40.3	23-80	3138	21.86
2008	60	44.8	26-95	2018	2.97
2009	423	35.32	20-46	2548	16.60
2010	131	29.86	15-45	2868	4.57
2011	17	22	15-26	1796	0.95
2012	293	50.27	18-109	4716	6.21
2013	31	52.83	22-80	2381	1.30
2014	5	40.6	33-48	1670	0.30
2015	461	44.9	22-79	2031	22.7
2016	426	41.1	21-70	1588	26.8
2017	25	34.6	29-55	1642	1.52
2018	57	48.2	23-70	1668	3.42

Table 5. The lower Green River (Reach 3), total captures by year for native and endangered fish during young-of-year (YOY) monitoring from 1986-2018. Species listed are: YOY Colorado Pikeminnow (CS YOY; 10-99 mm), juvenile pikeminnow (CS JUV; 100-399 mm), unidentified *Gila* spp. (CH), bonytail (BT), humpback chub (HB), razorback sucker (RZ), flannelmouth sucker (FM), bluehead sucker (BH), and speckled dace (SD). In most years, species other than CS were only enumerated during the first seine haul within primary backwaters.

Year	CS YOY	CS JUV	CH	BT	HB	RZ	FM	BH	SD
1986	813	0	15	0	0	0	0	0	24
1987	849	9	1	0	0	0	5	1	0
1988	2,892	109	0	0	0	0	2	0	2
1989	1,494	59	1	0	0	0	17	0	0
1990	418	21	0	0	0	0	0	0	7
1991	186	3	0	0	0	0	0	2	2
1992	122	12	18	0	0	0	3	7	4
1993	1,616	2	0	0	0	0	12	33	43
1994	354	0	7	0	1	0	0	1	6
1995	56	1	5	0	0	0	12	17	35
1996	410	1	0	0	0	0	1	21	20
1997	39	8	2	0	0	0	0	2	2
1998	252	0	0	0	0	0	0	3	30
1999	384	0	2	0	0	0	90	5	24
2000	705	3	1	0	0	0	0	0	5
2001	17	0	0	0	0	0	0	0	3
2002	22	0	1	0	0	0	4	0	4
2003	124	0	5	0	0	0	0	0	2
2004	80	0	0	0	0	0	1	1	0
2005	63	1	0	0	0	0	0	0	0
2006	331	0	6	0	0	0	0	0	0
2007	686	0	1	2	0	0	0	0	0
2008	60	1	0	0	0	0	8	0	1
2009	423	0	1	0	0	0	0	0	2
2010	131	3	0	0	0	0	7	3	12
2011	17	0	0	0	0	0	1	0	0
2012	293	0	2	0	0	2	9	0	0
2013	31	0	0	0	0	0	0	0	0
2014	5	0	0	0	0	0	7	0	0
2015	461	0	6	0	0	0	9	0	9
2016	426	0	0	0	0	0	4	9	0
2017	25	0	0	1	0	0	10	0	1
2018	57	0	0	0	0	0	2	0	2

Table 6. The lower Green River (Reach 3), total captures by year for nonnative fish during young-of-year monitoring from 1986-2018. Only fish enumerated in primary backwater first seine hauls are included to maintain consistency among years and reaches. Species listed: Black Bullhead (BB), Black Crappie (BC), Channel Catfish (CC), Common Carp (CP), Fathead Minnow (FH), unidentified *Gambusia* spp. (GA), Green Sunfish (GS), Gizzard Shad (GZ), Largemouth Bass (LG), Red Shiner (RS), Sand Shiner (SS), White Sucker (WS), and Yellow Bullhead (YB).

YEAR	BB	BC	CC	CP	FH	GA	GS	GZ	LG	RS	SS	WS	YB
1986	7	0	4	12	87	0	9	0	0	663	4	0	0
1987	0	0	1	0	34	0	5	0	0	1,303	4	0	0
1988	1	0	110	2	1,790	7	1	0	0	4,317	38	0	0
1989	1	0	73	1	170	0	3	0	0	5,826	113	0	0
1990	1	0	37	4	228	0	0	0	0	9,599	129	0	0
1991	0	0	8	3	314	0	2	0	0	7,746	1,123	0	0
1992	1	0	24	1	500	0	0	0	0	2,737	180	0	0
1993	1	0	11	1	249	0	0	0	0	3,443	1,362	0	0
1994	0	0	6	8	500	1	8	0	0	8,007	1,196	0	0
1995	7	0	4	16	363	0	6	0	0	3,478	969	0	0
1996	0	0	0	0	1,097	2	2	0	0	11,858	3,751	0	0
1997	0	0	17	1	79	4	3	0	0	855	320	1	0
1998	0	6	0	1	120	17	0	0	0	1,709	178	0	0
1999	0	1	2	37	340	1	0	0	0	845	156	0	0
2000	3	0	12	3	234	0	1	0	0	3,591	574	4	0
2001	0	0	6	0	0	0	0	0	0	0	0	0	0
2002	0	0	122	2	14,721	0	1	0	0	26,710	2,135	0	0
2003	5	0	11	1	201	0	12	0	0	4,707	43	0	0
2004	3	0	7	0	215	0	1	0	0	297	190	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	2	1	6	3	1,187	1	4	0	1	8,623	0	0	0
2007	0	0	23	0	2,183	0	0	1	2	8,807	35	0	0
2008	0	2	13	116	1,074	0	0	1	1	4,458	250	0	6
2009	0	0	3	0	1,044	0	0	1	0	2,766	15	0	0
2010	0	0	0	0	150	0	5	4	0	1,028	1,025	0	0
2011	0	8	6	15	314	0	0	0	0	1,842	1,096	0	0
2012	8	0	5	5	3,085	0	4	15	0	2,043	8,620	0	3
2013	0	0	19	6	1,025	0	6	6	0	2,550	9,975	0	0
2014	1	0	3	11	47	0	0	0	0	658	866	0	0
2015	2	0	26	0	570	0	5	2	0	1,969	466	0	0
2016	3	0	1	1	1,055	0	0	0	0	3,730	2790	0	0
2017	0	0	1	3	692	0	1	3	0	5,467	1,028	4	0
2018	0	0	6	0	431	0	1	1	0	1,185	648	0	0

Table 7. The lower Colorado River (Reach 1) total numbers, lengths and mean catch-per-unit-effort (CPUE; fish/100m^2), by year for young-of-year Colorado Pikeminnow caught during ISMP monitoring from 1986—2018.

Reach 1 Year	YOY Colorado Pikeminnow Caught	Mean Length (mm)	Length Range (mm)	Total Area Sampled (m^2)	CPUE (fish/100m^2)
1986	192	27.86	17-36	1343.6	14.29
1987	176	40.93		2225.8	7.91
1988	172	47.98		3786.8	4.54
1989	132	42.67		3739.2	3.53
1990	179	41.90		2565.8	6.98
1991	150	34.17		2271	6.61
1992	151	33.55		3663.2	4.12
1993	206	32.28	22-47	2858.8	7.21
1994	142	64.07	32-96	3139.8	4.52
1995	85	20.46	11-35	2890	2.94
1996	866	39.6	20-81	4113.8	21.05
1997	12	18.3	13-34	2774.8	0.43
1998	88	34.5	20-60	4663.8	1.89
1999	13	25	19-43	4710	0.28
2000	398	45.7	25-82	6389.6	6.23
2001	17	42.3	23-65	4046.8	0.42
2002	25	57.2	32-87	3033.8	0.82
2003	0	N/A	N/A	2837.8	0.00
2004	16	47	33-63	1620	0.99
2005	19	36.1	28-48	1722	1.10
2006	4	42	27-53	1682.4	0.24
2007	24	37.2	28-47	2802	0.86
2008	0	N/A	N/A	2568	0.00
2009	243	32.75	15-63	2193.4	9.46
2010	27	35.93	26-61	2630.4	1.03
2011	59	24.15	18-36	1195.2	4.94
2012	54	56.65	53-83	2240	2.41
2013	1	31	31	1769	0.05
2014	8	32.25	23-43	2544	0.31
2015	1331	28.75	16-51	1251	106.39
2016	150	35.5	22-48	1454	10.32
2017	2	40.5	28-53	1002.5	0.20
2018	78	44.8	28-87	969	8.05

Table 8. The lower Colorado River (Reach 1), total captures by year for native and endangered fish during young-of-year (YOY) monitoring from 1986-2018. Species listed are: YOY Colorado Pikeminnow (CS YOY; 10-99 mm), juvenile pikeminnow (CS JUV; 100-399 mm), unidentified *Gila* spp. (CH), Razorback Sucker (RZ), Flannelmouth Sucker (FM), Bluehead Sucker (BH), and Speckled Dace (SD). In most years species other than CS were only enumerated during the first haul within primary backwaters.

Year	CS YOY	CS JUV	CH	RZ	FM	BH	SD
1986	192	0	194	0	0	0	41
1987	176	2	27	0	2	7	2
1988	172	37	11	0	4	0	0
1989	132	7	130	0	2	3	2
1990	179	11	6	0	4	2	0
1991	150	0	8	0	1	0	5
1992	151	1	45	0	2	25	9
1993	206	3	216	0	69	198	23
1994	142	0	15	0	0	11	1
1995	85	0	119	0	2	176	28
1996	866	0	30	0	3	87	29
1997	12	0	4	0	1	12	4
1998	88	0	11	0	1	8	9
1999	13	2	1	0	0	1	0
2000	398	9	21	0	1	58	0
2001	17	0	1	0	0	0	1
2002	25	0	35	0	0	1	0
2003	0	0	0	0	0	0	0
2004	16	0	4	0	9	5	0
2005	19	0	0	0	0	0	0
2006	4	0	0	0	9	1	3
2007	24	0	0	0	2	0	0
2008	0	0	0	0	4	8	0
2009	243	0	0	0	5	3	1
2010	27	3	2	0	15	0	0
2011	59	0	3	0	31	0	2
2012	54	0	0	3	39	4	0
2013	1	0	5	0	0	1	0
2014	8	0	0	0	3	0	0
2015	1331	0	3	0	120	0	0
2016	150	3	19	0	5	4	0
2017	2	0	1	0	0	0	0
2018	78	0	29	0	5	2	0

Table 9. The lower Colorado River (Reach 1), total captures by year for nonnative fish during young-of-year monitoring from 1986-2018. Only fish enumerated in primary backwater first seine hauls are included to maintain consistency among years and reaches. Species listed: Black Bullhead (BB), Black Crappie (BC), Bluegill (BG), Channel Catfish (CC), Common Carp (CP), Fathead Minnow (FH), unidentified *Gambusia* spp. (GA), Green Sunfish (GS), Gizzard Shad (GZ), Largemouth Bass (LG), Plains Killifish (PK), Red Shiner (RS), Smallmouth Bass (SM), Sand Shiner (SS), Walleye (WE), White Sucker (WS), and Yellow Bullhead (YB).

YEAR	BB	BC	BG	CC	CP	FH	GA	GS	GZ	LG	PK	RS	SM	SS	WE	WS	YB
1986	0	0	0	4	0	456	2	0	0	1	6	1,077	0	240	0	0	0
1987	1	0	0	10	1	233	1	0	0	0	0	2,159	0	428	0	0	0
1988	0	0	0	0	4	10,650	0	1	0	0	36	1,786	0	2,161	0	0	0
1989	11	0	0	8	12	3,613	0	2	0	0	9	6,973	0	951	0	1	0
1990	2	0	2	11	4	5,698	1	1	0	1	10	6,593	0	889	0	0	0
1991	1	0	0	8	1	2,632	0	0	0	0	6	4,368	0	1,652	0	1	0
1992	1	0	0	0	1	2,809	2	7	0	0	7	6,470	0	3,991	0	1	0
1993	3	0	0	1	8	2,091	4	1	0	0	0	3,870	0	1,449	0	2	0
1994	1	0	0	1	2	4,795	14	34	0	0	0	4,393	0	2,520	0	2	0
1995	2	0	0	17	3	1,105	71	2	0	1	0	1,079	0	926	0	0	0
1996	0	0	2	1	0	2,591	3	15	0	1	8	3,851	0	5,998	0	0	0
1997	0	0	0	12	2	37	3	0	0	2	0	1,244	0	224	0	0	0
1998	0	0	0	1	0	265	1	6	0	0	2	6,297	0	8,751	0	0	0
1999	0	1	1	21	3	137	1	1	0	0	2	1,891	0	2,303	0	0	0
2000	4	0	0	0	1	1,265	24	2	0	1	0	15,099	0	22,343	0	1	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	1	0	0	4	3	4,963	1	0	0	0	1	11,691	0	2,920	0	0	0
2003	2	0	0	0	1	2,192	4	0	0	0	7	788	0	1,162	0	0	0
2004	0	0	0	0	1	352	0	0	0	0	0	625	0	535	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	1	2	0	4	1	159	94	10	0	2	1	3,030	0	103	0	0	1
2007	1	0	0	1	5	597	52	0	15	0	0	1,063	1	0	0	6	0
2008	0	0	0	1	5	280	1	0	17	1	0	536	0	5	0	1	1
2009	3	7	0	0	6	260	36	0	57	0	0	3,124	0	12	0	0	0
2010	0	0	0	2	0	377	3	0	174	5	0	657	0	622	1	0	0
2011	0	6	0	0	2	24	12	0	20	3	0	1345	0	58	0	0	0
2012	36	0	0	15	14	3,182*	2	6	70	2	0	471*	0	5,204*	0	0	0
2013	5	0	0	24	1	666	0	1	116	1	2	1,566	2	4,640	0	0	0
2014	0	0	0	23	1	55	0	4	23	0	3	974	0	399	0	0	0
2015	617	0	0	1	0	556	87	1	261	2	1	1,696	0	1,089	0	1	0
2016	1	0	1	0	2	426	10	0	7	4	0	1,828	0	825	0	0	0
2017	2	5	0	0	5	408	25	2	74	0	0	968	3	692	0	0	0
2018	1	0	0	8	0	528	37	0	126	0	0	1348	1	1270	0	0	0

*1,990 nonnative cyprinids were not identified to species. Based on the percentage of Sand Shiner (58.8%), Fathead Minnow (35.9%), and Red Shiner (5.3%) positively identified in this reach, these fish were applied proportionately to Sand Shiner (n = 1,117), Fathead Minnow (n = 682), and Red Shiner (n = 101).

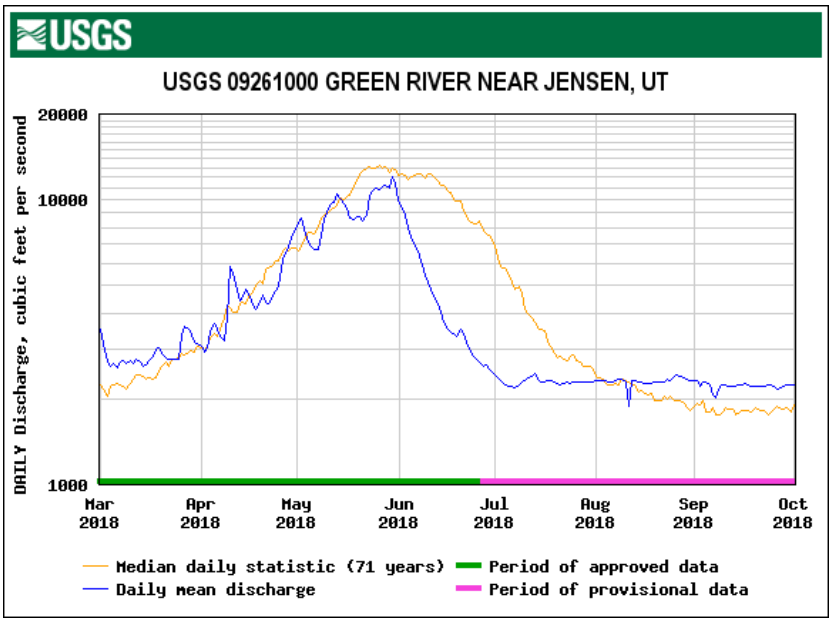

Figure 1. Middle Green River (Reach 4) discharge measured from USGS gage #09261000 at Jensen, Utah for the period of 1 March 2018 to 1 October 2018.

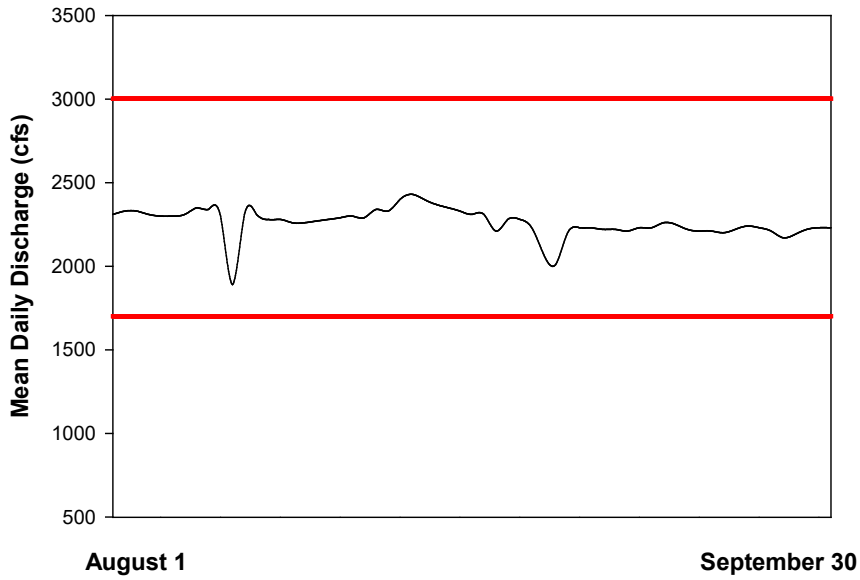

Figure 2. Middle Green River mean daily discharge (cubic ft/sec; cfs) for August and September 2018 measured at Jensen, UT (USGS gage #09261000). Areas between the red lines indicate recommended discharge for the months of August and September to benefit age-0 Colorado pikeminnow recruitment based on Bestgen and Hill (2016).

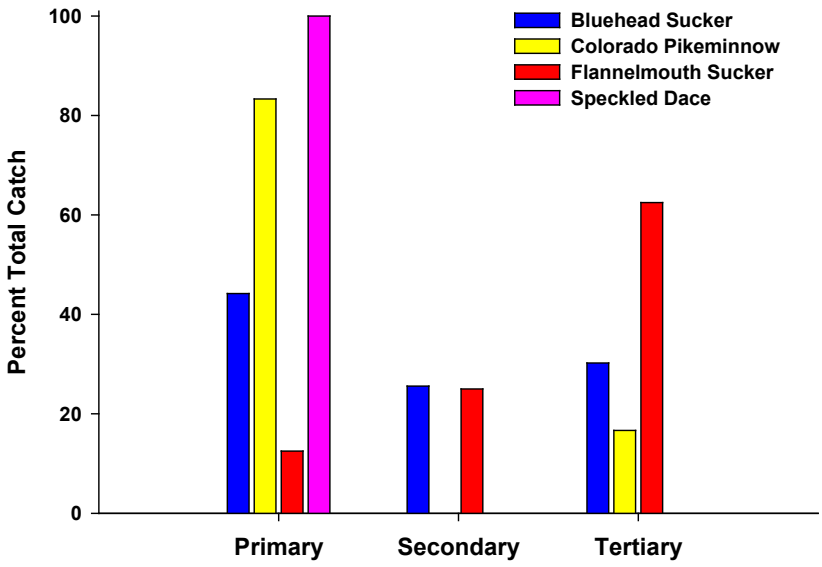

Figure 3. Proportional abundance (percent young-of-year sampled from all backwaters in the middle Green River) of native species captured in primary, secondary and tertiary backwaters during 2018 ISMP sampling.

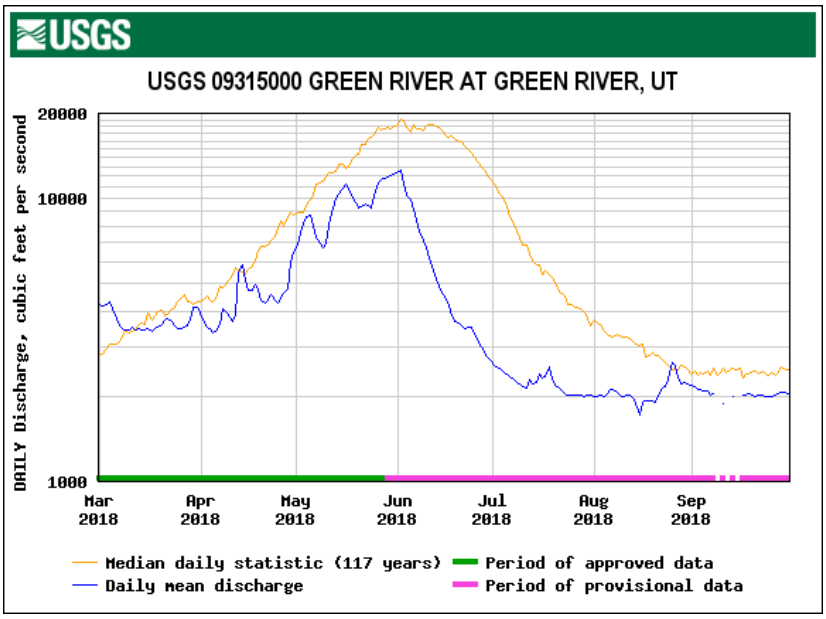

Figure 4. The lower Green River (Reach 3) daily mean flows measured from USGS gage #09315000 at Green River, Utah from 1 March 2018 to 30 September 2018.

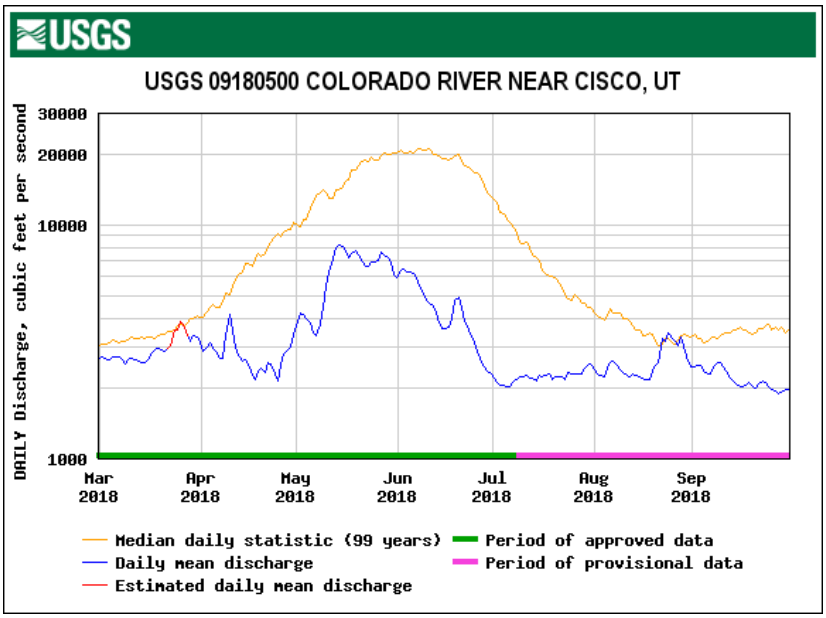

Figure 5. The lower Colorado River (Reach 1) daily mean flows measured from USGS gage #09180500 near Cisco, Utah from 1 March 2018 to 30 September 2018.