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Successful Spawning by Stocked Razorback Sucker in the Gunnison and Colorado Rivers, as evidenced by Larval Fish Collections, 2002-2007

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EXECUTIVE SUMMARY

Fish larvae were annually sampled from May to late June or early July in the Gunnison River during 2002–2007 and in the upper Colorado River during 2004–2007 as a means to determine whether stocked razorback sucker *Xyrauchen texanus* were successfully reproducing. Shorelines were sampled weekly with fine-mesh hand seines at 1–6 locations per 8-km (5-mile) segment and preserved samples were identified to species at the Larval Fish Laboratory at Colorado State University. In the Gunnison River, 0–5 specimens positively identified as razorback sucker were found annually along with 1–5 specimens identified as possible razorback sucker. In the Colorado River, 1–13 positively identified razorback sucker were collected annually along with 1–6 possible ones. Mean number of positively identified razorback sucker per sample collected annually from the Gunnison River declined over the study period while mean number per sample in the Colorado River increased; however, the decrease in the Gunnison River was not statistically significant. Very limited light trapping was also conducted in 2002 and 2003 in the Gunnison River with one positively identified razorback sucker larva being collected by this means. Back calculation of hatching and spawning dates across all years indicated a spawning range from April 18 to May 24 in the Gunnison River and April 27 to May 31 in the Colorado River. Specimens were widely distributed in both rivers. Although about 27,000 razorback sucker were stocked in the Gunnison River between 1994 and 2007, no estimate of surviving adults is available from that river. In the Colorado River, a population of 1,066 adults was estimated for the entire system (95% CI: 377–3703) in 2005 using mark-recapture methods (almost 79,000 razorback sucker were stocked through 2007). From this estimate, 640 adults were calculated to be in the upper-river larval study area. Spawning locations in the Colorado River appeared to be widely distributed from Loma, Colorado to Moab, Utah based on the capture locations of one or more running-ripe females during 2005, 2007 and 2008. Based on the wide distribution of possible spawning sites, it is difficult at this time to recommend particular areas that might be managed as nursery habitat in the future. However, based on the limited data available, the reach downstream of Whitewater on the Gunnison River and the reach

downstream of the Colorado-Utah state line on the Colorado River deserve consideration. Additional monitoring of larvae and adults will be needed to see if abundance of razorback sucker larvae increases as more razorback sucker are stocked. In addition, some means to assess survival of larval razorback sucker and recruitment to the adult phase needs to be developed.

INTRODUCTION

The last capture of a wild razorback sucker *Xyrauchen texanus* in the Gunnison River occurred near Delta, Colorado in 1981 (Holden et al. 1981). Restoration stocking in the Gunnison River began in 1994 and by 2007 about 27,400 razorback sucker had been stocked there and most of these were released at Delta. Similarly, the last wild razorback sucker captured in the upper Colorado River was at the Walter Walker State Wildlife Area near Grand Junction, Colorado in 1993. Stocking of hatchery-reared razorback sucker into the Colorado mainstem began in 1999. By the end of 2007, 78,723 juvenile, sub-adult, and adult razorback sucker had been stocked in that river with most of the fish being released between Palisade and Loma, Colorado.

To establish a self-sustaining population, some stocked individuals need to 1) survive, 2) successfully spawn in either the Gunnison or upper Colorado rivers, and 3) resulting progeny need to be retained in or return to the Gunnison and upper Colorado rivers and survive to adulthood in sufficient numbers to maintain adult populations there without additional human intervention.

This project was initiated in an attempt to determine, through the collection of larval razorback sucker, if this species was successfully reproducing in the Gunnison River. The study area was subsequently expanded to include the upper Colorado River mainstem. An additional objective, contingent upon the discovery of razorback sucker larvae, was to use patterns of larval distribution to identify spawning sites and areas that could be managed as nursery habitats. In the Green River system, natural bottomlands downstream of a known razorback sucker spawning site are currently managed to flood during spring runoff so that they might entrain drifting larval razorback sucker and serve as rearing areas. In the Gunnison and Colorado rivers, off-channel rearing areas might similarly be needed if razorback sucker larvae are present.

In addition to reporting results from larval fish collections, we provide supporting information on locations of adult razorback sucker in breeding condition and estimates of adult abundance obtained during concurrent studies.

STUDY AREA AND METHODS

Sampling Gunnison River larvae began in 2002. The Gunnison River core study area extended from the Redlands Diversion Dam (river kilometer [RK] 4.8; river mile [RM] 3.0) near Grand Junction upstream to the Highway 50 bridge (RK 91.7; RM 57.0) in Delta (Figure 1). The primary method of sampling larval fish was for one person to seine shoreline and backwater habitats using 0.5-mm-mesh material (0.5 m wide by 0.8 m tall) suspended between two handles. During 2002-2003, light traps were also used to collect larval fish in select locations. The study area was sampled weekly during and immediately after the suspected spawning period for 7–8 weeks starting in early to mid-May. An inflatable zodiac raft outfitted with an outboard motor was used to traverse the study area in a downstream direction. When flows were high enough, a 5.2-m-long jet boat was employed which allowed access to sampling sites upstream of the Highway 50 bridge to the Hartland Diversion Dam (RK 96.4; RM 59.9). The study area was divided into twelve 5.0 mile (8.05 km) reaches (upstream starting point at RM 59.9) and 1–6 sites in each reach were sampled on each pass, depending on the availability of quiescent shoreline habitats. Location of sampling sites often varied among passes according to river conditions, but some sites were repeatedly sampled. At each site, up to 10 minutes of seining effort was expended searching for larvae. The objective was to acquire a sample of larvae from each site. If a large sample was collected right away, sampling was curtailed. In many cases, no larvae were found and the site location was recorded. For sites yielding larvae, specimens were placed in a polyethylene jar containing 100% ethanol. Date, RM location, reach, and sample bottle number were recorded both inside (paper label) and outside the jar (permanent marker), as well as on field data sheets. At the end of each field season, sample bottles were shipped to the Larval Fish Laboratory, Colorado State University, for sorting, identification, enumeration, and archiving of larval specimens. All identifications were based on morphological characteristics.

Two sites in the Gunnison River were sampled with a light trap in 2002 and one site in 2003. Light traps were deployed in the evening and larval fish collected in

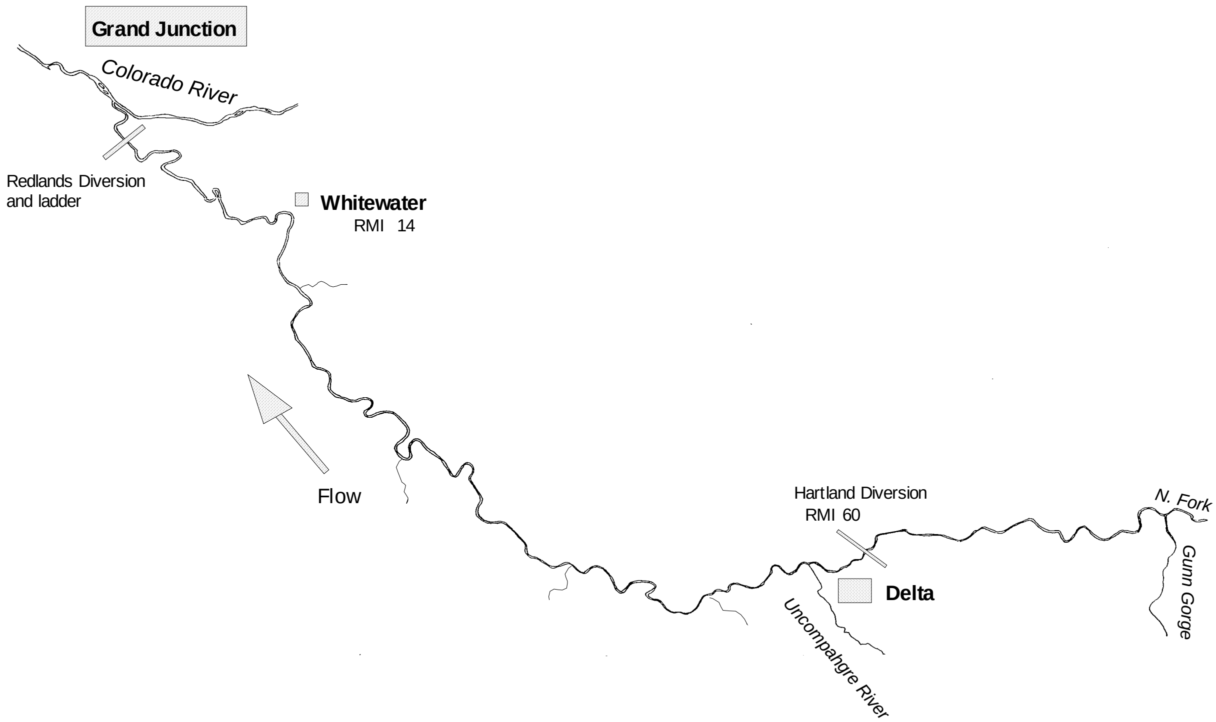


Figure 1. Gunnison River study area. Larval sampling extended from the Redlands Diversion dam at RK 4.8 (RM 3.0) upstream as far as the Hartland Diversion dam at RK 96.4 (RM 59.9).

the traps were removed and preserved just prior to sunrise. The extensive amount of travel time, intensive labor involved, and the limited road access to sampling sites prompted us to abandon this methodology after 2003.

In 2004, the study was modified to include 93 km (58 miles) of the upper Colorado River. The study area extended from Westwater Wash (RK 200.8; RM 124.8) in Utah upstream to the Grand Valley Irrigation Company diversion dam (RK 297.8; RM 185.1) at Palisade, Colorado (Figure 2). Larval fish sampling protocol in the Colorado River was the same as described for the Gunnison River study area, except that a jet boat was used at all times instead of an inflatable craft. Sampling of larvae in both rivers concluded in 2007.

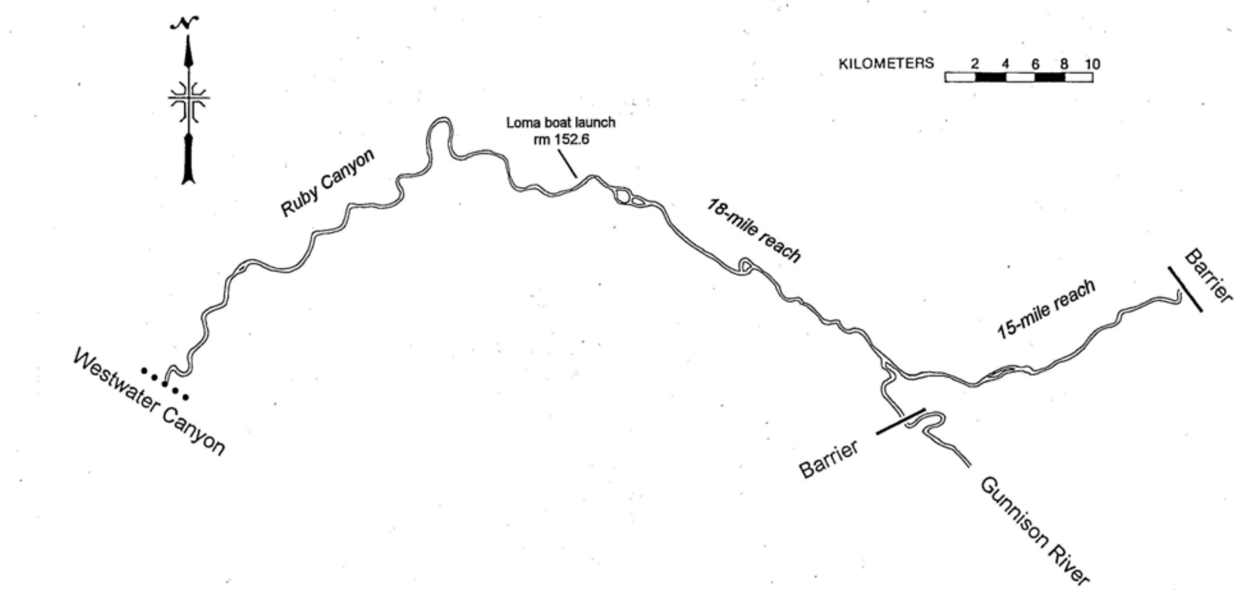


Figure 2. Colorado River study area. Larval sampling extended from just above Westwater Canyon at RK 200.8 (RM 124.8) upstream to the top of the 15-mile reach at the Price Stubb Diversion Dam (marked barrier) at RK 297.8 (RM 185.1).

Spawning and hatch periods of razorback sucker were back calculated based on total length of razorback sucker larvae collected during our survey and formulae reported by Bozek et al. (1990), Muth et al. (1998) and Bestgen et al. (2002). Assuming a razorback sucker hatching length of 8 mm and a growth rate of 0.30 mm per day (Muth et al. 1998; Bestgen et al. 2002, Bestgen 2008), an 18-mm long larva collected on 22 June would have grown 10 mm since hatching 33.3 days earlier (May 20). The relationship between egg incubation time and water temperature was established by Bozek et al. (1990) who experimentally tested incubation time for this species at 10, 15 and 20 degrees C. Mean water temperature 10–13 days (range of estimated incubation periods based on available temperatures) prior to the estimated hatching date was calculated from mean daily water temperatures taken at the U. S. Geological Survey (USGS) Whitewater gauge, RK 25.7 (RM 16), for the Gunnison River and the USGS Colorado-Utah state line gauge, RK 212.2 (RM 131.9), for the Colorado River. Spawning dates were calculated from estimated hatching dates by interpolating values of time and water temperature established by Bozek et al. (1990).

Hence, a larva hatched on 20 May would have been spawned on 7 May if the preceding main-channel water temperature averaged 13.9°C during an estimated 13-day incubation period.

To determine if catch rates of larvae increased or decreased during the study period, the mean number of razorback sucker larvae per sample was calculated annually for each river and values were compared among years. To do this, it was assumed that the average effort per sample (area sampled and duration of sampling) was similar among years. Because annual data sets that contain a high proportion of zeros (no razorback sucker larvae in individual samples) are generally non-normally distributed, normality can be improved by first log-transforming (*ln* (n + 1)) the value for each sample before calculating the mean. The mean is then transformed back to a standard value for comparisons. This was done as appropriate and the overlap or non-overlap of 95% confidence intervals (CI) of plotted means was used to identify significant differences in catch rates among years.

The Huggins (1989, 1991) closed population model in Program MARK (White and Burnham 1999) was used to estimate abundance of stocked razorback sucker in the Colorado River in 2005. Capture data for stocked razorback sucker were obtained during a 5-pass Colorado pikeminnow mark-recapture monitoring survey that extended from Palisade, Colorado to the Green River confluence in Utah (for methods, see Osmundson and White 2009). All stocked razorback sucker had been in the wild at least five months and none were stocked in spring prior to the sampling effort. Some had been in the river for several years; others had been stocked the previous fall. Individuals $\geq$ 400 mm total length (TL) were considered adults, consistent with the criteria in the razorback sucker Recovery Goals (USFWS 2002).

RESULTS

Gunnison River

Depending on the year, the number of sites seined annually for larvae in the Gunnison River ranged from 223 to 314 with 41–79 % of those sampling efforts yielding fish larvae (Table 1). In most instances the absence of larvae was because sampling occurred prior to their emergence. As larvae began to appear throughout the river, they were encountered at almost every site sampled. Sampling was initiated prior to the general emergence of fish larvae in all years as evidenced by the lack of larvae in shoreline habitats during the first weeks of annual sampling. In the very low water year of 2002, water warmed early and sampling was initiated on 2 May and ended on 20 June. In 2005, a more average flow year, sampling was started on 16 May and continued through 7 July (Table 2). Total number of fish larvae collected per year ranged from 2,440 (2003) to 23,785 (2006). Mean number of fish larvae per collected sample ranged from 21.4 (2003) to 142.2 (2005).

Specimens from the Gunnison River positively identified as razorback sucker larvae were captured in five of the six years of this study, but their numbers were extremely low, ranging from 1 to 5 per year (Table 1). Specimens that possessed some characters unique to the species but lacked other characters typical of the species were not considered positive identifications; instead, they were tentatively identified as possible razorback sucker. Some of these might have been hybrids between razorback sucker and other sucker species, some had extreme pigment patterns that were difficult to distinguish from another species of sucker, and some had non-normal morphological characters. Hence, specimens fell into one of two categories: those positively identified as razorback sucker (RZ) and those tentatively identified as possible razorback sucker, denoted ‘RZ (?)’. Possible razorback sucker were also low in number, ranging from 1 to 5 per year. The mean number of positive razorback sucker specimens per collected sample was 0.00–0.031 and consisted of 0.00–0.10 percent of all fish larvae collected per year. Although reproduction was documented, razorback sucker larvae in the Gunnison River were extremely rare.

Nonnative white sucker *Catostomus commersonii* was the most abundant larvae collected in seine samples during May–June, followed by native bluehead sucker *Catostomus discobolus* larvae (Table 3). Fathead minnow *Pimephales promelas* larvae were extremely abundant during the low-water year of 2002. Timing of peaks in larval abundance varied among species and varied among years within species (Appendix: Tables IV-VI; Figs. II-XII).

Table 1. Seining results for Gunnison River sampling, 2002–2007. The number of specimens positively identified as razorback sucker (No. RZ) and tentatively identified as possible razorback sucker (No. RZ?) are as listed. Mean and percent (%) samples with RZ refer only to positively identified razorback sucker specimens. One positive razorback sucker larva caught in 2002 with a light trap is not included.

Year	Sites Seined	Samples collected	Total fish	No. RZ	No. RZ?	Mean RZ per sample	% RZ of all fish
2002	223	128	4,107	4	3	0.031	0.097
2003	232	121	2,440	2	5	0.017	0.082
2004	291	204	8,590	1	1	0.005	0.012
2005	293	120	17,067	1	1	0.008	0.006
2006	314	247	23,785	1	22	0.004	0.004
2007	292	212	10,208	0	1	0.000	0.000
Total	**1,645**	**1,032**	**66,197**	**9**	**33**		

Table 2. Start and end dates of larval sampling in the Gunnison and Colorado rivers and dates of first and last razorback sucker (RZ) larval collections (both positive and possible RZ specimens), 2002–2007.

Year	River	Start	First RZ	Last RZ	Finish
2002	Gunnison	May 2	May 21	Jun 6	Jun 20
	Colorado				
2003	Gunnison	May 12	May 21	Jun 10	Jun 27
	Colorado				
2004	Gunnison	May 5	Jun 16	Jun 16	Jun 25
	Colorado	May 13	May 20	May 27	Jun 24
2005	Gunnison	May 16	Jun 24	July 7	July 7
	Colorado	May 19	Jun 27	Jun 27	July 12
2006	Gunnison	May 15	May 31	July 5	July 5
	Colorado	May 18	Jun 8	Jun 16	July 10
2007	Gunnison	May 7	May 15	May 15	Jun 27
	Colorado	May 8	May 29	Jun 22	Jun 29

In addition to the seine results, eight light trap samples were collected in 2002 and five in 2003. In 2002, light traps were set on eight dates between May 22 and June 7; six were on the east bank just downstream (RK 24.0, RM 14.9) of the mouth of East Creek at Whitewater and two were at the mouth of Roubideau Creek (RK 80.8, RM

Table 3. Species composition of seine samples from the Gunnison River, 2002–2007. Only species comprising more than 1% of the total in at least one year are shown, with the exception of razorback sucker which are included for comparison. Possible razorback and white sucker are denoted with a question mark (?).

Species	2002	2003	2004	2005	2006	2007	Mean
Gila species	6.31	13.69	6.59	0.71	9.54	3.89	6.79
fathead minnow	37.55	0.45	0.13	0.90	0.34	0.05	6.57
speckled dace	11.88	2.21	2.82	0.37	2.86	2.34	3.75
sand shiner	5.87	0.25	0.00	0.01	0.03	0.00	1.02
bluehead sucker	9.13	22.34	2.83	43.65	20.51	45.32	23.96
flannelmouth sucker	0.63	11.07	3.28	10.37	6.15	11.44	7.16
longnose sucker	0.00	1.31	0.00	0.00	0.00	0.00	0.22
unidentified sucker	0.17	0.98	0.50	0.69	1.05	0.20	0.60
white sucker	26.69	43.93	75.88	42.50	57.12	35.59	46.95
white sucker?	0.07	1.56	5.18	0.36	1.00	0.73	1.48
nonnative cyprinid	0.00	0.00	1.27	0.00	0.08	0.06	0.23
razorback sucker	0.10	0.08	0.01	0.01	0.00	0.00	0.03
razorback sucker?	0.07	0.20	0.01	0.01	0.09	0.01	0.07
total	**98.47**	**98.07**	**98.50**	**99.57**	**98.78**	**99.63**	**98.83**

50.2) downstream of Delta. One positive razorback sucker larva was collected at the Roubideau Creek site on June 6. On 27 June 2003, five light traps were set in a backwater (RK 19.1, RM 11.9) at the mouth of Bang's Canyon; no razorback sucker larvae were collected during that sampling effort.

Back-calculation of spawning dates from all positive razorback sucker larvae across the six years indicated a range extending from 18 April to 24 May (Appendix Table I). Sample sizes of positively identified specimens were too small to be of much use in estimating spawning duration, but evidence of earliest spawning was 27 April in 2002, 18 April in 2003, 24 May in 2004, 23 May in 2005, and 8 May in 2006. Mean daily main-channel water temperature on days of earliest estimated spawning were 13.7°C in 2002, 11.3°C in 2003, 15.0°C in 2004, 12.5°C in 2005, and 13.8°C in 2006. There did not appear to be a relationship between discharge and first estimated dates of razorback sucker spawning: discharge at the Whitewater gauge on these days was 865 cfs (2002), 2,380 cfs (2003), and 4,270 cfs (2006; Figures 3 and 4).

In general, razorback sucker larvae were widely distributed throughout the study area (Table 4 and Figure 5). There was a total of 10 positively identified razorback sucker larvae. Six were collected at or downstream of East Creek at Whitewater (≤ RK 24.3, <RM 15.1); two were taken near Delta (RK 80.8 and 84.8, RM 50.2 and 52.70); and two were captured near the center of the study area (RK 53.7 and 71.9, RM 33.4 and 44.7). When the distribution of specimens identified as possible razorback sucker (including possible hybrids) was examined, those individuals were more widespread than the positively identified specimens, with one 20.7-kilometer (12.9-mile) gap in distribution between RK 28.2 and 48.9 (RM 17.5 and 30.4) where none was found.

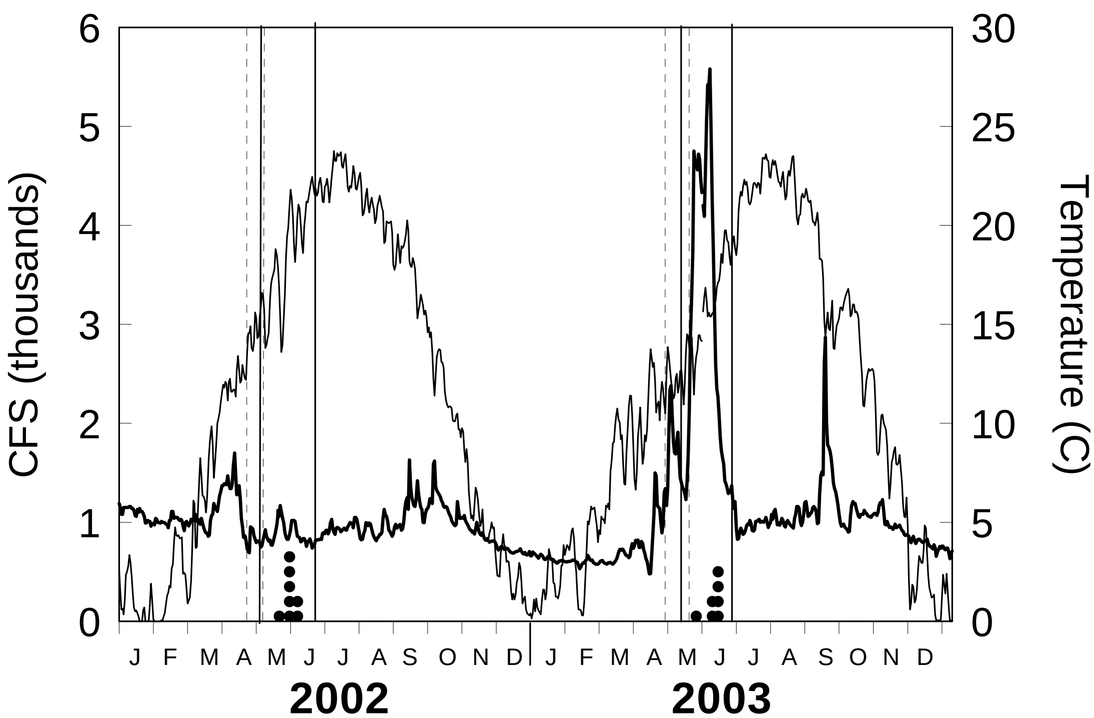


Figure 3. Collections of razorback sucker larvae in the Gunnison River in relation to the calendar year, spring hydrograph (dark lines), and thermal regime (light lines) during 2002 and 2003. Solid vertical lines bracket period of annual seine sampling; dashed vertical lines: the estimated spawning period that produced the captured razorback larvae (dots). Discharge and water temperature were measured at the USGS gauge at Whitewater (RK 24.1, RM 15). Analyses utilized both positively identified razorback sucker larvae and possible razorback sucker larvae.

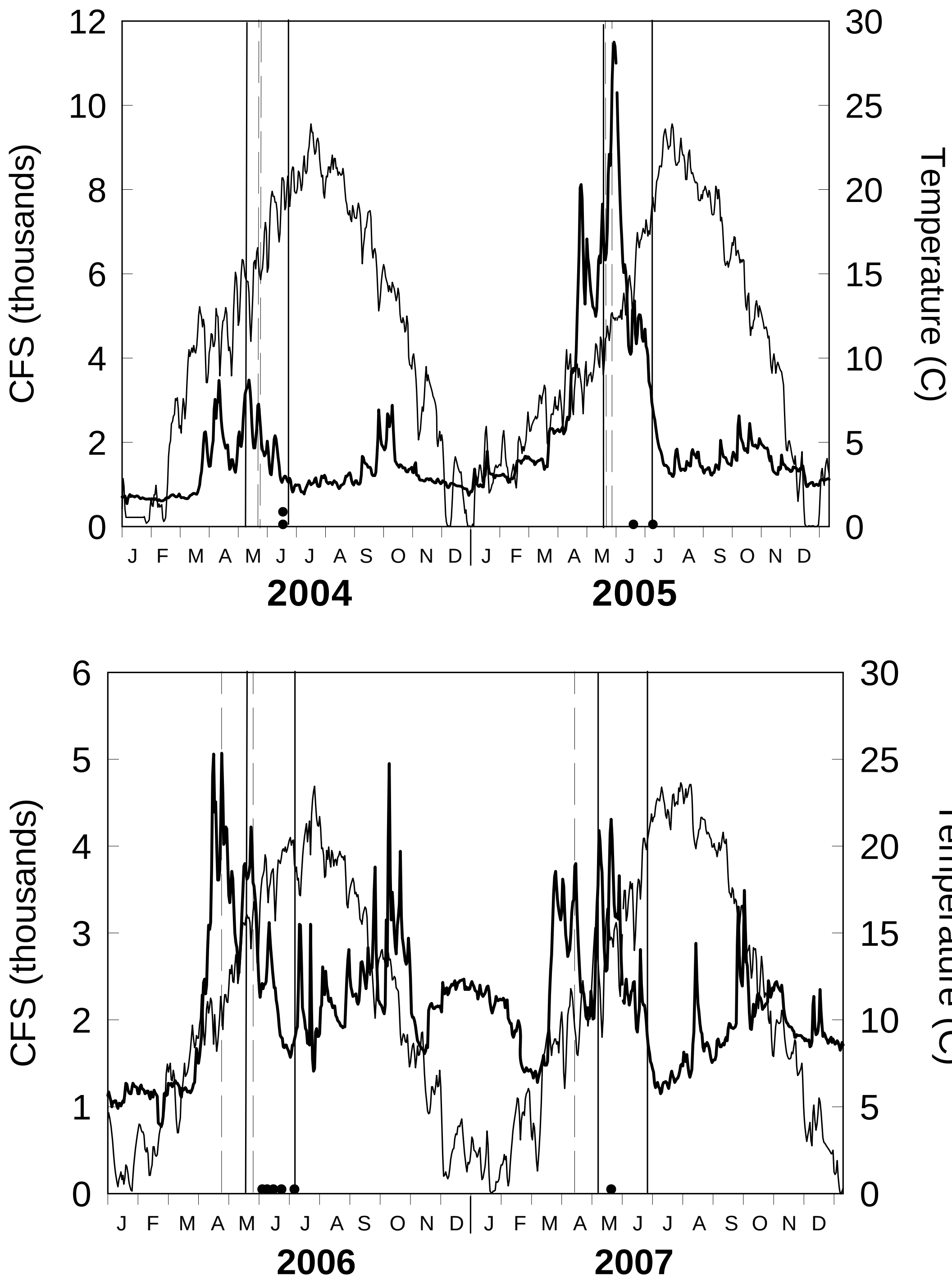


Figure 4. Collections of razorback sucker larvae in the Gunnison River in relation to the calendar year, spring hydrograph (dark lines), and thermal regime (light lines) during 2004 and 2005 (top), 2006 and 2007 (bottom). Solid vertical lines bracket the period of annual seine sampling; dashed vertical lines: the estimated spawning period that produced the captured razorback larvae (dots). Discharge and temperature were measured at the USGS gauge at Whitewater (RK 24.1, RM 15). Analyses utilized both positively identified razorback sucker larvae and possible razorback sucker larvae.

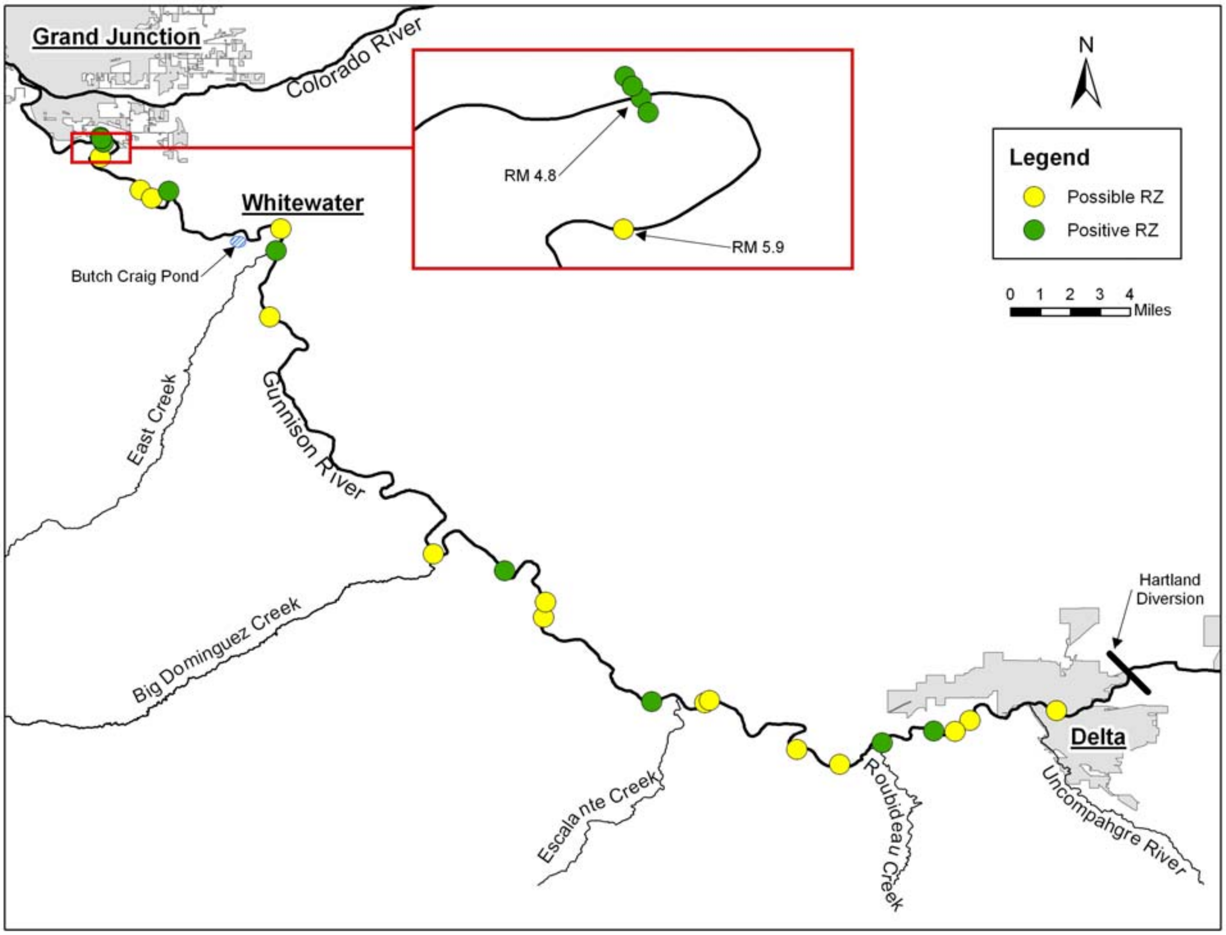


Figure 5. Collection locations of larvae both positively identified as razorback sucker (green dots) and tentatively identified as possible razorback sucker (yellow dots) from the Gunnison River study area during 2002–2007.

Table 4. Locations of positively identified razorback sucker (RZ) and possible RZ(?) larvae collection sites in the Gunnison River, 2002–2007.

Year	Date	RK location	RM location	No. captured	Identification	Method
2002	May 21	11.1–14.6	6.9–9.1	1	RZ(?)	Hand seine
2002	May 30	7.7	4.8	3	RZ	Hand seine
2002	May 30	9.5–13.5	5.9–8.4	2	RZ(?)	Hand seine
2002	Jun 6	7.7	4.8	1	RZ	Hand seine
2002	Jun 6	80.8	50.2	1	RZ	Light trap
2003	May 21	24.3	15.1	1	RZ	Hand seine
2003	Jun 4	59.5	37.0	1	RZ(?)	Hand seine
2003	Jun 5	28.2	17.5	1	RZ(?)	Hand seine
2003	Jun 9	87.0	54.1	1	RZ(?)	Hand seine
2003	Jun 9	84.8	52.7	1	RZ	Hand seine
2003	Jun9	76.9	47.8	1	RZ(?)	Hand seine
2003	Jun 10	48.9	30.4	1	RZ(?)	Hand seine
2004	Jun 16	58.6	36.4	1	RZ(?)	Hand seine
2004	Jun 16	54.1	33.6	1	RZ	Hand seine
2005	Jun 24	69.5	43.2	1	RZ(?)	Hand seine
2005	Jul 7	15.4	9.6	1	RZ	Hand seine
2006	Jun 2	53.7	33.4	1	RZ(?)	Hand seine
2006	Jun 5	92.2	57.3	1	RZ(?)	Hand seine
2006	Jun 14	86.4	53.7	1	RZ(?)	Hand seine
2006	Jun 22	67.1	41.7	1	RZ	Hand seine
2006	Jul 5	79.6	49.5	1	RZ(?)	Hand seine
2007	May 15	23.0	14.3	1	RZ(?)	Hand seine

Colorado River

Larval Collections

Initiation and termination of sampling in the Colorado River usually followed that of the Gunnison River during the years both rivers were sampled (Table 2). From 201 to 307 sites were seined annually for larvae in the Colorado River with 46–81% of the sampling efforts yielding fish larvae (Table 5). Sampling efforts that did not yield larvae generally occurred prior to the annual emergence of larvae. Total number of fish larvae collected annually ranged from 2,158 (2005) to 9,436 (2007) with the mean number of fish larvae per collected sample ranging from 23.2 (2005) to 48.7 (2006).

Specimens positively identified as razorback sucker were captured in all four years, but numbers were low, ranging from 1 to 13 per year (Table 5). The total number of razorback sucker larvae collected per year increased during the study period. As with Gunnison River samples, some specimens could only tentatively be identified as possible razorback sucker. There were generally fewer of these individuals in Colorado River samples than those positively identified. The annual, geometric mean number of positive razorback sucker specimens per collected sample ranged from 0.004 to 0.038. In contrast to the Gunnison River, these annual means increased over time with the mean in 2007 being significantly greater than the mean in 2004 (Figure 6). Only in 2007 was the Colorado River geometric mean CPE significantly higher than the Gunnison River mean.

Also, positively identified razorback sucker specimens comprised 0.02–0.14 percent of all fish larvae collected per year. As in the Gunnison River, nonnative white sucker larvae were very abundant. In the Colorado River, white sucker were about equally abundant as native bluehead sucker larvae and more abundant than native flannelmouth sucker *Catostomus latipinnis* larvae (Table 6). Timing of peaks in larval abundance varied among species and varied among years within species (Appendix: Tables IV-VI; Figs. VIII-XXII).

Back-calculation of spawning dates from positively identified razorback sucker larvae from the Colorado River during the four sampling years indicated a spawning period extending from April 27 to May 31 (Appendix Table II). Sample sizes in 2004 and 2005 were too small to be of much use in estimating spawning duration (Figure 7), but estimates of earliest spawning from first-appearing, positively-identified razorback sucker larvae was 27 April in 2004, 24 may in 2005, 4 May in 2006, and 3 May in 2007. Latest spawning was 31 May in 2006 and 30 May in 2007. Spawning commenced about two weeks later than in the Gunnison River and lasted about four weeks. Mean daily main-channel water temperature on the day of earliest estimated spawning was 15.6°C in 2004, 13.9°C in 2005, 12.4°C in 2006, and 14.2°C in 2007. There were too few razorback sucker larvae to discern any relationship between discharge and the first estimated dates of spawning. Discharge at the Colorado-Utah

Table 5. Seining results for Colorado River sampling, 2004–2007. The number of specimens positively identified as razorback sucker (RZ) and tentatively identified as possible razorback sucker (RZ?) are listed. Mean and percent (%) samples with RZ refer only to specimens positively identified as razorback sucker.

Year	Sites Seined	Samples of larvae	Total fish	No. RZ	No. RZ?	Mean RZ per sample	% RZ of all fish
2004	206	167	6,161	1	1	0.006	0.016
2005	201	93	2,158	3	1	0.032	0.139
2006	270	185	9,013	5	3	0.032	0.055
2007	307	225	9,436	13	6	0.058	0.138
Totals	**984**	**670**	**26,768**	**22**	**11**		

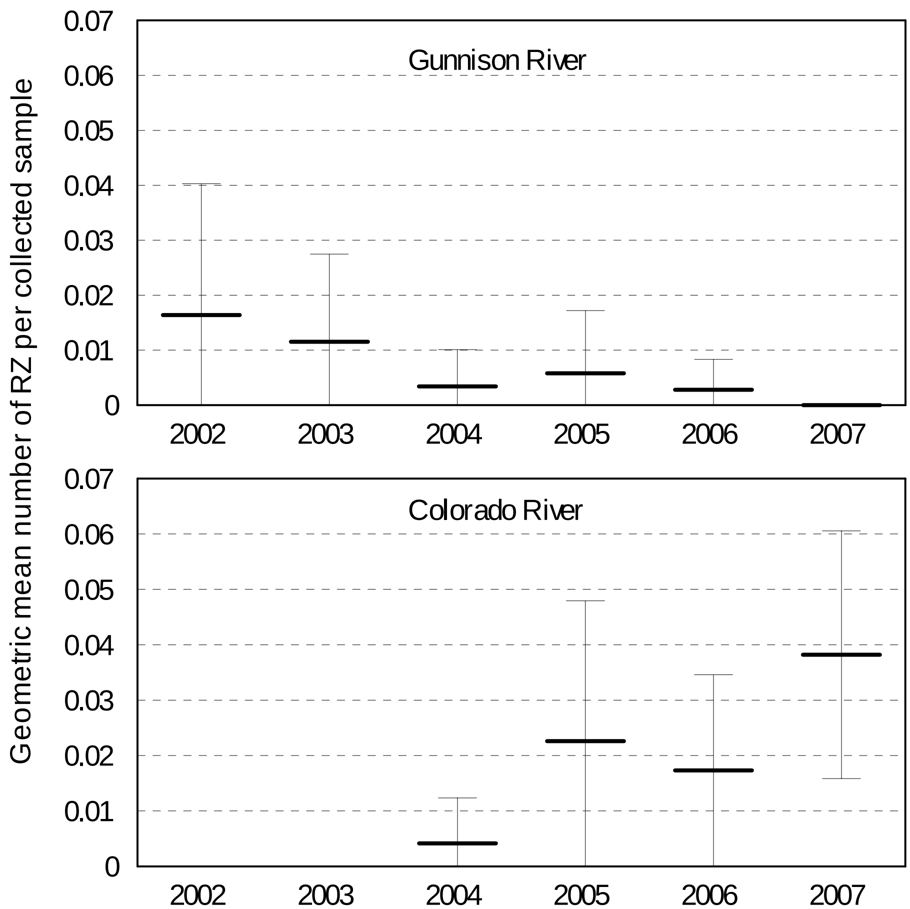


Figure 6. Annual geometric mean number of positively identified razorback sucker specimens per collected sample of fish from the Gunnison and Colorado rivers, 2002-2007. No sampling was conducted in the Colorado River during 2002 and 2003. Numbers in each sample were log-transformed (*ln* (n + 1)) before calculating the mean; the mean was then transformed backed to a standard value.

Table 6. Species composition of seine samples from the Colorado River, 2004–2007. Only species comprising more than one percent of the total in at least one year are shown. Both positive and possible razorback sucker larvae are also shown for comparison.

Species	2002	2003	2004	2005	2006	2007	Mean
Gila species	-	-	1.90	0.79	2.50	0.47	1.41
common carp	-	-	0.15	1.48	0.00	0.01	0.41
fathead minnow	-	-	5.19	4.22	1.23	0.30	2.73
red shiner	-	-	0.24	0.51	1.89	0.13	0.69
speckled dace	-	-	3.34	0.42	2.09	1.59	1.86
bluehead sucker	-	-	36.84	36.38	28.31	34.35	33.97
flannelmouth sucker	-	-	24.44	15.94	23.39	27.07	22.71
white sucker	-	-	25.22	37.53	38.93	33.99	33.92
razorback sucker	-	-	0.02	0.14	0.06	0.14	0.09
razorback sucker?	-	-	0.02	0.05	0.03	0.03	0.03
Totals	-	-	**97.37**	**97.45**	**98.43**	**98.08**	**97.82**

state line gauge on the earliest estimated spawning date was 2,920 cfs in 2004, 29,400 cfs in 2005, 11,400 cfs in 2006, and 9,800 cfs in 2007 (Figure 7).

In general, razorback sucker larvae were widely distributed throughout the Colorado River study area (Figure 8 and Table 7). Twenty-two larvae were positively identified as razorback sucker. They were distributed throughout the study area from the Gunnison River confluence downstream to Westwater. Specimens tentatively identified as possible razorback sucker had a similar distribution. No positively identified razorback sucker larvae were collected from the 15-mile reach upstream of the Gunnison River confluence, but two possible razorback sucker larvae were collected there.

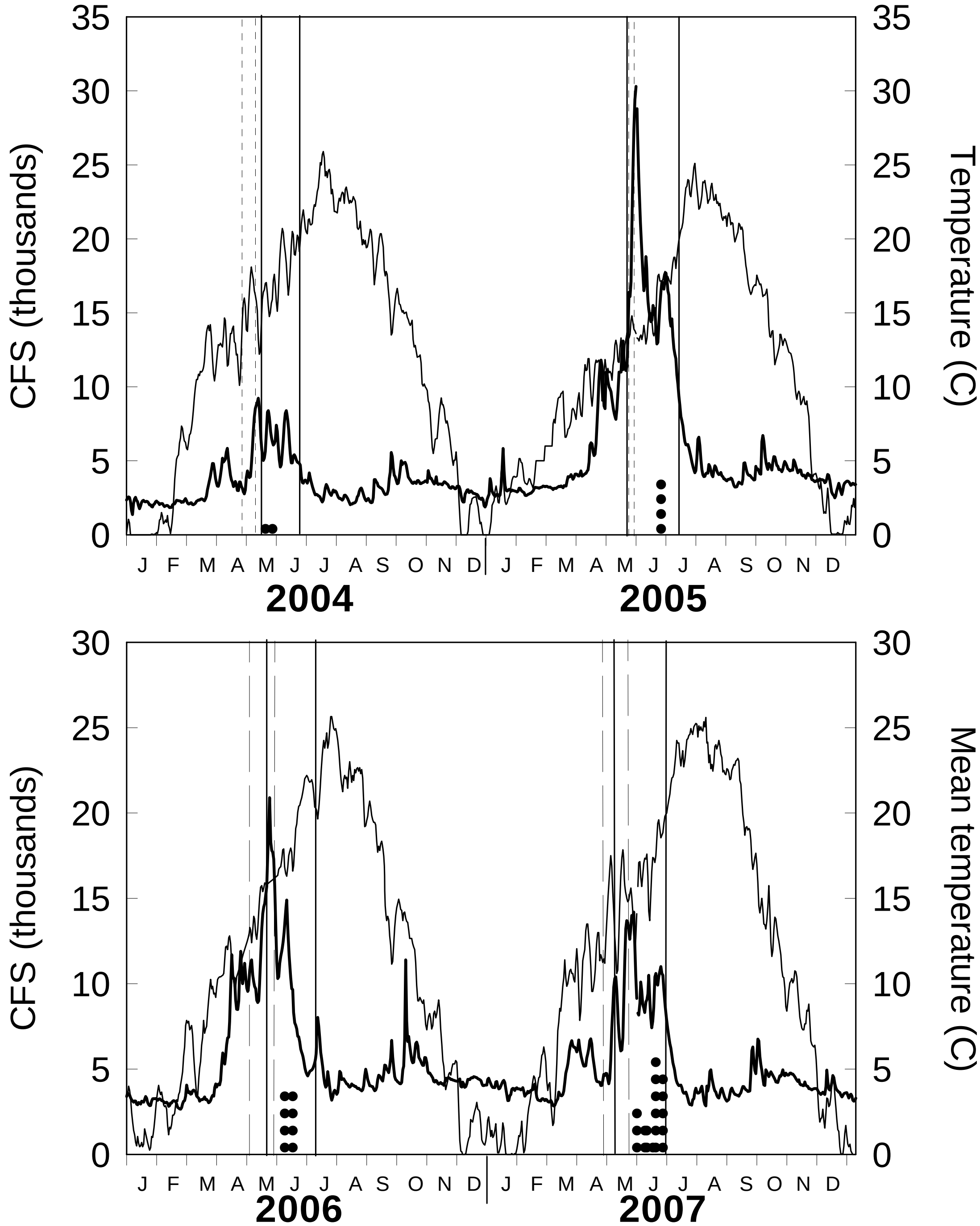


Figure 7. Collections of razorback sucker larvae in the Colorado River in relation to the calendar year, spring hydrograph (dark lines), and thermal regime (light lines) during 2004, 2005 (top), 2006, and 2007 (bottom). Solid vertical lines bracket period of annual seine sampling; dashed vertical lines: estimated spawning period that produced the captured razorback larvae (dots). Discharge and water temperature were measured at the USGS gauge at Colorado-Utah state line (RK 212.4, RM 132.0). Analyses utilized both positively identified razorback sucker larvae and possible razorback sucker larvae.

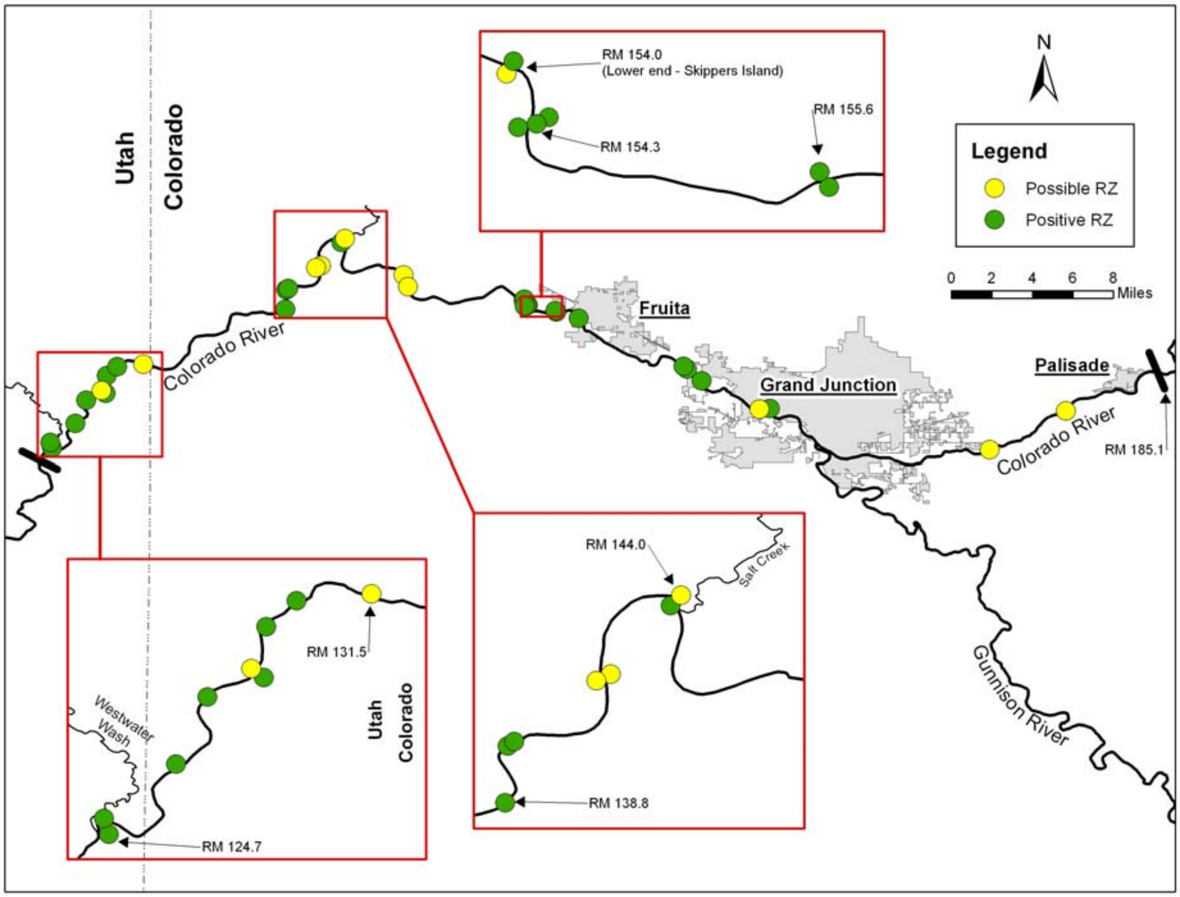


Figure 8. Collection locations of larvae both positively identified as razorback sucker (green dots) and tentatively identified as possible razorback sucker (yellow dots) from the Colorado River study area during 2004–2007.

Table 7. Locations of positively identified razorback sucker (RZ) and possible razorback sucker (?) larvae collection sites in the Colorado River, 2004–2007.

Year	Date	RK location	RM location	No. captured	Identification	Method
2004	May 20	261.8	162.7	1	RZ	Hand seine
2004	May 27	247.8	154.0	1	RZ(?)	Hand seine
2005	Jun 27	231.7	144.0	1	RZ	Hand seine
2005	Jun 27	231.7	144.0	1	RZ(?)	Hand seine
2005	Jun 27	225.1	139.9	1	RZ	Hand seine
2005	Jun 27	208.7	129.7	1	RZ	Hand seine
2006	Jun 16	252.3	156.8	1	RZ	Hand seine
2006	Jun 16	250.4	155.6	2	RZ	Hand seine
2006	Jun 16	238.1	148.0	1	RZ(?)	Hand seine
2006	Jun 08	211.6	131.5	1	RZ(?)	Hand seine
2006	Jun 08	209.7	130.3	1	RZ	Hand seine
2006	Jun 08	207.6	129.0	1	RZ	Hand seine
2006	Jun 08	207.6	129.0	1	RZ(?)	Hand seine
2007	May 29	263.1	163.5	1	RZ	Hand seine
2007	May 29	261.5	162.5	1	RZ	Hand seine
2007	May 29	248.3	154.3	1	RZ	Hand seine
2007	Jun 04	248.3	154.3	2	RZ	Hand seine
2007	Jun 05	223.3	138.8	1	RZ	Hand seine
2007	Jun 05	206.0	128.0	1	RZ	Hand seine
2007	Jun 11	269.0	167.2	1	RZ	Hand seine
2007	Jun 14	228.5	142.0	2	RZ(?)	Hand seine
2007	Jun 14	225.3	140.0	1	RZ	Hand seine
2007	Jun 14	203.7	126.6	1	RZ	Hand seine
2007	Jun 14	200.6	124.7	2	RZ	Hand seine
2007	Jun 21	292.2	181.6	1	RZ(?)	Hand seine
2007	Jun 21	286.1	177.8	1	RZ(?)	Hand seine
2007	Jun 21	268.4	166.8	1	RZ(?)	Hand seine
2007	Jun 22	247.8	154.0	1	RZ	Hand seine
2007	Jun 22	239.3	148.7	1	RZ(?)	Hand seine

Adult Population Size

In 2005, there were 426 captures of stocked razorback sucker in the Colorado River of which 145 (34%) were adults ($\geq$ 400 mm TL). Of all captures, 52% were from the larval razorback sucker study area (Palisade-to-Westwater reach), and 48% from the more downstream Cottonwood-Wash-to-Green-River-confluence reach. About 60% of the captured adults were from the upstream larval study area. Although 40% of adult captures occurred downstream of Cottonwood Wash, very few (1%) occurred in the most downstream 75 km (46 miles) of the Colorado pikeminnow study area (Potash to the Green River confluence). In contrast, 4% of captures of immature razorback sucker occurred downstream of Potash. Whether this disparity in distribution was related to differential habitat preference, differential post-stocking dispersal, or to upstream spawning movements of adult razorback sucker during the spring Colorado pikeminnow sampling season will require additional investigation. Total captures and recaptures by pass are provided in Appendix Table III.

Abundance estimates for stocked razorback sucker of all sizes were produced with six models (M_t, M_t + length, M_{tb}, M_{tb} + length, M_b, and M_0), with point estimates ranging from 530 to 2,135. The weighted average of these six estimates was 2,010 with a 95% confidence interval of 504–24,594 (number of different fish captured [M_{t+1}] used as the lower limit for a log-based CI). Model M_t (capture probabilities are allowed to vary with sampling pass) had the greatest weight (0.53). Models M_t and M_t + length (weight = 0.20) produced nearly identical point estimates and standard errors: 2,135 for Model M_t (SE = 347); 2,137 for Model M_t + length (SE = 348); the 95% confidence interval for both was 1,576–2,958. For adults, point estimates of the same six models ranged from 191 to 1,066, with a weighted average of 741 (95% CI = 241–3,543). Model M_t + length (a model that allows capture probabilities to vary with sampling pass and with fish length) had the highest weight (0.49) and the point estimate produced from it ($\hat{N}$ = 1,066) was substantially higher than the next two highest weighted models, M_{tb} + length (weight = 0.24; $\hat{N}$ = 284) and M_t (weight= 0.20; $\hat{N}$ = 646). The 95% confidence interval of the M_t + length estimate was 377–3,703. Probability of capture for adults of average length of 437 mm TL ranged from 0.018 to 0.057.

To obtain an estimate of how many razorback sucker adults might have been present in the upper reach during the 2005 spawning period, the percent of total adult captures in the upper reach was assumed indicative of the actual percent occurrence there, and, for lack of a more accurate method, was applied to the river-wide M_t + length point estimate, the model with the highest weight for adults. Reach-specific abundance estimates were not possible because two individuals moved between the upper and lower reaches between capture and recapture events during the spring sampling period, and hence, the assumption of within-year reach closure was violated. Assuming the upper reach was inhabited by 60% of the adult population, a total there of 640 adults was calculated. Assuming also a male:female sex ratio of 1:1 (Manual Uliberri, Dexter National Fish Hatchery, personal communication) the breeding population of razorback sucker in the upper reach included an estimated 320 females.

Hamman (1985) reported mean fecundity of hatchery-reared female razorback sucker at 49,838 eggs/kg body mass. Using the mean mass of 871 g (SE = 25.4; N = 82) from individuals ≥ 400 mm TL from our 2005 sample (both genders) and the estimate of 320 females, we calculated a total of 13,890,847 eggs produced in the upper reach. Similarly, McAda and Wydoski (1980) reported mean fecundity of wild-caught razorback sucker from the Green River at 34,845 eggs/kg body mass. Again using a mean mass of 871 g and the estimate of 320 females, we calculated a total of 9,711,998 eggs produced. Considering the wide confidence intervals about the river-wide population estimate, the actual number of eggs produced may have been substantially more or less than these estimates. Nevertheless, these values provide a rough idea of the possible egg output of razorback sucker in a year when only three positively identified razorback sucker larvae were collected.

Adult Spawning

During the Colorado pikeminnow population sampling of 2005 and 2008, breeding condition of each captured razorback sucker was recorded. Females in a running-ripe condition are probably a good indication that spawning is underway or is about to occur. In 2005, four such fish were captured between 13 May and 8 June. In 2008, five running-ripe females were captured between 15 May and 16 June. In 2007, a year in which no Colorado pikeminnow sampling occurred, one running-ripe female razorback sucker was captured on 31 May. Although we do not have larval data from 2008 with which to compare estimated spawning dates, estimated spawning dates from the four Colorado River larvae collected in 2005 (24 May to 29 May) and the 19 collected in 2007 (3 May to 30 May) were consistent with the dates of running-ripe females captured in those years. The one running-ripe female from 2007 was captured one day after the last spawning date estimated from larvae collected that year.

Captures of running-ripe females from 2005, 2007, and 2008 were distributed between Loma, Colorado (RK 247.8, RM 154) and Moab, Utah (RK 103.0, RM 64), indicating that spawning likely occurs at multiple sites (Figure 9).

A suspected razorback sucker spawning site was identified in 2007 near Loma, Colorado and is noteworthy because of the number of individuals encountered. Electrofishing on 24 May over an inundated gravel-bar and adjacent eddy at the downstream end of Skipper's Island (RK 247.8; RM 154.0) resulted in the capture of 11 razorback sucker. When the site was re-sampled the following week (31 May) 15 razorback sucker were captured, including two captured the previous week. Of the 24 unique razorback sucker captured at this site, 16 were sexually mature and in various

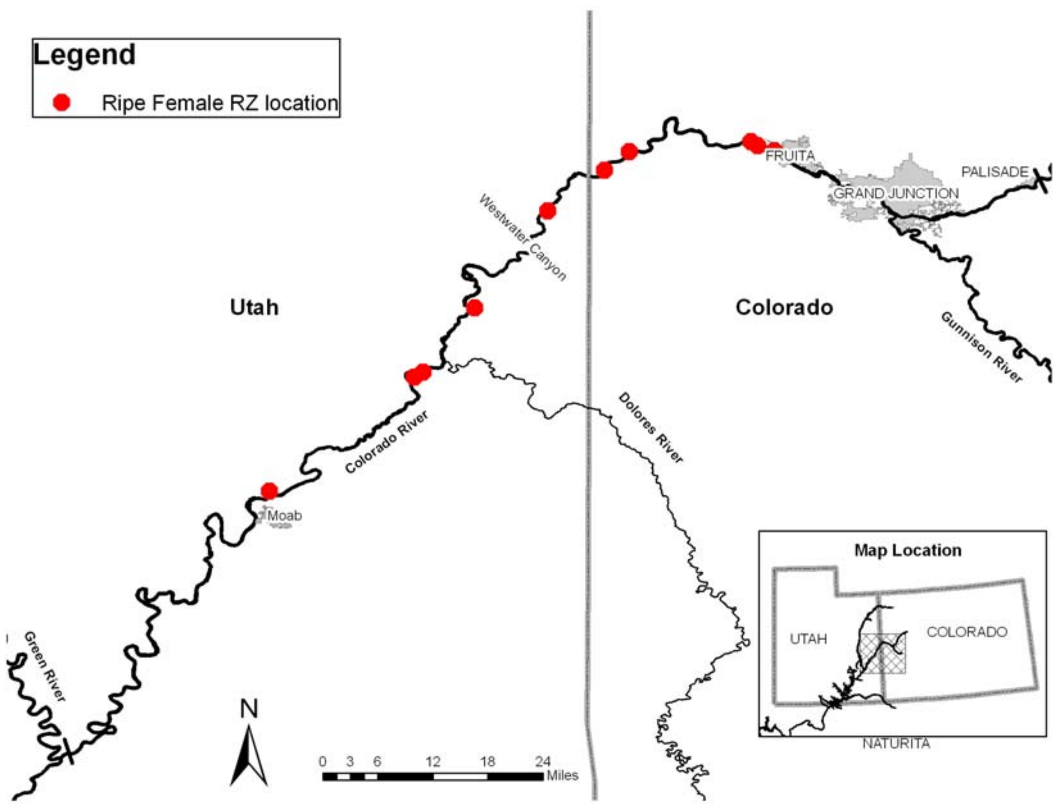


Figure 9. Distribution of running-ripe female razorback sucker captured in the Colorado River during 2005, 2007 and 2008.

phases of breeding condition: four appeared spent, one was a running ripe male, one was a running-ripe female, and the other 10 were not yet ripe.

DISCUSSION

After 13 years of stocking razorback sucker in the Gunnison River, comparatively few larvae were found over a six-year sampling effort. While the number of positively identified razorback sucker larvae collected annually declined between 2002 and 2007, the decline in mean number per sample was not statistically significant. Whether the number of stocked adults in the Gunnison River declined over the same period is not known because no comprehensive enumeration efforts for adults have been made there. In the Colorado River, the total number of positively identified razorback sucker larvae collected was also very low. However, there the mean number collected per sample appeared to increase over the study period with a significantly higher mean in 2007 than in 2004. In 2005, 640 adults (320 females) were estimated to inhabit the 97-RK-long (60 RM) Colorado River larvae sampling area (6.6/RK); however, despite the potential production of millions of eggs, only three larvae were positively identified as razorback sucker from 93 larval collections. In contrast, 472 razorback sucker larvae were collected with hand seines (three passes; 208 larval collections) from a 223-RK-long (139 RM) San Juan River study area in spring 2003 (Brandenburg et al. 2004), a year in which the study area was inhabited by an estimated 566 (2.2/RK) adult razorback suckers (Ryden 2006).

There were some additional differences between results from the Gunnison and Colorado rivers worth noting, as well as some consistencies. The Gunnison River generally yielded higher numbers of fish larvae (all species combined) per sample. Although mean number of total fish larvae per sample was similar between rivers in 2004 and 2007, it was six times higher in the Gunnison River than in the Colorado River in 2005, and twice as high in 2006. In both rivers there appeared to be no relation between discharge and date of first razorback sucker spawning. However, spawning commenced at similar temperatures in both rivers: 11.3-15.0°C in the

Gunnison River and 12.4-15.6 in the Colorado River. These temperatures are consistent with the 10-16°C range reported by Bestgen et al. (2002) for razorback sucker spawning in the middle Green River. Earliest spawning in the Colorado River was generally about two weeks later than in the Gunnison River.

In the Gunnison River, six of 10 positively identified razorback sucker larvae were collected downstream of Whitewater, Colorado (RK 24.3; RM 15.1), suggesting a possible reach (Whitewater to Redlands Diversion Dam [RK 4.8; RM 3.0) for creating or managing nursery habitat. The Butch Craig Pond management area (an off-channel pond with upstream and downstream connections to the river during high flow) at RK 20.4 (RM 12.7) is situated in the upper portion of this reach. Whether all the razorback sucker larvae found in this reach came from spawning upstream of this site is not known. If most spawning occurred downstream of the Butch Craig Pond, the site might not be in the ideal location. In the Colorado River, razorback sucker larvae were widely distributed but nine of 22 positively identified specimens were found in a seven-mile reach between the Colorado-Utah state line (RK 212; RM 132) and the top of Westwater Canyon (RK 201; RM 125). Given these preliminary results, management of some portion of the river (as nursery habitat) between RK 212 and 201 might be considered in the future.

Of all larvae identified as positive or possible razorback sucker, the Gunnison River yielded a higher percentage of ambiguous (possible) specimens (60%) than did the Colorado River (33%). Clearly, reproduction and recruitment of pure razorback sucker are needed for recovery. However, at this time it is not known whether hybridization with other sucker species is the reason so many specimens could not be positively identified in the Gunnison River or because of morphological adaptations to life in the Gunnison River. This question warrants additional study and should be able to be determined through genetic analysis.

One key question regarding future prospects for recovery is whether annual abundance of razorback sucker larvae is related more to the number of adults present in the system or to environmental variables that may affect spawning and hatching success and survival of produced larvae. For the Colorado River, increased numbers of captured larval razorback sucker from 2004 to 2007 may in part reflect increased numbers of breeding-age females in the system, but adults were not sampled in all years. Many more years of larval data and adult population estimation will be needed before this question can be answered. It is reasonable to assume more adults will produce more larvae. However, in the San Juan River, estimates of adults increased from 379 (2.2/RK) in 2003, to 566 (4.8/RK) in 2004 to 1,204 (9.6/RK) in 2005 (Ryden 2006) while larvae collected annually decreased from 472 to 41 to 19 before rebounding to 202 in 2006 (Brandenburg and Farrington 2008), a year for which no adult estimate was available. This suggests that annual variation in number of larvae in the San Juan River may be influenced more by unknown environmental variables that affect hatching success or survival of larvae than by the number of eggs produced. If so, it is uncertain whether drivers of larval abundance in the San Juan River can be extrapolated to the Colorado and Gunnison rivers where other or additional factors may be at work. The consistently small number of razorback sucker larvae found in samples during our study suggests that two things will likely be needed before larvae occur in sufficient quantities to assure some level of recruitment to the adult stage: (1) much larger adult populations to produce more eggs, and (2) much improved egg hatching success and/or initial survival of larvae. Once numbers of larvae in the system are increased, determining the long-term fate (survival) of wild-produced larvae will then be needed to evaluate the success of razorback sucker recovery efforts in the Gunnison and Colorado rivers.

Whether any larvae have survived to recruit to the adult stage cannot be ascertained with current techniques. Improper tagging, PIT tag loss in stocked individuals, and faulty tags preclude using the presence or absence of such tags as a definitive means of determining origin. Hence, assessing the state of recovery of this species will remain elusive until techniques are developed that allow identification of wild-produced adults. A temporary solution to this problem might be to prohibit the stocking of any razorback sucker smaller than a specified length so that captured individuals less than that length could be presumed to have been produced in the wild. Although this would allow documentation of wild recruitment it would not allow its quantification because wild-produced individuals growing beyond the minimum size would lose their ability to have their origin identified.

Although the presence of razorback sucker larvae documented during this study is an important step in the recovery process, it appears that producing a self-sustaining population will require a long-term effort that will include stocking, monitoring, research that identifies limiting factors, and management actions that address those limiting factors.

SUMMARY AND CONCLUSIONS

-- Stocked razorback sucker in the Gunnison and Colorado rivers spawned and produced larvae.

-- Spawning likely occurred at multiple sites within each river.

-- Larvae were widely distributed.

-- Absolute numbers of larvae collected were relatively small.

-- The absolute number of larvae positively identified as razorback sucker increased over time in the Colorado River while the number collected from the Gunnison River declined. Differences in mean number per sample among years were only significant in the Colorado River.

-- The number of breeding-age fish should increase over time in the Colorado River as young surviving stocked fish mature and more fish are stocked; at present, retention of stocked fish in the Gunnison River and population size there is unknown.

-- Whether any naturally-produced razorback sucker larvae are surviving and recruiting to the adult population is unknown.

RECOMMENDATIONS

-- Population abundance of razorback sucker in the Colorado River should be estimated in years of Colorado pikeminnow monitoring when razorback sucker are already being captured, requiring no additional field effort.

- -- Estimation of stocked fish abundance in the Gunnison River is also warranted but would require an additional field effort. Population estimates there would help us determine whether a decline in larval abundance in the Gunnison might in part be related to a decline in adult numbers.
- -- Larval sampling should be reinitiated in both rivers to document trends in reproductive success.
- -- Light trapping might be appropriate in locations just downstream of known spawning sites such as the suspected site near Loma.
- -- Specimens tentatively identified as possible razorback sucker should be genetically analyzed for confirmation and to determine whether hybridization with other suckers is significant enough to warrant management actions.
- -- Initiate a radio-telemetry study to help identify razorback sucker spawning locations in each river.
- -- Develop management plans for floodplain habitats that might serve as nursery areas for young razorback suckers downstream of important spawning locations.
- -- Develop links between sucker spawning events and environmental variables that influence spawning site selection and timing such that management actions might be devised to enhance spatial or temporal reproductive isolation among species. This need is contingent on first verifying that hybridization commonly occurs and poses a serious obstacle to recovery.
- -- Develop a means by which naturally-produced razorback sucker can be identified and discerned from stocked individuals, so managers know whether reproduction is leading to self-sustaining populations. One temporary solution: prohibit stocking of any individuals smaller than a specified length. Then, when a captured individual lacks a PIT tag, and is smaller than the minimum stocking size, the assumption can be made that the fish was produced in the wild.

LITERATURE

Bestgen, K. R. 2008. Effects of water temperature on growth of razorback sucker larvae. Western North American Naturalist 68:15–20.

Bestgen, K.R., G.B. Haines, R. Brunson, T. Chart, M. Trammell, R.T. Muth, G. Birchell, K. Christopherson, and J.M. Bundy. 2002. Status of wild razorback sucker in the Green River Basin, Utah and Colorado, determined from basinwide monitoring and other sampling programs. Final Report of Larval Fish Laboratory Colorado State University to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Bozek, M. A., L. J. Paulson, and G. R. Wilde. 1990. Effects of ambient Lake Mohave temperatures on development, oxygen consumption, and hatching success of the razorback sucker. Environmental Biology of Fishes 27:255–263.

Brandenburg, W. H., M. A. Farrington, and S. J. Gottlieb. 2004. Razorback sucker larval fish survey in the San Juan River during 2003. Final Report. University of New Mexico, Albuquerque.

Brandenburg, W. H., and M. A. Gottlieb. 2008. Colorado pikeminnow and razorback sucker larval fish survey in the San Juan River during 2007. Final Report. University of New Mexico, Albuquerque.

Hamman, R. L. 1985. Induced spawning of hatchery-reared razorback sucker. Progressive Fish Culturist 47:187-189.

Holden, P. B., C. Richard, L. W. Crist, and J. R. Campbell. 1981. Aquatic biology studies for proposed Colorado Ute Electrical Association power plant near Grand Junction, Colorado. BIOWEST, Inc., Logan, Utah.

Huggins, R. M. 1989. On the statistical analysis of capture-recapture experiments. Biometrika 76:133140.

Huggins, R. M. 1991. Some practical aspects of a conditional likelihood approach to capture experiments. Biometrics 47:725–732.

McAda, C. M., and R. S. Wydoski. 1980. The razorback sucker, *Xyrauchen texanus*, in the Upper Colorado River Basin, 1974-76. Technical Papers of the U. S. Fish and Wildlife Service 99. U. S. Fish and Wildlife Service, Washington, D.C.

Muth, R. T., G. B. Haines, S. M. Meismer, E. J. Wick, T. E. Chart, D. E. Snyder, and J. M. Bundy. 1998. Reproduction and early life history of razorback sucker in the Green River, Utah and Colorado, 1992-1996. Final Report of Colorado State University Larval Fish Laboratory to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Osmundson, D. B., and G. C. White. 2009. Population status and trends of Colorado pikeminnow of the upper Colorado River, 1991–2005. Final Report. U. S. Fish and Wildlife Service, Grand Junction, Colorado.

Ryden, D. W. 2006. Augmentation and monitoring of the San Juan razorback sucker population: 2005 interim progress report. Final Report. U. S. Fish and Wildlife Service, Grand Junction, Colorado.

USFWS. 2002. Razorback sucker (*Xyrauchen texanus*) Recovery Goals: amendment and supplement to the Razorback Sucker Recovery Plan. U. S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 (Supplement):120–139.

APPENDIX

Appendix Table I. Summary information for back calculation of hatching and spawning dates for positively identified razorback sucker (RZ) and possible RZ(?) larvae collected from the Gunnison River, 2002–2007.

Date collected	Total length (mm)	Estimated hatch date	Mean temperature (C)	Incubation time (days)	Estimated spawn date	Identification
			2002			
May 30	14	May 10	15.0	11	Apr 29	RZ
May 30	14	May 10	15.0	11	Apr 29	RZ
May 30	15	May 7	15.0	11	Apr 27	RZ
May 30	15	May 7	15.0	11	Apr 27	RZ(?)
May 30	16	May 3	14.1	13	Apr 21	RZ(?)
May 30	12	May 8	15.1	11	Apr 28	RZ(?)
Jun 6	14	May 17	15.8	10	May 7	RZ
Jun 6	15	May 14	15.3	11	May 6	RZ
			2003			
May 21	14	May 1	13.6	14	Apr 18	RZ
Jun 4	12	May 22	16.4	10	May 12	RZ(?)
Jun 5	16	May 9	15.2	11	Apr 29	RZ(?)
Jun 9	14	May 20	13.9	13	May 7	RZ(?)
Jun 9	15	May 17	13.9	13	May 4	RZ
Jun 9	15	May 17	13.9	13	May 4	RZ(?)
Jun 10	17	May 11	15.3	11	Apr 30	RZ(?)
			2004			
Jun 16	12	Jun 3	16.5	10	May 24	RZ(?)
Jun 16	12	Jun 3	16.5	10	May 24	RZ
			2005			
Jul 7	17	Jun 7	12.8	15	May 23	RZ
Jun 24	14	Jun 4	11.9	16	May 19	RZ(?)
			2006			
Jun 2	13	May 16	14.8	12	May 4	RZ(?)
Jun 5	14	May 16	14.8	12	May 4	RZ(?)
Jun 14	16	May 18	15.4	11	May 7	RZ(?)
Jun 22	18	May 20	14.6	12	May 8	RZ
Jul 5	17	Jun 5	16.3	10	May 26	RZ(?)
			2007			
May 15	13	Apr 27	13.2	14	Apr 13	RZ(?)

Appendix Table II. Summary information for back calculation of hatching and spawning dates for positively identified razorback sucker (RZ) and possible RZ(?) larvae collected from the Colorado River, 2004–2007.

Date collected	Total length (mm)	Estimated hatch date	Mean temperature (C)	Incubation time (days)	Estimated spawn date	Identification
			2004			
May 20	12	May 7	15.8	10	Apr 27	RZ
May 27	11	May 17	15.3	11	May 06	RZ(?)
			2005			
Jun 27	14	Jun 7	13.5	14	May 24	RZ
Jun 27	13	Jun 10	13.8	13	May 28	RZ(?)
Jun 27	14	Jun 7	13.5	14	May 24	RZ
Jun 27	12	Jun 11	13.9	13	May 29	RZ
			2006			
Jun 16	11	Jun 6	16.5	10	May 27	RZ
Jun 16	10	Jun 9	17.0	9	May 31	RZ
Jun 16	12	Jun 3	16.2	10	May 24	RZ
Jun 16	11	Jun 6	16.5	10	May 27	RZ(?)
Jun 8	11	May 29	16.0	10	May 19	RZ(?)
Jun 8	13	May 22	15.9	11	May 11	RZ
Jun 8	12	May 26	15.8	10	May 16	RZ
Jun 8	13	May 22	15.0	11	May 11	RZ(?)
			2007			
May 29	12	May 16	13.7	13	May 03	RZ
May 29	11	May 19	15.3	11	May 08	RZ
May 29	12	May 16	14.3	13	May 03	RZ
Jun 04	10	May 28	14.1	13	May 11	RZ
Jun 04	11	May 25	14.1	13	May 11	RZ
Jun 05	12	May 23	15.3	11	May 12	RZ
Jun 05	10	May 29	14.9	12	May 17	RZ
Jun 11	12	Jun 01	13.8	13	May 19	RZ
Jun 14	14	May 25	14.6	12	May 13	RZ(?)
Jun 14	16	May 18	15.9	10	May 08	RZ(?)
Jun 14	10	Jun 07	16.5	10	May 28	RZ
Jun 14	10	Jun 07	16.5	10	May 28	RZ
Jun 14	10	Jun 07	16.5	10	May 28	RZ
Jun 14	12	Jun 01	15.0	12	May 20	RZ
Jun 21	14	Jun 01	13.8	13	May 19	RZ(?)
Jun 21	14	Jun 01	13.8	13	May 19	RZ(?)
Jun 21	12	Jun 08	15.7	11	May 28	RZ(?)
Jun 22	12	Jun 09	16.1	10	May 30	RZ
Jun 22	14	Jun 02	13.7	13	May 20	RZ(?)

Appendix Table III. Total number of stocked razorback sucker captured in each sampling pass in the Colorado River during a 2005 Colorado pikeminnow monitoring effort (see Osmundson and White 2009). Totals include recaptures of the same fish caught in previous passes of 2005 (also provided in parentheses). Adults are those ≥ 400 mm TL.

	Pass1	Pass 2	Pass 3	Pass 4	Pass 5
All captures	114	103 (4)	111 (15)	65 (7)	35 (6)
Adults captured	39	26 (1)	45 (5)	21 (4)	14 (2)

Appendix Table IV. Mean number of roundtail chub and bluehead sucker larvae per sample collected from the Gunnison and Colorado rivers, 2002-2007, during 5-day intervals. NS = no sample taken during the time interval even though sampling was conducted. NSD = no sampling done during 5-day interval.

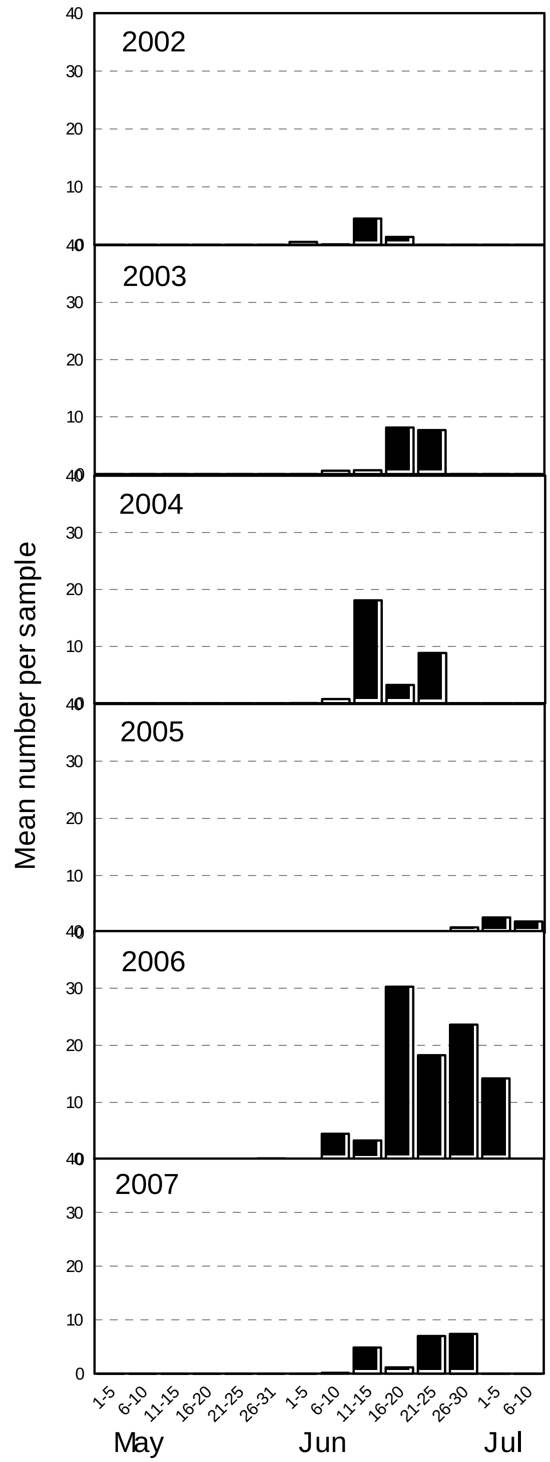
		Gunnison River						Colorado River			
		2002	2003	2004	2005	2006	2007	2004	2005	2006	2007
							Roundtail chub				
May	1-5	NS	NSD	0.00	NSD	NSD	NSD	NSD	NSD	NSD	NSD
	6-10	0.00	NSD	0.00	NSD	NSD	NS	NSD	NSD	NSD	0.00
	11-15	0.00	0.00	0.00	NSD	0.00	0.00	0.00	NSD	NSD	0.00
	16-20	0.00	0.00	0.00	NS	0.00	0.00	0.00	0.00	0.00	0.00
	21-25	0.00	0.00	0.00	NS	0.00	0.00	0.00	0.00	0.00	0.00
	26-31	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00
June	1-5	0.50	0.00	0.03	0.00	0.03	0.00	NSD	NSD	0.00	0.00
	6-10	0.10	0.60	0.74	0.00	4.50	0.17	0.00	0.00	0.11	NSD
	11-15	4.55	0.67	18.09	0.00	3.32	4.86	0.13	NSD	0.20	0.12
	16-20	1.35	8.16	3.19	0.00	30.24	1.15	0.88	0.00	1.19	NSD
	21-25	NSD	7.71	8.83	0.00	18.26	7.00	1.88	0.00	NSD	0.66
	26-30	NSD	NSD	NSD	0.96	23.59	7.38	NSD	0.09	1.33	0.57
July	1-5	NSD	NSD	NSD	2.70	14.19	NSD	NSD	NSD	NSD	NSD
	6-10	NSD	NSD	NSD	1.96	NSD	NSD	NSD	1.55	7.14	NSD
	11-15	NSD	NSD	NSD	NSD	NSD	NSD	NSD	0.00	NSD	NSD
							Bluehead sucker				
May	1-5	NS	NSD	0.00	NSD	NSD	NSD	NSD	NSD	NSD	NSD
	6-10	0.00	NSD	0.00	NSD	NSD	NS	NSD	NSD	NSD	0.22
	11-15	0.09	1.00	0.00	NSD	0.17	0.14	1.07	NSD	NSD	12.25
	16-20	0.00	5.00	0.24	NS	0.00	0.17	0.00	0.00	0.17	1.82
	21-25	1.27	46.50	0.00	NS	2.32	4.07	8.13	0.67	1.82	5.27
	26-31	4.42	3.26	0.64	0.00	6.00	35.78	11.05	3.00	2.79	14.07
June	1-5	0.78	1.41	1.40	0.50	8.06	26.47	NSD	NSD	10.87	10.88
	6-10	0.90	4.12	1.20	0.13	50.85	49.90	11.14	4.00	10.70	NSD
	11-15	1.95	1.00	2.18	0.20	21.76	24.41	7.93	NSD	4.27	25.65
	16-20	2.30	3.22	1.05	0.00	17.35	25.18	14.19	2.62	23.13	NSD
	21-25	NSD	6.57	2.63	15.04	26.00	18.89	23.86	4.72	NSD	16.95
	26-30	NSD	NSD	NSD	168.74	25.91	11.50	NSD	21.45	35.39	16.52
July	1-5	NSD	NSD	NSD	116.30	25.00	NSD	NSD	NSD	NSD	NSD
	6-10	NSD	NSD	NSD	35.52	NSD	NSD	NSD	22.91	17.91	NSD
	11-15	NSD	NSD	NSD	NSD	NSD	NSD	NSD	9.45	NSD	NSD

Appendix Table V. Mean number of flannelmouth sucker and speckled dace larvae per sample collected from the Gunnison and Colorado rivers, 2002-2007, during 5-day intervals. NS = no sample taken during the time interval even though sampling was conducted. NSD = no sampling done during 5-day interval.

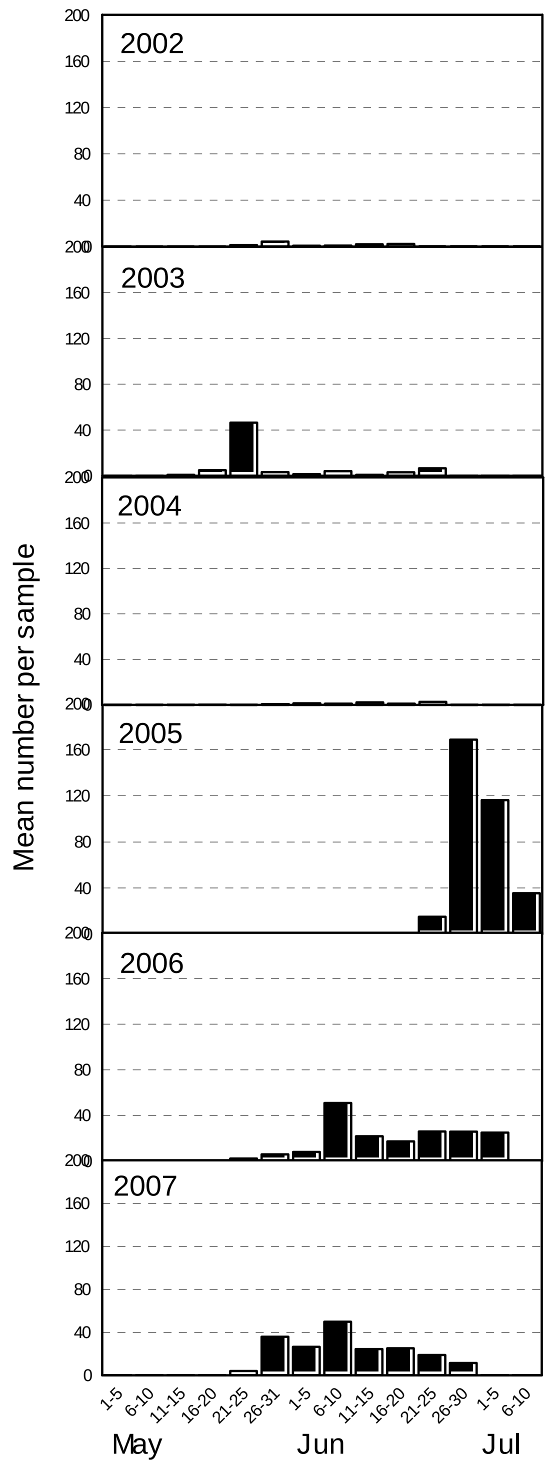
		Gunnison River						Colorado River			
		2002	2003	2004	2005	2006	2007	2004	2005	2006	2007
Flannelmouth sucker											
May	1-5	NS	NSD	0.00	NSD	NSD	NSD	NSD	NSD	NSD	NSD
	6-10	0.00	NSD	0.00	NSD	NSD	NS	NSD	NSD	NSD	10.67
	11-15	0.00	0.00	0.40	NSD	0.83	1.00	16.29	NSD	NSD	2.50
	16-20	0.00	0.00	2.52	NS	0.00	1.17	8.00	0.00	3.67	9.35
	21-25	0.58	0.00	0.89	NS	0.77	3.02	33.63	7.67	8.55	10.13
	26-31	0.10	0.63	1.55	0.00	1.06	5.11	33.84	1.75	4.26	11.21
June	1-5	0.42	2.76	3.29	5.50	6.58	2.67	NSD	NSD	28.80	7.39
	6-10	9.30	5.28	1.22	1.25	6.65	13.62	4.07	1.67	7.66	NSD
	11-15	26.28	0.67	0.09	0.67	12.68	11.05	2.40	NSD	10.40	15.90
	16-20	8.56	2.34	0.33	0.00	2.82	5.97	0.77	1.85	9.13	NSD
	21-25	NSD	0.00	0.07	4.32	9.88	0.33	2.94	2.11	NSD	17.79
	26-30	NSD	NSD	NSD	27.35	1.73	0.88	NSD	8.09	37.67	4.30
July	1-5	NSD	NSD	NSD	41.20	1.46	NSD	NSD	NSD	NSD	NSD
	6-10	NSD	NSD	NSD	7.13	NSD	NSD	NSD	2.45	0.09	NSD
	11-15	NSD	NSD	NSD	NSD	NSD	NSD	NSD	5.82	NSD	NSD
Speckled dace											
May	1-5	NS	NSD	0.00	NSD	NSD	NSD	NSD	NSD	NSD	NSD
	6-10	0.00	NSD	0.00	NSD	NSD	NS	NSD	NSD	NSD	0.00
	11-15	0.00	0.00	0.00	NSD	0.00	0.00	0.07	NSD	NSD	0.00
	16-20	0.00	0.00	0.00	NS	0.00	0.00	0.00	0.00	0.00	0.00
	21-25	0.77	0.00	0.00	NS	0.00	0.00	0.00	0.00	0.00	0.00
	26-31	7.84	0.05	0.00	0.00	0.13	0.06	0.16	0.00	0.00	0.03
June	1-5	2.50	0.18	0.17	0.00	0.19	0.53	NS	NSD	0.00	0.18
	6-10	1.60	0.32	0.30	0.00	2.20	0.48	0.10	0.00	0.02	NSD
	11-15	1.85	0.17	11.00	0.00	0.35	2.00	0.60	NSD	0.00	0.69
	16-20	1.09	0.75	1.81	0.00	14.76	1.26	1.27	0.00	1.45	NSD
	21-25	NSD	2.43	2.10	0.04	3.82	8.11	3.20	0.00	NSD	1.61
	26-30	NSD	NSD	NSD	1.17	6.27	2.08	NSD	0.00	2.61	1.96
July	1-5	NSD	NSD	NSD	1.25	3.12	NSD	NSD	NSD	NSD	NSD
	6-10	NSD	NSD	NSD	0.48	NSD	NSD	NSD	0.55	4.64	NSD
	11-15	NSD	NSD	NSD	NSD	NSD	NSD	NSD	0.27	NSD	NSD

Appendix Table VI. Mean number of flannelmouth sucker and speckled dace larvae per sample collected from the Gunnison and Colorado rivers, 2002-2007, during 5-day intervals. NS = no sample taken during the time interval even though sampling was conducted. NSD = no sampling done during 5-day interval.

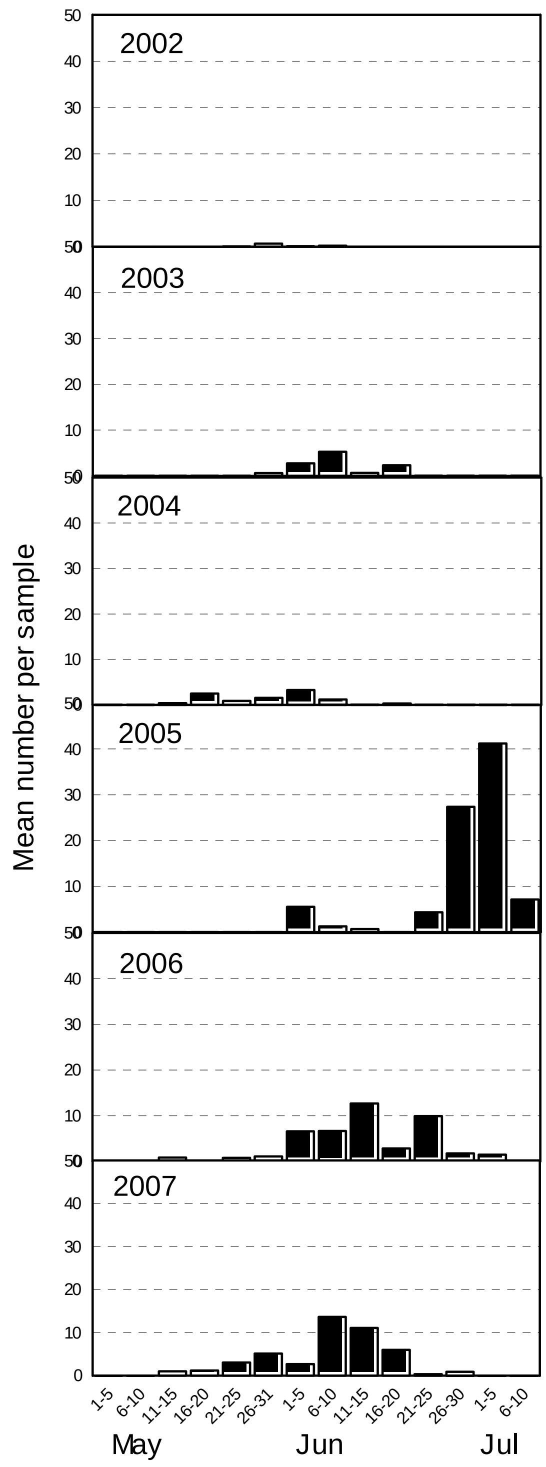
		Gunnison River						**Colorado River**			
		2002	2003	2004	2005	2006	2007	2004	2005	2006	2007
							White sucker				
May	1-5	NS	NSD	10.00	NSD	NSD	NSD	NSD	NSD	NSD	NSD
	6-10	0.00	NSD	27.60	NSD	NSD	NS	NSD	NSD	NSD	0.44
	11-15	7.50	2.00	1.20	NSD	2.33	2.86	20.07	NSD	NSD	1.00
	16-20	0.10	1.33	73.17	NS	3.00	1.67	5.67	0.00	0.67	0.94
	21-25	6.00	1.00	90.33	NS	6.48	20.36	38.00	0.17	0.36	7.13
	26-31	18.32	3.42	48.55	1.00	126.31	18.44	23.11	0.50	25.74	33.14
June	1-5	2.17	17.76	46.57	31.50	66.53	31.73	NSD	NSD	14.20	8.48
	6-10	9.90	17.72	19.63	20.38	123.95	16.28	6.07	2.00	35.66	NSD
	11-15	0.48	3.83	7.82	3.53	75.78	27.91	3.40	NSD	13.13	21.10
	16-20	0.21	4.72	7.24	0.00	22.18	17.05	0.81	5.42	23.65	NSD
	21-25	NSD	11.14	3.80	7.07	54.65	10.56	5.04	7.39	NSD	15.32
	26-30	NSD	NSD	NSD	64.00	13.59	3.92	NSD	27.27	10.17	4.30
July	1-5	NSD	NSD	NSD	260.80	5.46	NSD	NSD	NSD	NSD	NSD
	6-10	NSD	NSD	NSD	3.78	NSD	NSD	NSD	11.27	0.14	NSD
	11-15	NSD	NSD	NSD	NSD	NSD	NSD	NSD	8.64	NSD	NSD
							Fathead minnow				
May	1-5	NS	NSD	0.00	NSD	NSD	NSD	NSD	NSD	NSD	NSD
	6-10	0.00	NSD	0.00	NSD	NSD	NS	NSD	NSD	NSD	0.00
	11-15	0.00	0.33	0.00	NSD	0.00	0.00	0.21	NSD	NSD	0.00
	16-20	0.00	0.00	0.03	NS	0.00	0.00	0.00	0.00	0.00	0.00
	21-25	0.58	0.00	0.00	NS	0.00	0.00	0.25	0.00	0.00	0.00
	26-31	0.10	0.12	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.03
June	1-5	0.42	0.12	0.06	0.00	0.03	0.00	NSD	NSD	0.13	0.00
	6-10	9.30	0.50	0.07	0.00	0.25	0.00	0.62	0.00	0.23	NSD
	11-15	26.28	0.06	0.27	0.07	0.41	0.00	0.40	NS	1.00	0.33
	16-20	8.56	0.00	0.10	0.00	0.18	0.13	0.88	0.04	1.03	NSD
	21-25	NSD	0.00	0.00	0.04	0.50	0.00	5.24	0.00	NSD	0.11
	26-30	NSD	NSD	NSD	0.43	0.45	0.00	NSD	0.45	0.17	0.26
July	1-5	NSD	NSD	NSD	6.85	1.19	NSD	NSD	NSD	NSD	NSD
	6-10	NSD	NSD	NSD	0.17	NSD	NSD	NSD	1.45	2.18	NSD
	11-15	NSD	NSD	NSD	NSD	NSD	NSD	NSD	6.27	NSD	NSD



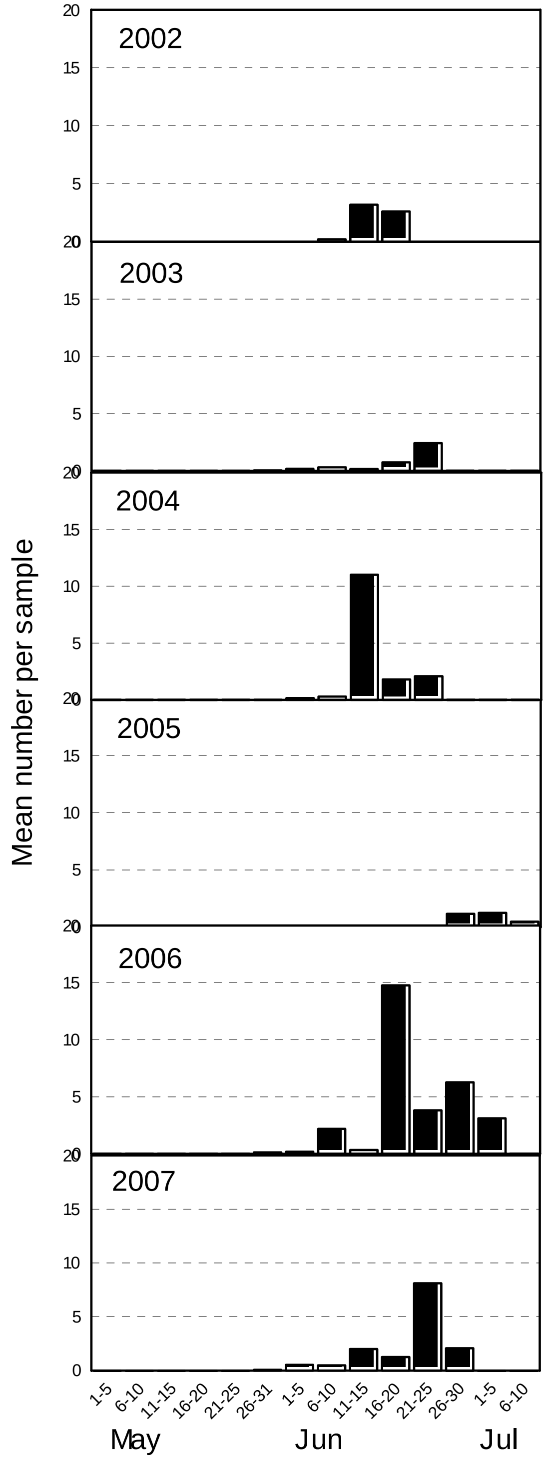
Appendix Figure I. Mean number of **roundtail chub** larvae present in larval samples collected from the **Gunnison River** within 5-day periods, 2002-2007. Only samples resulting in the collection of fish larvae were counted. Sample size within each 5-day period varied. First appearance of the species in spring is accurately reflected in the bar charts; however, presence is not always accurately reflected during the latter dates because the cessation of sampling varied by year and the last 2-3 5-day periods were not always sampled. Periods of non-sampling and mean numbers per sample are listed in Appendix Table IV.



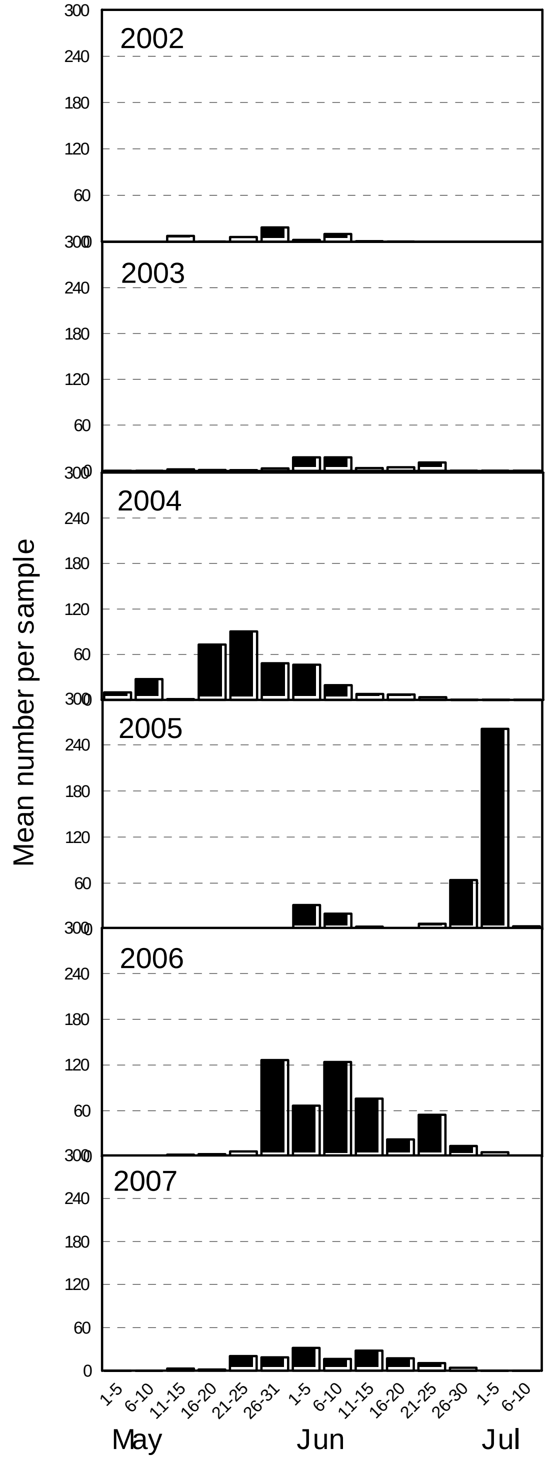
Appendix Figure II. Mean number of **bluehead sucker** larvae present in larval samples collected from the **Gunnison River** within 5-day periods, 2002-2007. Only samples resulting in the collection of fish larvae were counted. Sample size within each 5-day period varied. First appearance of the species in spring is accurately reflected in the bar charts; however, presence is not always accurately reflected during the latter dates because the cessation of sampling varied by year and the last 2-3 5-day periods were not always sampled. Periods of non-sampling and mean numbers per sample are listed in Appendix Table IV.



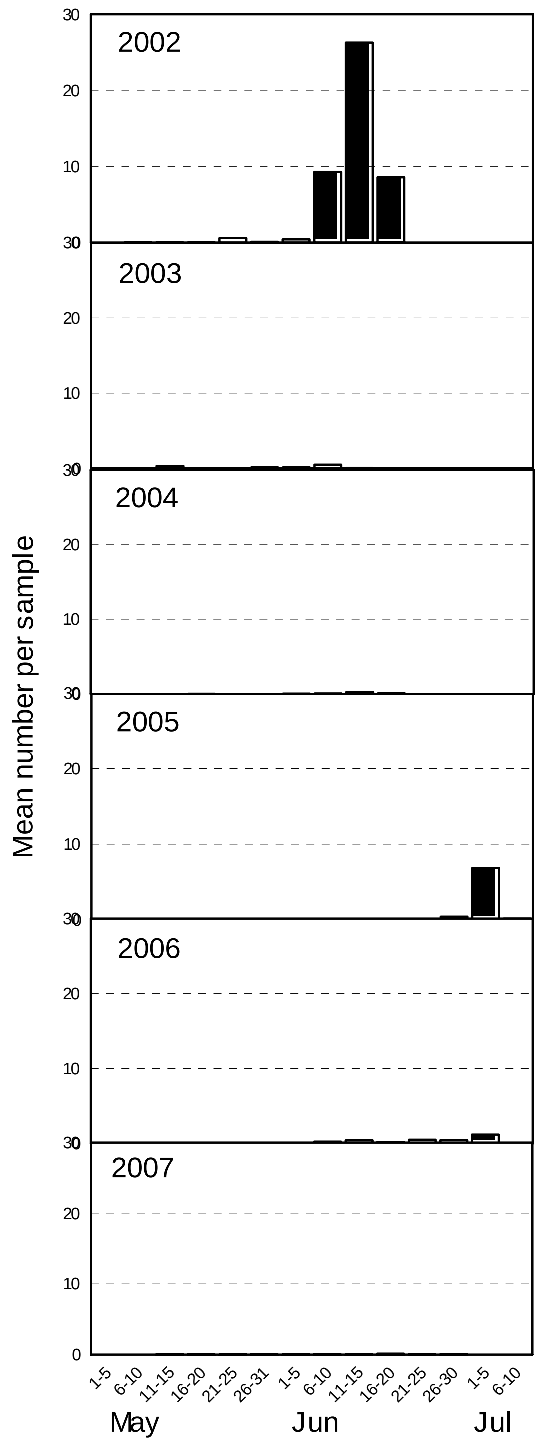
Appendix Figure III. Mean number of **flannelmouth sucker** larvae present in larval samples collected from the **Gunnison River** within 5-day periods, 2002-2007. Only samples resulting in the collection of fish larvae were counted. Sample size within each 5-day period varied. First appear-ance of the species in spring is accurately reflected in the bar charts; however, presence is not always accurately reflected during the latter dates because the cessation of sampling varied by year and the last 2-3 5-day periods were not always sampled. Periods of non-sampling and mean numbers per sample are listed in Appendix Table V.



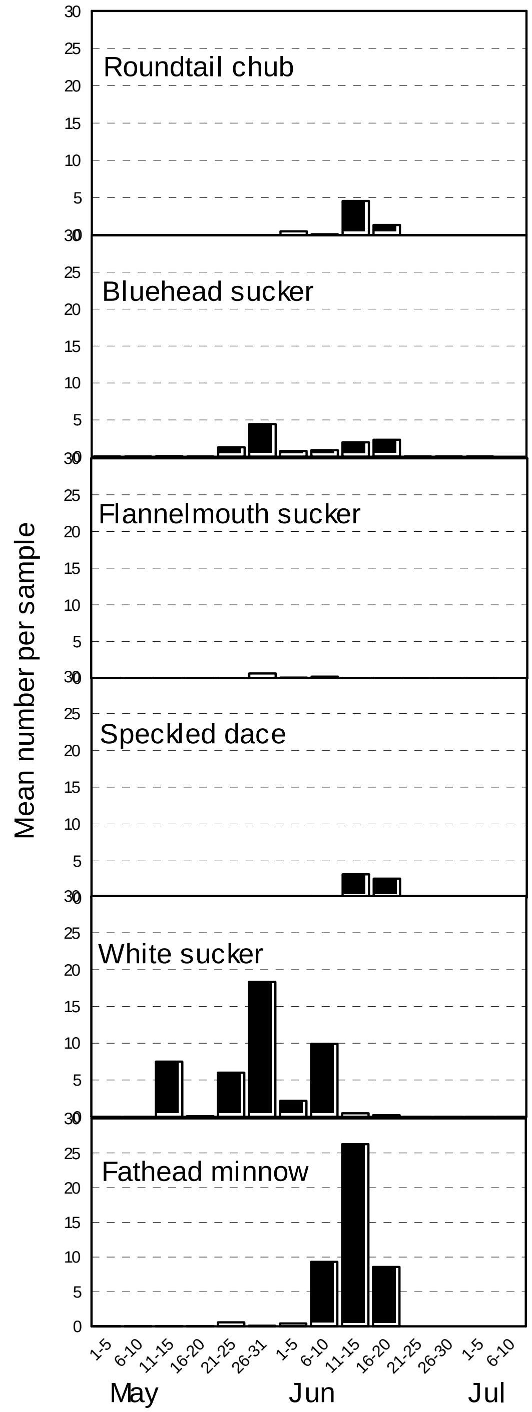
Appendix Figure IV. Mean number of **speckled dace** larvae present in larval samples collected from the **Gunnison River** within 5-day periods, 2002-2007. Only samples resulting in the collection of fish larvae were counted. Sample size within each 5-day period varied. First appearance of the species in spring is accurately reflected in the bar charts; however, presence is not always accurately reflected during the latter dates because the cessation of sampling varied by year and the last 2-3 5-day periods were not always sampled. Periods of non-sampling and mean numbers per sample are listed in Appendix Table V.



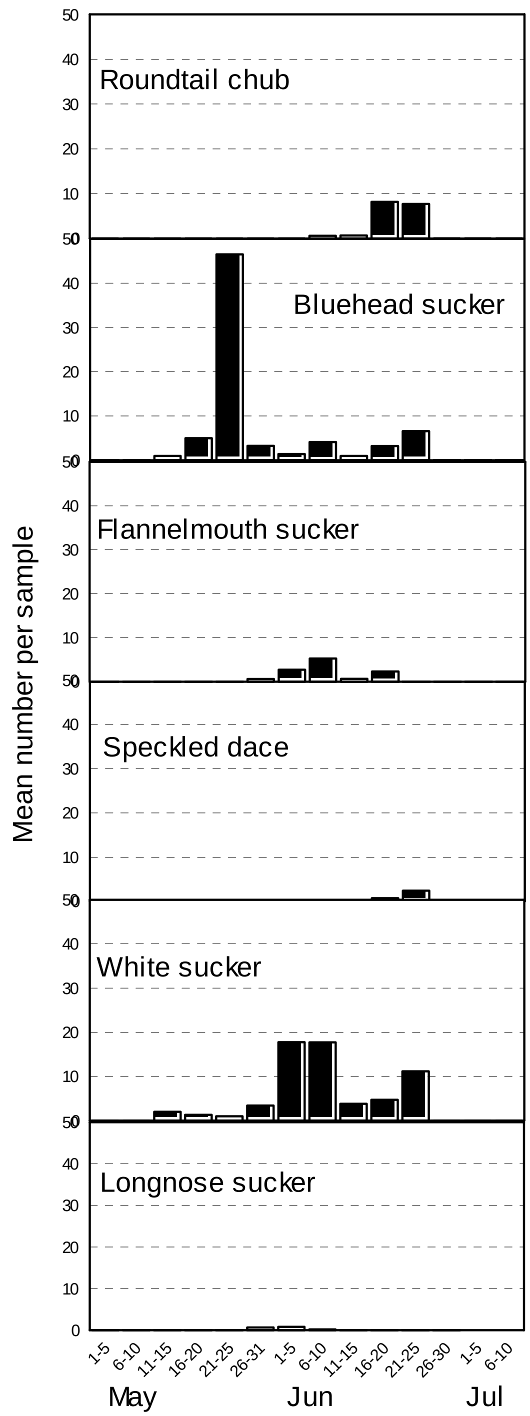
Appendix Figure V. Mean number of **white sucker** larvae present in larval samples collected from the **Gunnison River** within 5-day periods, 2002-2007. Only samples resulting in the collection of fish larvae were counted. Sample size within each 5-day period varied. First appearance of the species in spring is accurately reflected in the bar charts; however, presence is not always accurately reflected during the latter dates because the cessation of sampling varied by year and the last 2-3 5-day periods were not always sampled. Periods of non-sampling and mean numbers per sample are listed in Appendix Table VI.



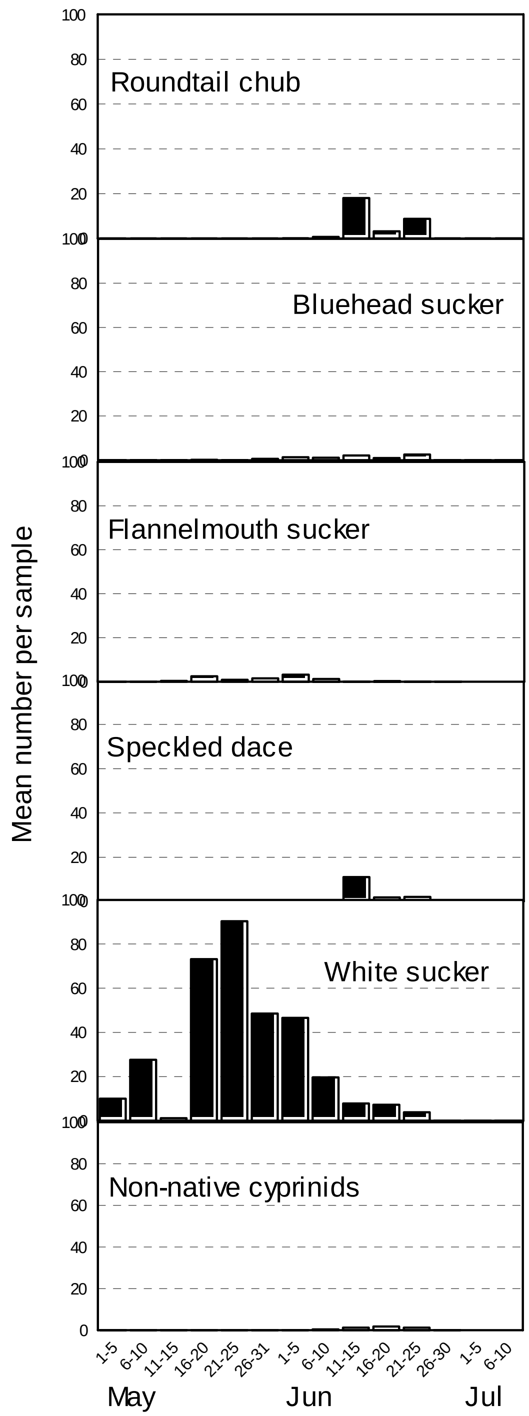
Appendix Figure VI. Mean number of **fathead minnow** larvae present in larval samples collected from the **Gunnison River** within 5-day periods, 2002-2007. Only samples resulting in the collection of fish larvae were counted. Sample size within each 5-day period varied. First appearance of the species in spring is accurately reflected in the bar charts; however, presence is not always accurately reflected during the latter dates because the cessation of sampling varied by year and the last 2-3 5-day periods were not always sampled. Periods of non-sampling and mean numbers per sample are listed in Appendix Table VI



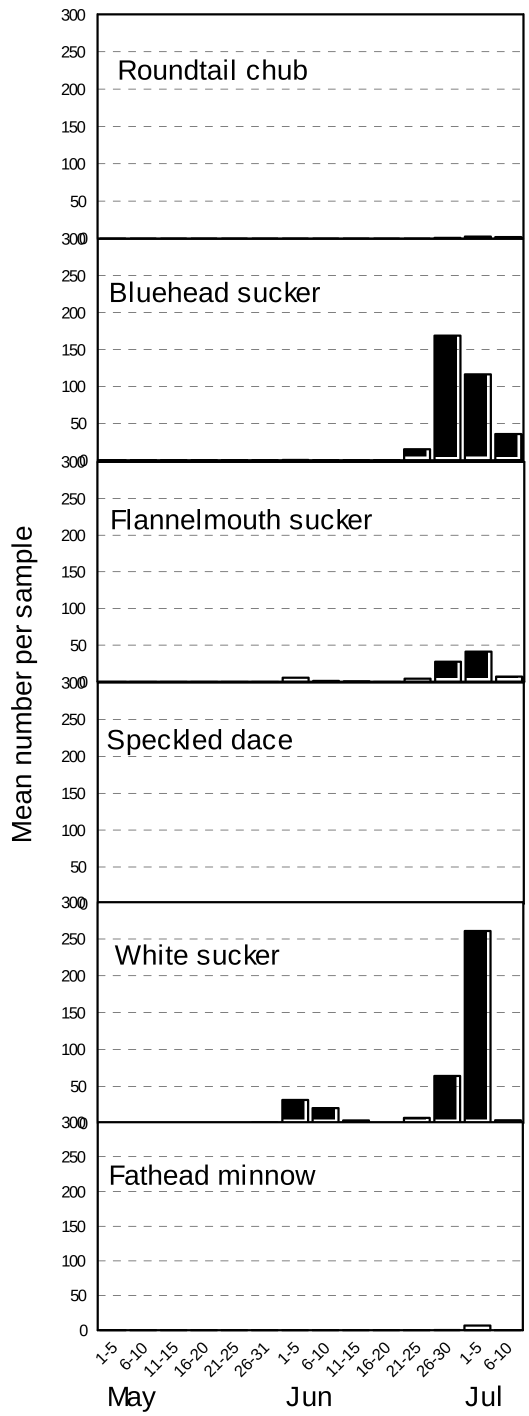
Appendix Figure VII. Relative abundance (mean number of larvae per sample) of the six most abundant species present in larval samples collected from the **Gunnison River** within 5-day periods of **2002**. Only samples resulting in the collection of fish larvae were counted. Sample sizes among 5-day periods varied. First appearance of the species in spring is accurately reflected in the bar charts; last appearance, however, is due in some cases to cessation of sampling. For 2002, sampling ended June 20. Mean numbers per sample are listed in Appendix Tables IV-VI.



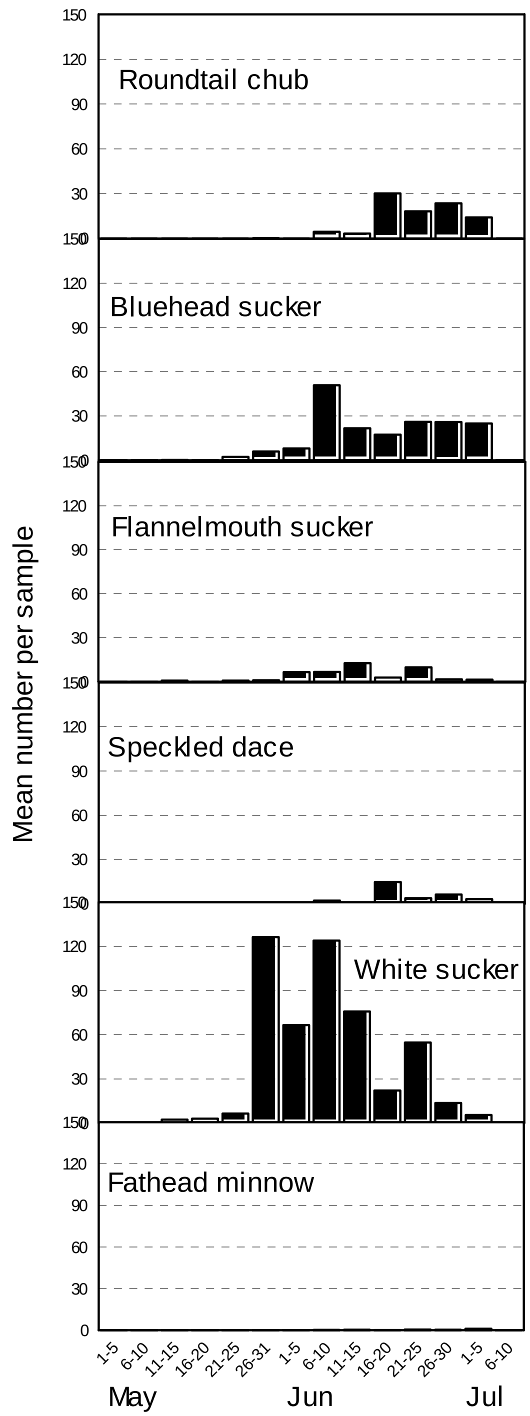
Appendix Figure VIII. Relative abundance (mean number of larvae per sample) of the six most abundant species present in larval samples collected from the **Gunnison River** within 5-day periods of **2003**. Only samples resulting in the collection of fish larvae were counted. Sample sizes among 5-day periods varied. First appearance of the species in spring is accurately reflected in the bar charts; last appearance, however, is due in some cases to cessation of sampling. For 2003, sampling ended June 27. Mean numbers per sample are listed in Appendix Tables IV-VI.



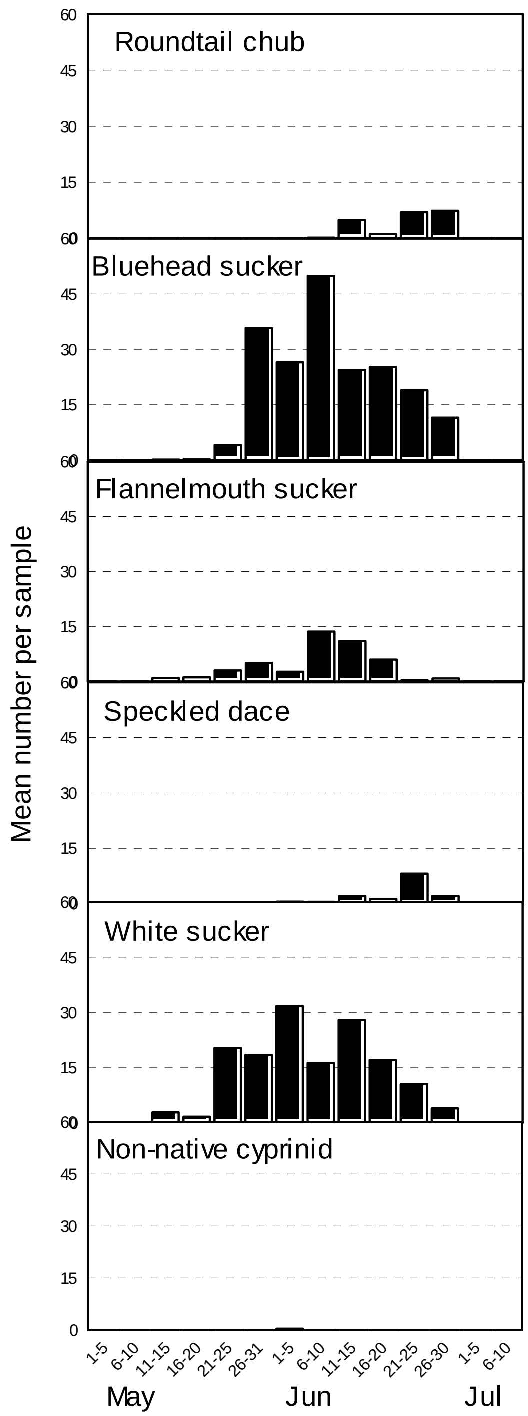
Appendix Figure IX. Relative abundance (mean number of larvae per sample) of the six most abundant species present in larval samples collected from the **Gunnison River** within 5-day periods of **2004**. Only samples resulting in the collection of fish larvae were counted. Sample sizes among 5-day periods varied. First appearance of the species in spring is accurately reflected in the bar charts; last appearance, however, is due in some cases to cessation of sampling. For 2004, sampling ended June 25. Mean numbers per sample are listed in Appendix Tables IV-VI.



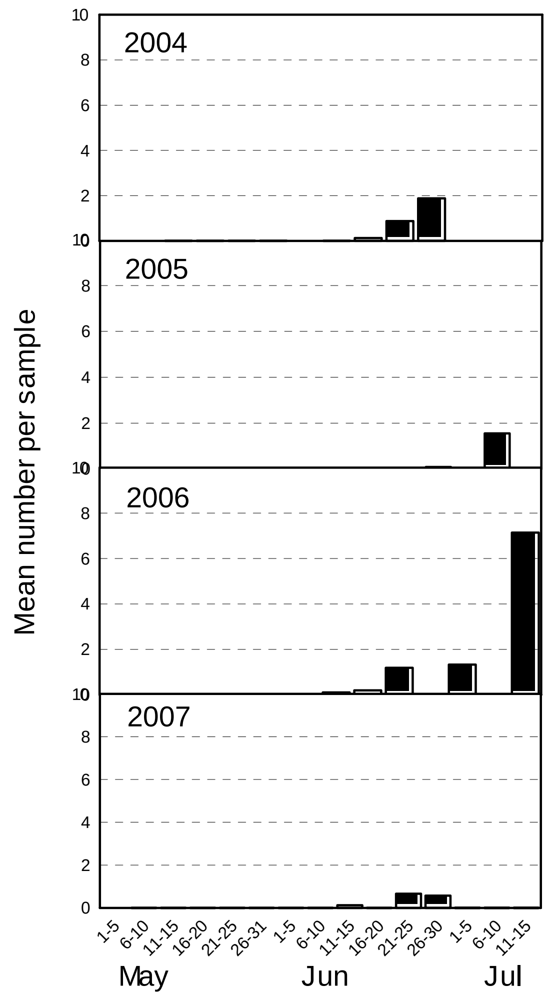
Appendix Figure X. Relative abundance (mean number of larvae per sample) of the six most abundant species present in larval samples collected from the **Gunnison River** within 5-day periods of **2005**. Only samples resulting in the collection of fish larvae were counted. Sample sizes among 5-day periods varied. First appearance of the species in spring is accurately reflected in the bar charts; last appearance, however, is due in some cases to cessation of sampling. For 2005, sampling ended July 7. Mean numbers per sample are listed in Appendix Tables IV-VI.



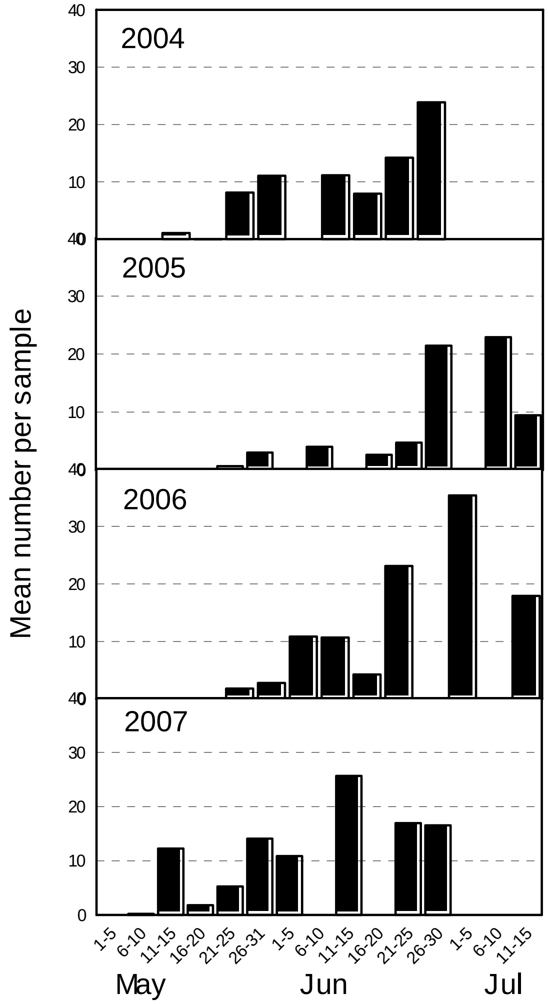
Appendix Figure XI. Relative abundance (mean number of larvae per sample) of the six most abundant species present in larval samples collected from the **Gunnison River** within 5-day periods of **2006**. Only samples resulting in the collection of fish larvae were counted. Sample sizes among 5-day periods varied. First appearance of the species in spring is accurately reflected in the bar charts; last appearance, however, is due in some cases to cessation of sampling. For 2006, sampling ended July 5. Mean numbers per sample are listed in Appendix Tables IV-VI.



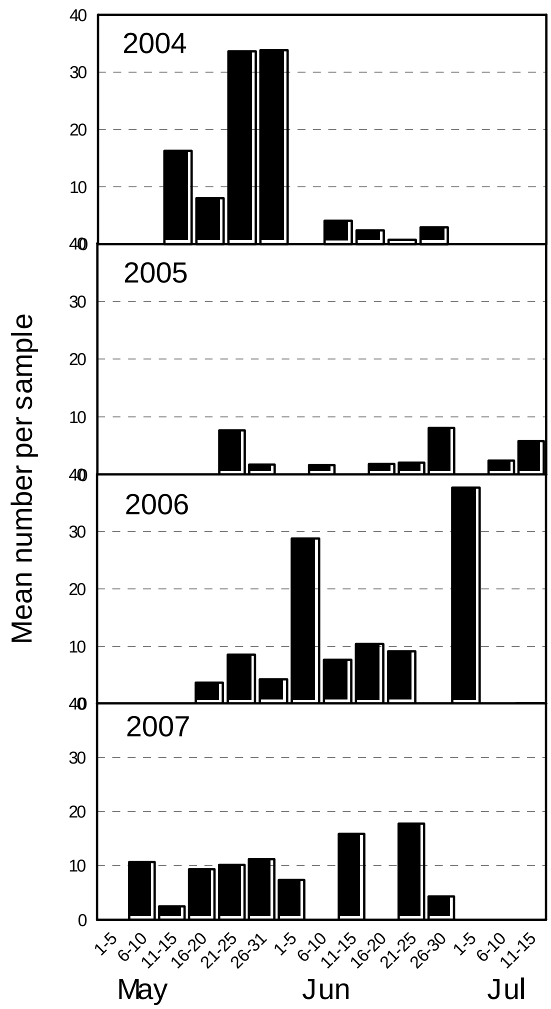
Appendix Figure XII. Relative abundance (mean number of larvae per sample) of the six most abundant species present in larval samples collected from the **Gunnison River** within 5-day periods of **2007**. Only samples resulting in the collection of fish larvae were counted. Sample sizes among 5-day periods varied. First appearance of the species in spring is accurately reflected in the bar charts; last appearance, however, is due in some cases to cessation of sampling. For 2007, sampling ended June 27. Mean numbers per sample are listed in Appendix Tables IV-VI.



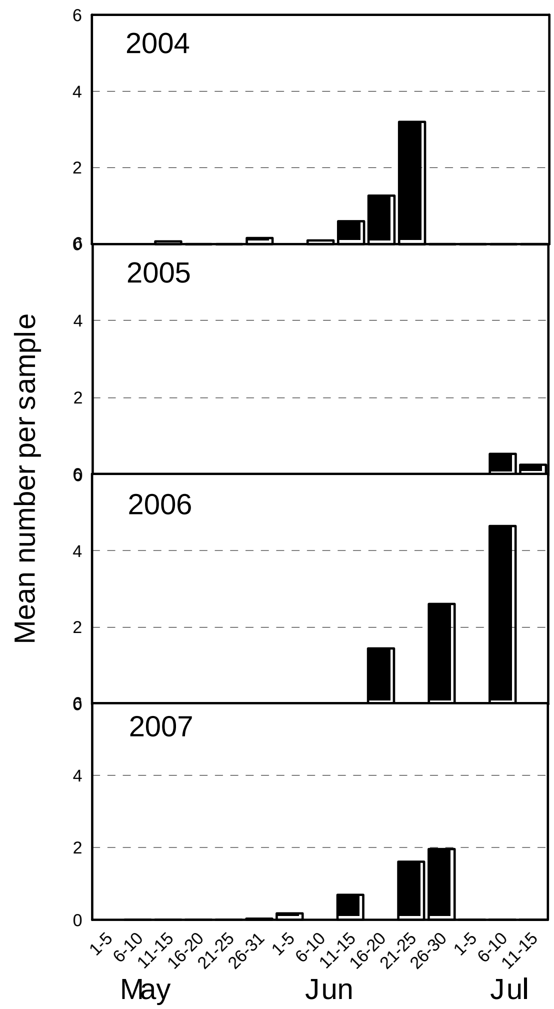
Appendix Figure XIII. Mean number of **roundtail chub** larvae present in larval samples collected from the **Colorado River** within 5-day periods, 2004-2007. Only samples resulting in the collection of fish larvae were counted. Sample size within each 5-day period varied. First appearance of the species in spring is accurately reflected in the bar charts; however, presence is not always accurately reflected during the latter dates because the cessation of sampling varied by year and the last 2-3 5-day periods were not always sampled. Periods of non-sampling and mean numbers per sample are listed in Appendix Table IV.



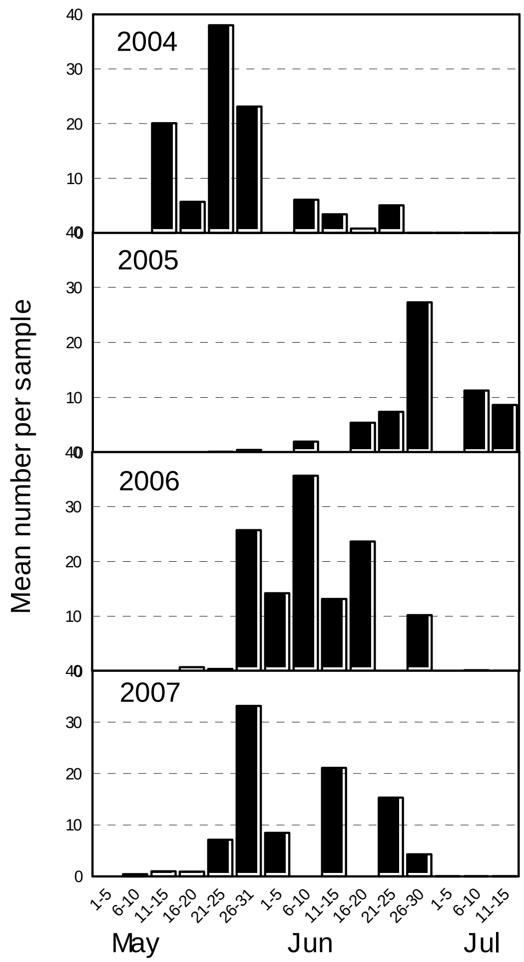
Appendix Figure XIV. Mean number of **bluehead sucker** larvae present in larval samples collected from the **Colorado River** within 5-day periods, 2004-2007. Only samples resulting in the collection of fish larvae were counted. Sample size within each 5-day period varied. First appearance of the species in spring is accurately reflected in the bar charts; however, presence is not always accurately reflected during the latter dates because the cessation of sampling varied by year and the last 2-3 5-day periods were not always sampled. Periods of non-sampling and mean numbers per sample are listed in Appendix Table IV.



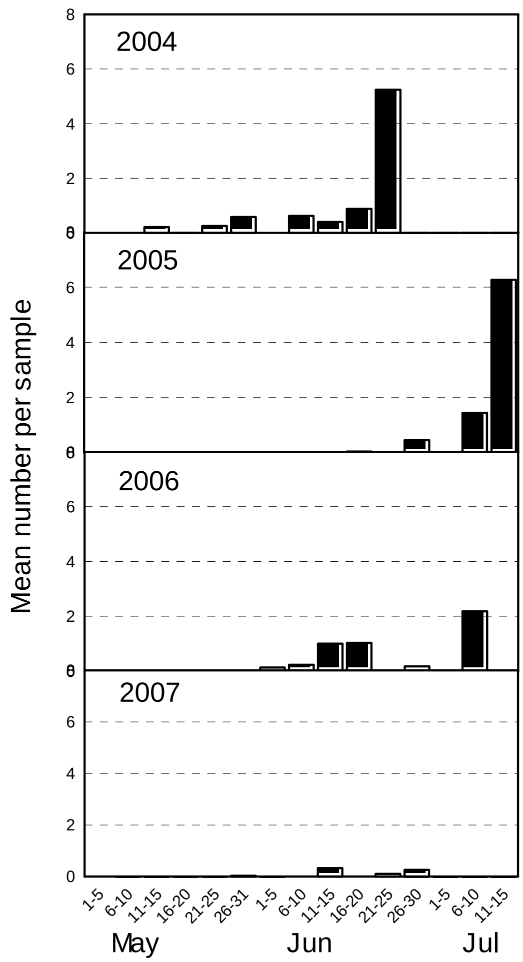
Appendix Figure XV. Mean number of **flannelmouth sucker** larvae present in larval samples collected from the **Colorado River** within 5-day periods, 2004-2007. Only samples resulting in the collection of fish larvae were counted. Sample size within each 5-day period varied. First appearance of the species in spring is accurately reflected in the bar charts; however, presence is not always accurately reflected during the latter dates because the cessation of sampling varied by year and the last 2-3 5-day periods were not always sampled. Periods of non-sampling and mean numbers per sample are listed in Appendix Table V.



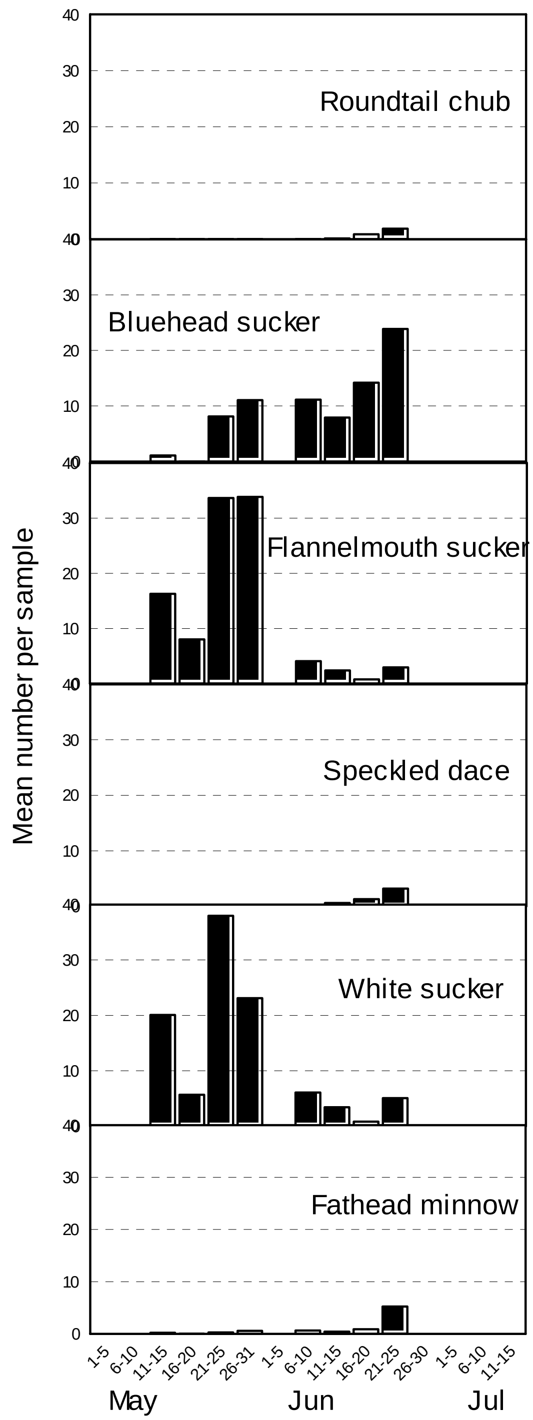
Appendix Figure XVI. Mean number of **speckled dace** larvae present in larval samples collected from the **Colorado River** within 5-day periods, 2004-2007. Only samples resulting in the collection of fish larvae were counted. Sample size within each 5-day period varied. First appearance of the species in spring is accurately reflected in the bar charts; however, presence is not always accurately reflected during the latter dates because the cessation of sampling varied by year and the last 2-3 5-day periods were not always sampled. Periods of non-sampling and mean numbers per sample are listed in Appendix Table V.



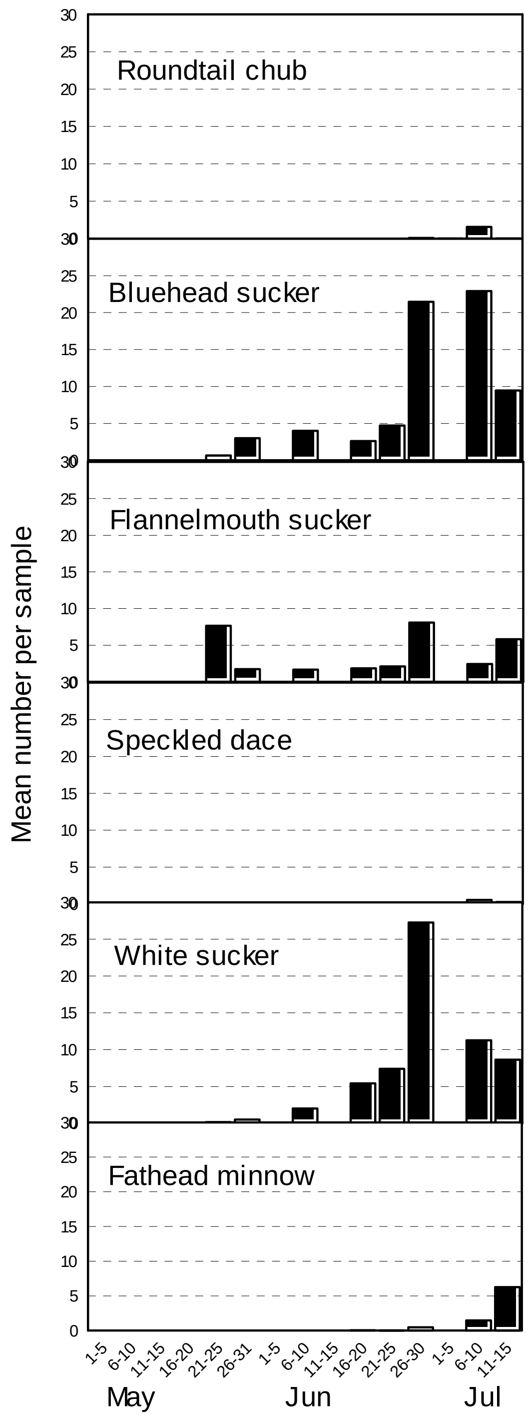
Appendix Figure XVII. Mean number of **white sucker** larvae present in larval samples collected from the **Colorado River** within 5-day periods, 2004-2007. Only samples resulting in the collection of fish larvae were counted. Sample size within each 5-day period varied. First appearance of the species in spring is accurately reflected in the bar charts; however, presence is not always accurately reflected during the latter dates because the cessation of sampling varied by year and the last 2-3 5-day periods were not always sampled. Periods of non-sampling and mean numbers per sample are listed in Appendix Table VI.



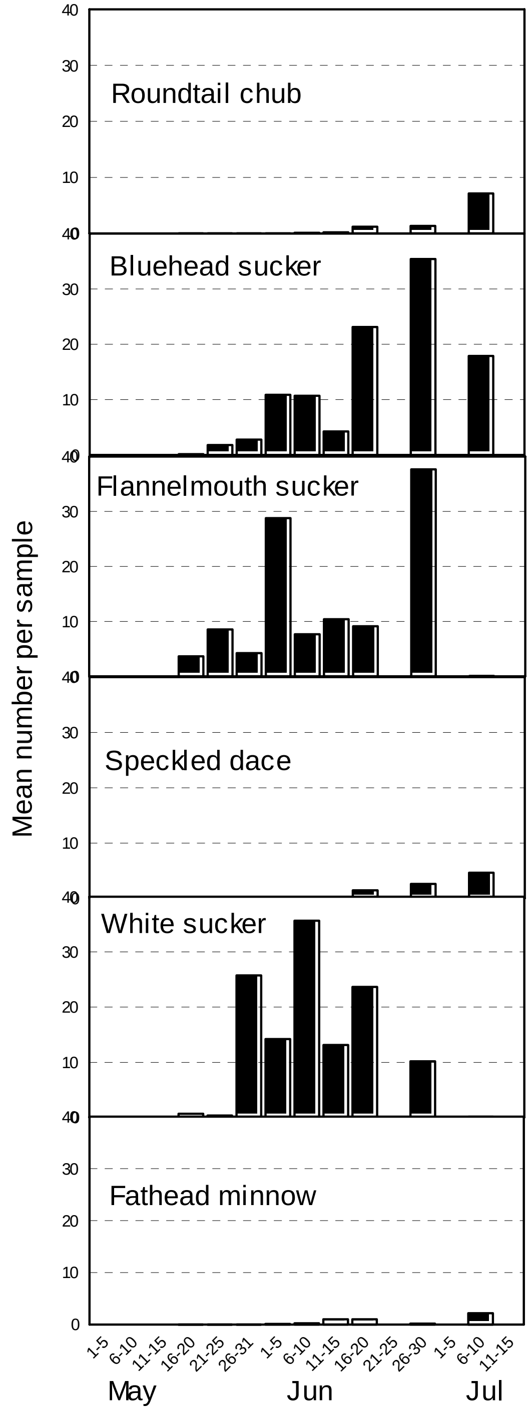
Appendix Figure XVIII. Mean number of **fathead minnow** larvae present in larval samples collected from the **Colorado River** within 5-day periods, 2004-2007. Only samples resulting in the collection of fish larvae were counted. Sample size within each 5-day period varied. First appearance of the species in spring is accurately reflected in the bar charts; however, presence is not always accurately reflected during the latter dates because the cessation of sampling varied by year and the last 2-3 5-day periods were not always sampled. Periods of non-sampling and mean numbers per sample are listed in Appendix Table VI.



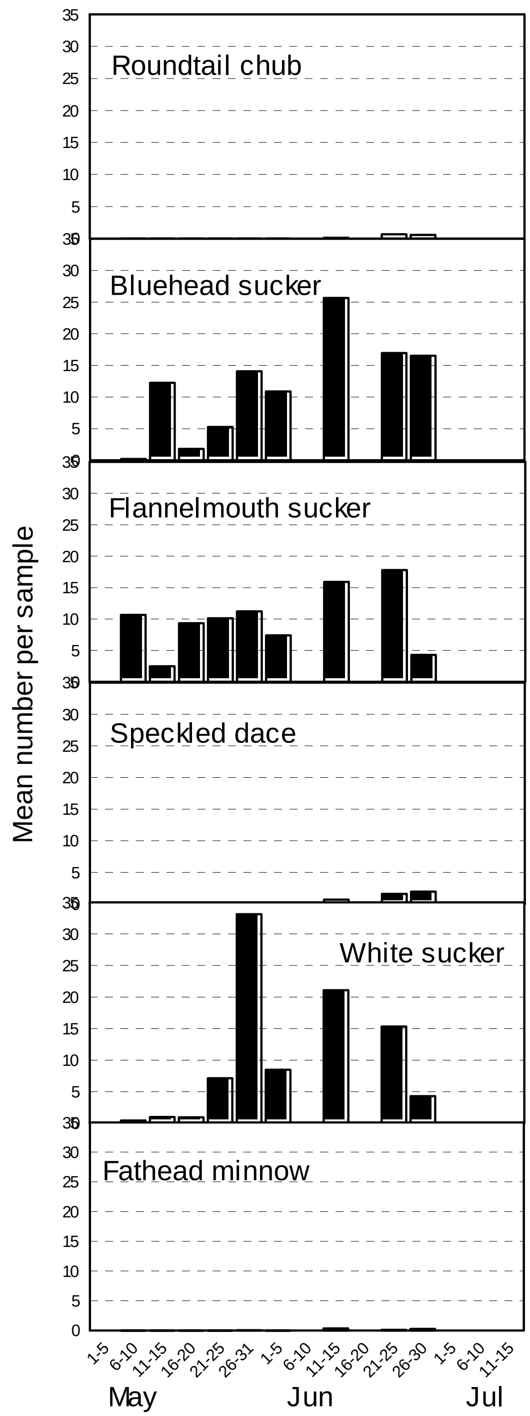
Appendix Figure XIX. Relative abundance (mean number of larvae per sample) of the six most abundant species present in larval samples collected from the **Colorado River** within 5-day periods of **2004**. Only samples resulting in the collection of fish larvae were counted. Sample sizes among 5-day periods varied. First appearance of the species in spring is accurately reflected in the bar charts; last appearance, however, is due in some cases to cessation of sampling. For 2004, sampling ended June 24. Mean numbers per sample are listed in Appendix Tables IV-VI.



Appendix Figure XX. Relative abundance (mean number of larvae per sample) of the six most abundant species present in larval samples collected from the **Colorado River** within 5-day periods of **2005**. Only samples resulting in the collection of fish larvae were counted. Sample sizes among 5-day periods varied. First appearance of the species in spring is accurately reflected in the bar charts; last appearance, however, is due in some cases to cessation of sampling. For 2005, sampling ended July 12. Mean numbers per sample are listed in Appendix Tables IV-VI.



Appendix Figure XXI. Relative abundance (mean number of larvae per sample) of the six most abundant species present in larval samples collected from the **Colorado River** within 5-day periods of **2006**. Only samples resulting in the collection of fish larvae were counted. Sample sizes among 5-day periods varied. First appearance of the species in spring is accurately reflected in the bar charts; last appearance, however, is due in some cases to cessation of sampling. For 2006, sampling ended July 10. Mean numbers per sample are listed in Appendix Tables IV-VI.



Appendix Figure XXII. Relative abundance (mean number of larvae per sample) of the six most abundant species present in larval samples collected from the **Colorado River** within 5-day periods of **2007**. Only samples resulting in the collection of fish larvae were counted. Sample sizes among 5-day periods varied. First appearance of the species in spring is accurately reflected in the bar charts; last appearance, however, is due in some cases to cessation of sampling. For 2007, sampling ended June 29. Mean numbers per sample are listed in Appendix Tables IV-VI.

Cover Photos:

Top: Razorback sucker *Xyrauchen texanus* recaptured from the Colorado River after being stocked three years earlier. USFWS Photo by D. B. Osmundson

Bottom: Razorback sucker embryos about to hatch. Photo by R. Dujay

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