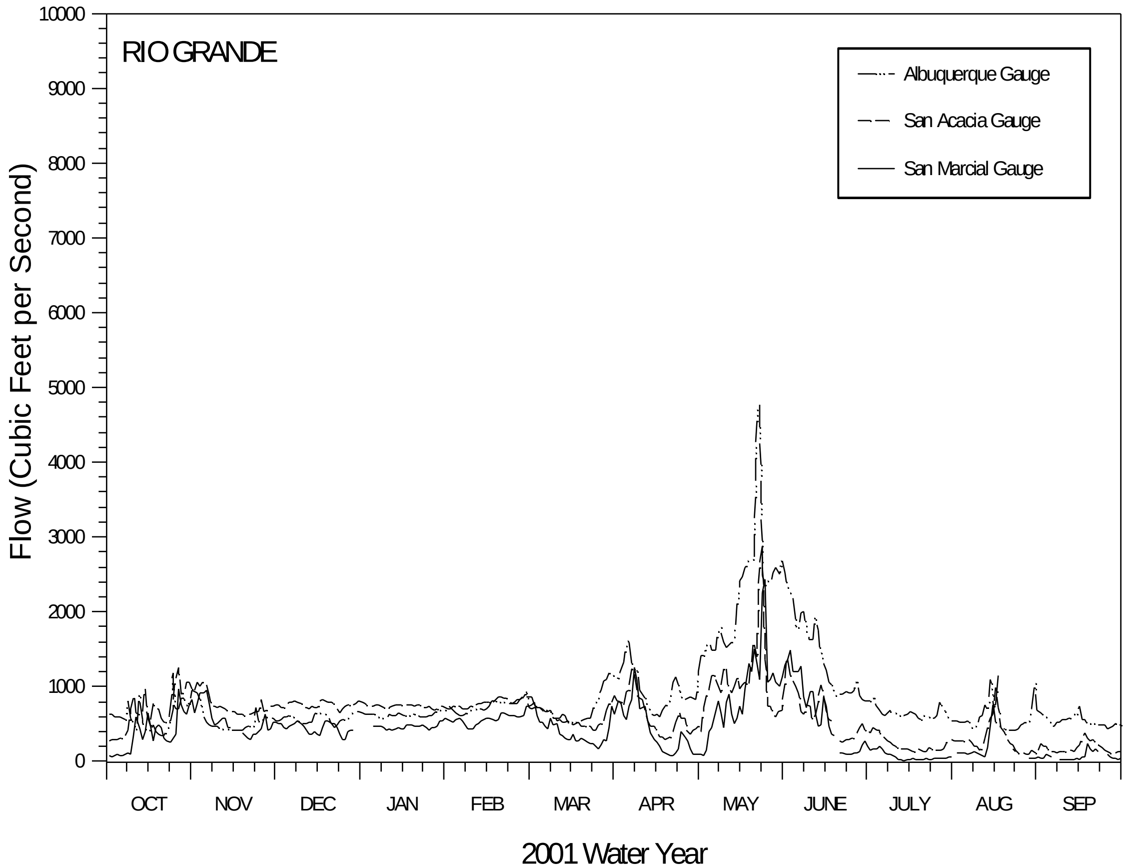
SPAWNING PERIODICITY OF RIO GRANDE SILVERY MINNOW DURING 2001

<u>Final Report</u>



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EXECUTIVE SUMMARY

The historical Middle Rio Grande fish fauna was reflective of a Great Plains river. At least five cyprinid species that can be characterized as Great Plains river fishes formerly occurred throughout the Middle Rio Grande. Spawning by members of this reproductive guild is associated with high-flow events such as spring runoff or summer rainstorms. Upon release, eggs are about 1.6 mm in diameter but quickly swell (ca. 3.0 mm) and remain suspended in the water column during development. The last remaining member of this reproductive guild in the Rio Grande, NM is the federally endangered Rio Grande silvery minnow (*Hybognathus amarus*). Population monitoring studies have shown an annual decline in the number and catch rate of Rio Grande silvery minnow since 1996. Currently over 90% of the catch of Rio Grande silvery minnow is in the San Acacia Reach of the Middle Rio Grande.

Sampling for Rio Grande silvery minnow eggs was initiated 1 May 2001 and concluded 19 June 2001. The location of the collecting activities was selected so as to maximize the potential number of eggs collected and rescue eggs destined to drift into Elephant Butte Reservoir where, if hatched, larvae would be subjected to a wide array of nonnative predators. Eggs were collected three times per day (ca. 0800 hr, 1200 hr, and 1800 hr) during two-hour sets. At the end of the sample period, plastic bags containing Rio Grande silvery minnow eggs were filled with oxygen, sealed, and transported by personnel from U.S. Fish and Wildlife Service to the BioPark-Albuquerque Aquarium (BioPark).

A total of 52,853 m^3 of water was sampled during the 50 day duration of this project yielding 89,542 Rio Grande silvery minnow eggs. Mean daily catch rates on dates that eggs were collected ranged from 0.08 to 2,288.68 eggs/100 m^3 of water sampled. The principal spawn of Rio Grande silvery minnow, as determined by egg catch rate, occurred on 8-10 May 2001. During these three days, 88,071(98.4%) eggs were collected at a cumulative rate of 517.9 eggs/100 m^3 of water sampled. Mean daily catch rate on 8 May 2001 was 2,288.7 eggs/100 m^3 of water sampled but declined to 510.4 on 9 May and 176.8 on 10 May. By 11 May 2001, there were few eggs still being captured (n=55) and catch rates were only 3.4 eggs/100 m^3 of water sampled. A second Rio Grande silvery minnow spawning event occurred from 17-20 May 2001. Catch rate on both 18 and 20 May 2001 was 17.5 eggs/100 m^3 of water sampled but cumulatively yielded only 301 eggs. A small number of eggs continued to be collected after 20 May 2001 through the remainder of the month (n=289) with catch rates generally remaining below 10 eggs/100 m^3 of water sampled (range 0.08 - 11.78 eggs /100 m^3 of water sampled; mean 2.7 eggs/100 m^3 of water sampled). Collecting efforts in June yielded a total of 83 Rio Grande silvery minnow eggs, all of which were taken on 13 June 2001.

Reducing the rate of downstream transport, allowing upstream passage, and salvaging eggs destined for Elephant Butte Reservoir are all options that will, to some degree, improve the current status of Rio Grande silvery minnow. While the most simple solution would appear to be collecting eggs from downstream localities and transporting them to rearing facilities, this method has only short term significance. The ability to efficiently sample even 1% of the entire volume of water that carries these reproductive propagules downstream would require a momumental effort. Future efforts should focus on reducing the deleterious effects that changes in river connectivity, flow patterns, and habitat heterogeneity have on the downstream displacement of Rio Grande silvery minnow eggs and larvae. Eliminating diversion structures would allow upstream passage of individuals to reaches from which they were displaced. Efforts to improve degraded riverine habitats could include returning the flow regime to a more historical pattern (i.e., allowing passage of large flow events) and removing or relocating structures that inhibit the lateral movement of the Rio Grande (e.g., jetty-jacks, levees, and water conveyance ditches). The long-term recovery of Rio Grande silvery minnow will depend on taking management actions that attempt to restore the natural processes of this river.

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INTRODUCTION

The reach of the Rio Grande between Cochiti Dam and Elephant Butte Reservoir (Middle Rio Grande) has been greatly modified over the last 50 years (Lagasse, 1985). Historically, this section of the river gradually meandered through a wide floodplain in vegetated valley. Extensive braiding of the river as it flowed over the shifting sand substrate was common and flow was generally perennial except during times of severe or extended drought (Scurlock, 1998). The Middle Rio Grande was relatively shallow throughout most of the year because of regionally low precipitation levels (Gold and Dennis, 1985) but was subjected to periods of high flow. Flow was generally greatest during the annual spring snow melt runoff (April-June), however intense localized summer rainstorms (monsoonal events) often caused severe flooding and were important in maintaining perennial flow. Historically, the Middle Rio Grande possessed all of the characteristics distinctive of a Great Plains aquatic ecosystem.

The historical Middle Rio Grande fish fauna was also reflective of a Great Plains river. At least five cyprinid species that can be characterized as Great Plains river fishes formerly occurred in the Middle Rio Grande (Platania and Altenbach, 1998). Of the aforementioned species, speckled chub, *Macrhybopsis aestivalis*, Rio Grande shiner, *Notropis jemezanus*, and Rio Grande bluntnose shiner, *Notropis simus simus*, have been extirpated from the Middle Rio Grande. A fourth species, phantom shiner, *Notropis orca*, is extinct (Bestgen and Platania, 1990). Rio Grande silvery minnow, *Hybognathus amarus*, is the only extant member of the Great Plains River cyprinid fish fauna fish (Bestgen and Platania, 1991; Platania, 1991).

This group of cyprinids shared several life-history characteristics. All were small (generally < 100 mm TL), short-lived (2-5 years), fishes that occupied mainstem habitats. Four of the species are characterized as omnivorous while Rio Grande silvery minnow is herbivorous and feeds on epipsammonic algae. In addition to these shared traits, all five species were members of a reproductive guild of fishes characterized by pelagic spawning and production of semibuoyant eggs.

Spawning by members of this reproductive guild is associated with high-flow events such as spring runoff or summer rainstorms. Upon release, eggs about 1.6 mm in diameter but quickly swell (ca. 3.0 mm) and remain suspended in the water column during development. Egg hatching time is temperature dependent but usually occurs in 24-48 hours. Recently hatched larval fish remain a component of the drift until development of the gas bladder. This physiological development corresponds with a shift in swimming behavior as larvae actively seek low-velocity habitats.

The 3-5 days necessary for propagules to attain the developmental stage that allows them to control their horizontal movements allows time for considerable downstream dispersal of eggs and larvae in the Middle Rio Grande. As has been well documented for other aquatic organisms, it is necessary for at least some portion of the drifting propagules to settle in appropriate low-velocity habitats or move upstream to maintain viable populations (Speirs and Gurney, 2001). Historically, there were no permanent barriers to upstream dispersal of fishes in the Middle Rio Grande. There are currently three instream diversion structures between Cochiti Dam and Elephant Butte Reservoir that are barriers to upstream movement of fishes and fragment the once continuous range of the only remaining member of this reproductive guild.

Population monitoring studies of Rio Grande silvery minnow have shown an annual decline in the number and catch rate of this species since 1996 (Dudley and Platania, 1999, 2000, 2001). Currently over 90% of the catch of Rio Grande silvery minnow is in the San Acacia Reach of the Middle Rio Grande (Dudley and Platania, 2001). Multi-agency efforts in areas of habitat improvement, research, and propagation are underway in an attempt to increase population size and distribution with the ultimate goal being recovery of this species.

This study was designed to acquire information on the timing, duration, and magnitude of spawning by Rio Grande silvery minnow. Previous efforts indicated that Rio Grande silvery minnow spawning occurs over a relatively short period during spring runoff. This information will be useful in assessing progress of efforts to recover populations of this endangered fish (U.S. Department of the Interior, 1994; U.S. Fish and Wildlife Service, 1999). Additional goals of this study were to acquire Rio Grande silvery minnow eggs for rearing and use in propagation efforts and provide eggs for genetic analysis.

STUDY AREA

The San Acacia Reach of the Middle Rio Grande is about 56 miles (91 km) long extending from the apron of San Acacia Diversion Dam to the head of Elephant Butte Reservoir. Sections of this reach are characterized by a wide river channel, meandering flow, sand substrate, high suspended sediment load, and broad variety of aquatic mesohabitats. Conversely, some segments in this reach are relatively narrow and result in increased water velocity and decreased habitat heterogeneity. The 12 mile (19 km) reach of the Rio Grande downstream of San Marcial Railroad bridge crossing is confined to a channel that is about 50 m wide. Substrate in this segment of the river is predominately sand but braiding of the channel is uncommon except under conditions of relatively low flow.

The location of the collecting activities was selected so as to maximize the potential number of eggs collected and rescue eggs destined to drift into Elephant Butte Reservoir where, if hatched, larvae would be subjected to a wide array of nonnative predators. The Rio Grande silvery minnow egg collecting site was located about 10 miles (16 km) downstream of the San Marcial Railroad bridge crossing at River Mile 58.8 (UTM Zone 13: 3716150 Northing; 307846 Easting). This site was located near the downstream-most point in the San Acacia Reach (Figure 1). In addition to easy accessibility and favorable river conditions, (i.e., wide river channel, current being carried through a single river channel, gently sloped banks, moderate gradient) the only means of vehicle access to this site was gated and could be secured.

METHODS

Sampling for Rio Grande silvery minnow eggs was initiated 1 May 2001 and concluded 19 June 2001. Moore Egg Collectors (MEC) were used, following the protocol described in Altenbach et al., 2000, to collect drifting Rio Grande silvery minnow eggs. This collecting technique was employed because it has proven more efficient than drift-nets, allowed for quantification of catch rate, and is a nonlethal sampling method (Altenbach et al., 2000). Mechanical flow-meters were attached to each of the MEC's so that volume of water filtered could be calculated and catch rate per unit of water determined. Catch rate for this study is reported as the number of eggs collected per 100 cubic meters of water sampled.

The MEC's were generally operated three times per day (ca. 0800 hr, 1200 hr, and 1800 hr) for two-hours per set. During the first spawning peak, both the number of MEC's deployed and the duration of sampling were increased in an effort to maximize the number of Rio Grande silvery minnow eggs collected. Between 8-10 May 2001 as many as 10 individuals (from U.S. Bureau of Reclamation and U.S. Fish and Wildlife Service) assisted in collecting Rio Grande silvery minnow eggs.

Eggs were enumerated as collected and placed in a small plastic bag containing river water and a tag inscribed with a unique alpha-numeric code. At the end of the sample period, the plastic bag containing Rio Grande silvery minnow eggs was carried to shore, filled with oxygen, and sealed. The bag was then placed in a large volume ice chest that contained a small amount of ice to maintained the samples at temperatures of about 20 °C. Personnel from U.S. Fish and Wildlife

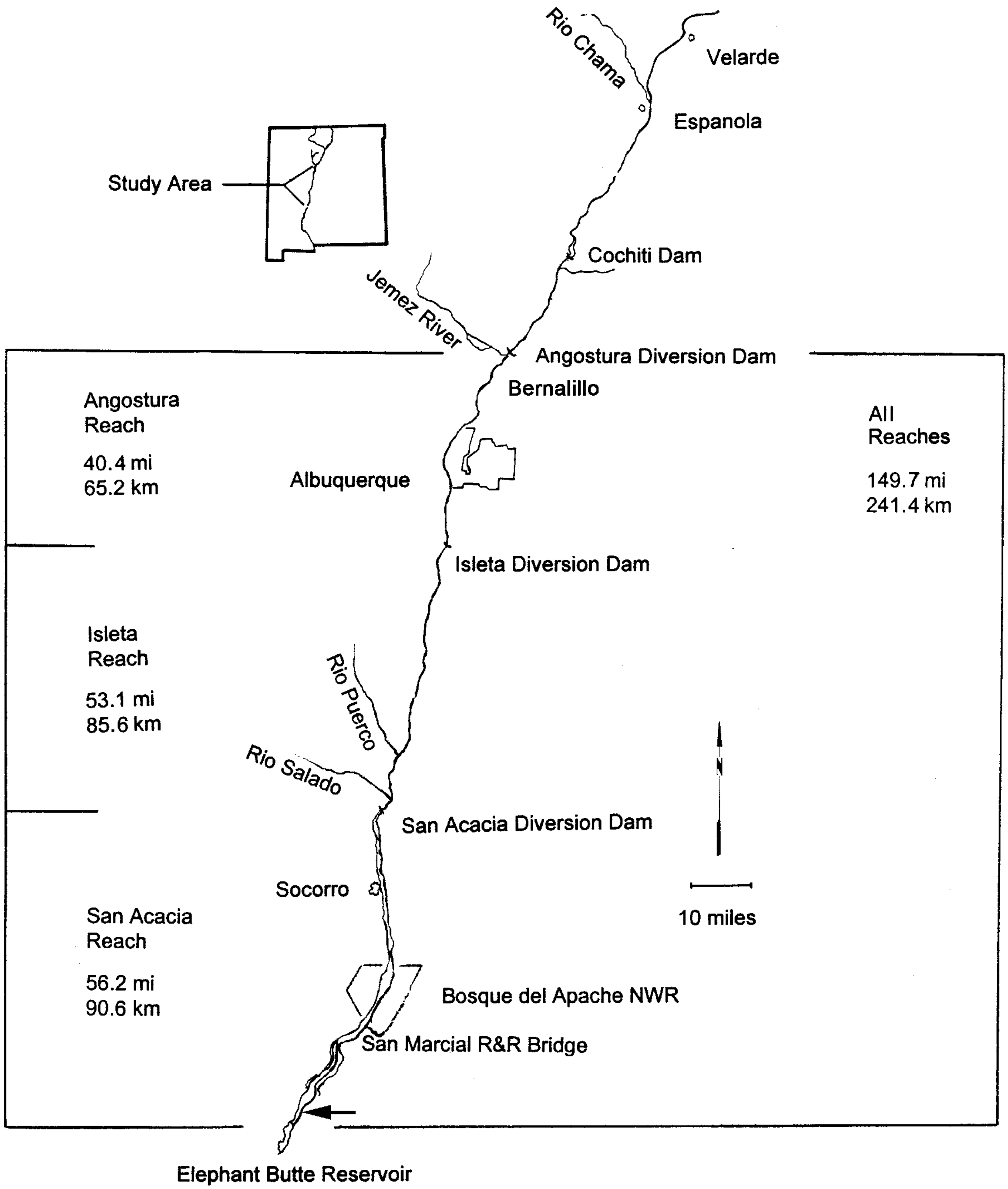

Figure 1. Map of the Middle Rio Grande, NM (arrow indicates sampling locality).

Service assumed responsibility for transporting ice chests containing Rio Grande silvery minnow eggs from the study site to the BioPark-Albuquerque Aquarium (BioPark) on 8, 9, and 10 May 2001.

The extremely large number of eggs taken during 8-10 May 2001 precluded the ability to obtain an accurate count. Instead, a volumetric determination of the number of eggs in each of the aforementioned samples was performed at the BioPark by their personnel and forwarded to the appropriate parties. These three dates (8-10 May 2001) are the only ones on which eggs counts were determined through the volumetric method.

Water temperature was recorded by a temperature logging device deployed at the study site on 4 May 2001 and programmed to record temperatures hourly. The data logger was retrieved on 28 June 2001 and information downloaded. Hourly water temperature data were synthesized and are presented in this report as mean, minimum, and maximum daily water temperatures. Mean daily discharge data for this study (Figure 2) were acquired from the U.S. Geological Survey river gauge at the San Marcial Railroad Bridge crossing over the Rio Grande (gauge # 08358400) and are presented in cubic feet per second (cfs).

Some minor changes in sampling protocol are provided herein to improve the information gained from this or future similar research activities. Volumetric determination of the number of eggs lacks the rigor necessary for effective evaluation of the relative level of spawning by Rio Grande silvery minnow. In future studies, a single MEC should be dedicated for determining the number of eggs being collected. On most occasions, the eggs can be easily counted and retained for propagation. However, enumerating eggs during peak spawning events is not possible and it is during that period that an accurate count is essential. On those occasions (peak spawn) the eggs will need to be preserved and counted under laboratory conditions. If the aforementioned protocol is followed, it will not be necessary to determine catch rate of any of the other MEC's.

RESULTS

Rio Grande Silvery Minnow Egg Collection

A total of 52,853 m^3 of water was sampled during the 50 day duration of this project yielding 89,542 Rio Grande silvery minnow eggs. Mean daily catch rates on dates that eggs were collected ranged from 0.08 to 2,288.68 eggs/100 m^3 of water sampled. The mean daily catch rate for the duration of the study was 169.42 eggs/100 m^3 of water sampled. However, this value has little biological meaning as it includes dates on which no eggs were collected (n=16). The mean daily catch rate of eggs on dates when at least one egg was collected (236.4 eggs/100 m^3 of water sampled; n=22) varied little from dates on which >10 eggs were collected (298.6 eggs/100 m^3 of water sampled; n=15).

The principal spawn of Rio Grande silvery minnow, as determined by egg catch rate, occurred on 8-10 May 2001 (Figure 3). During these three days, 88,071(98.4%) eggs were collected at a cumulative rate of 517.9 eggs/100 m^3 of water sampled. Mean daily catch rate on 8 May 2001 was 2,288.7 eggs/100 m^3 of water sampled but declined to 510.4 on 9 May and 176.8 on 10 May. By 11 May 2001, there were few eggs still being captured (n=55) and catch rates were only 3.4 eggs/100 m^3 of water sampled. Egg catch rate on 8 May 2001 gradually increased between 1000 hr until 2300 hr.

While the maximum catch rate was obtained on 8 May 2001, the greatest number of eggs (n=39,939) was collected on 10 May 2001 (Figure 4). This upsurge in number of eggs collected was primarily due to the five-fold increase in collecting effort afforded by the addition of personnel. The low number of eggs (n=55) and low catch rate (3.4 eggs/100 m^3 of water sampled) on 11 May 2001 indicated the general cessation in Rio Grande silvery minnow spawning activity.

A second Rio Grande silvery minnow spawning event occurred from 17-20 May 2001. Cumulative egg collecting efforts during these days produced only 958 Rio Grande silvery minnow

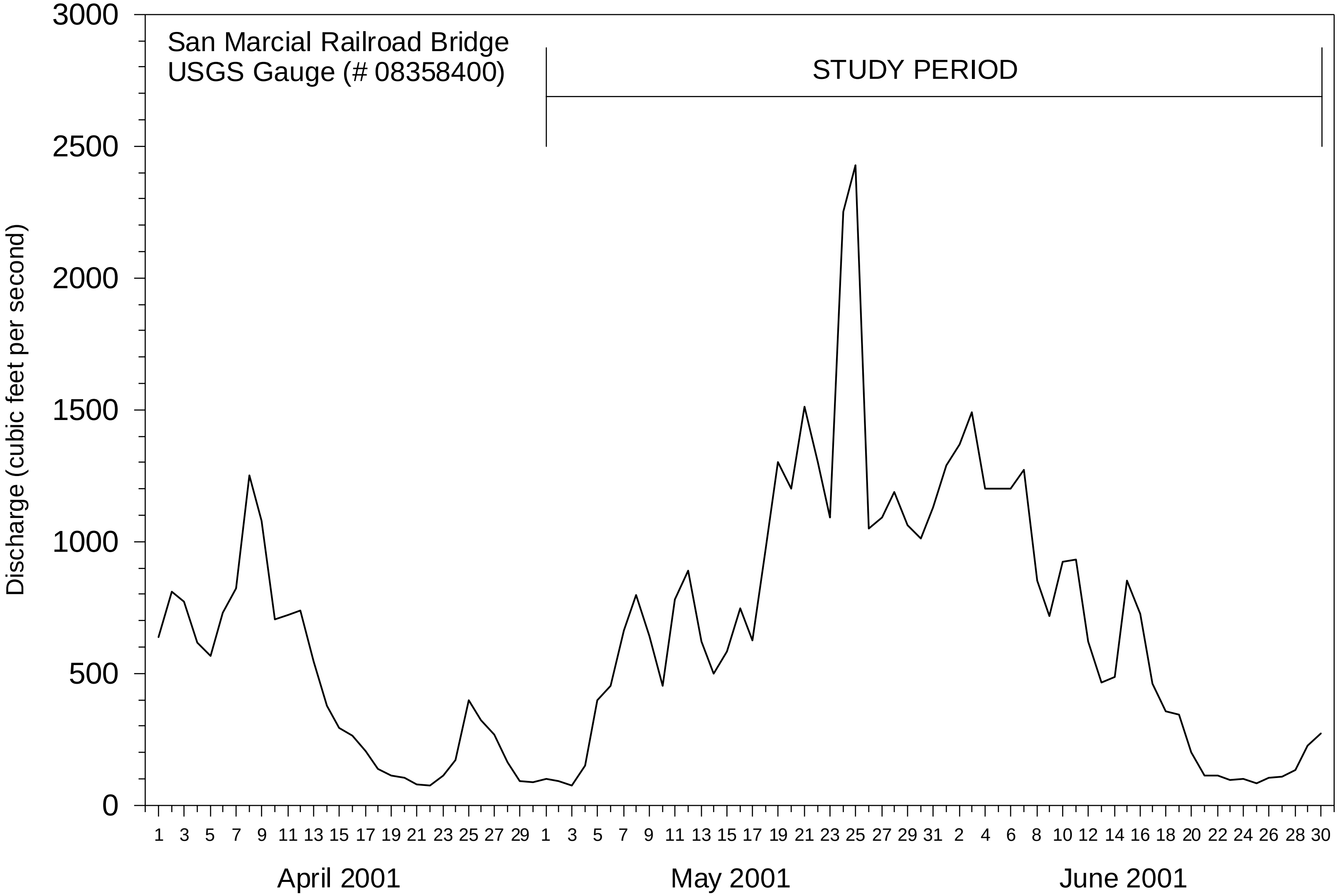

Figure 2. Hydrograph of the Rio Grande, NM at San Marcial before and during the 2001 study period.

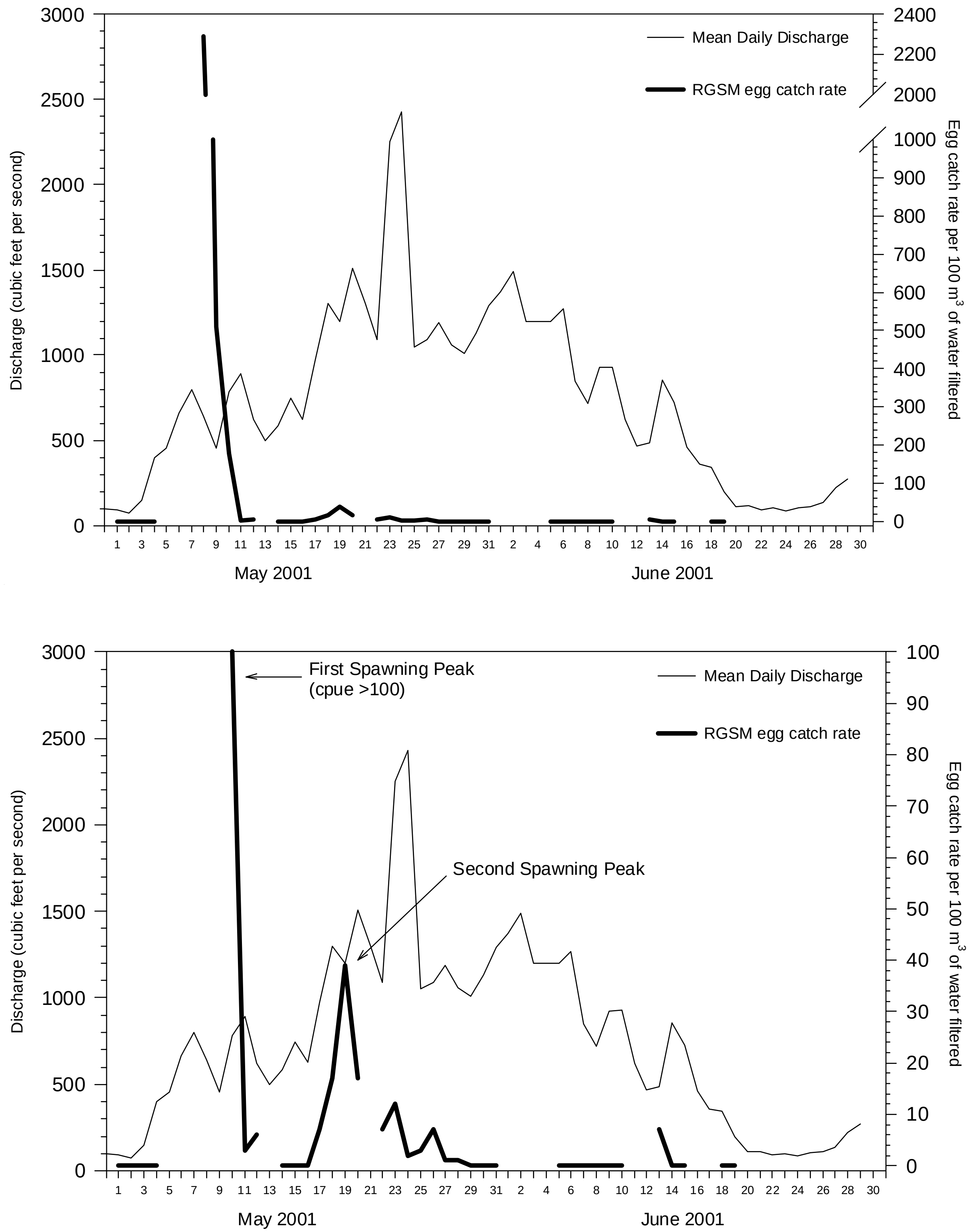

Figure 3. Rio Grande silvery minnow catch rates (CPUE) during the 2001 study period compared with mean daily discharge at San Marcial. *Note: Rio Grande silvery minnow catch rate data are the same but are presented as two graphs with different scales for comparison.

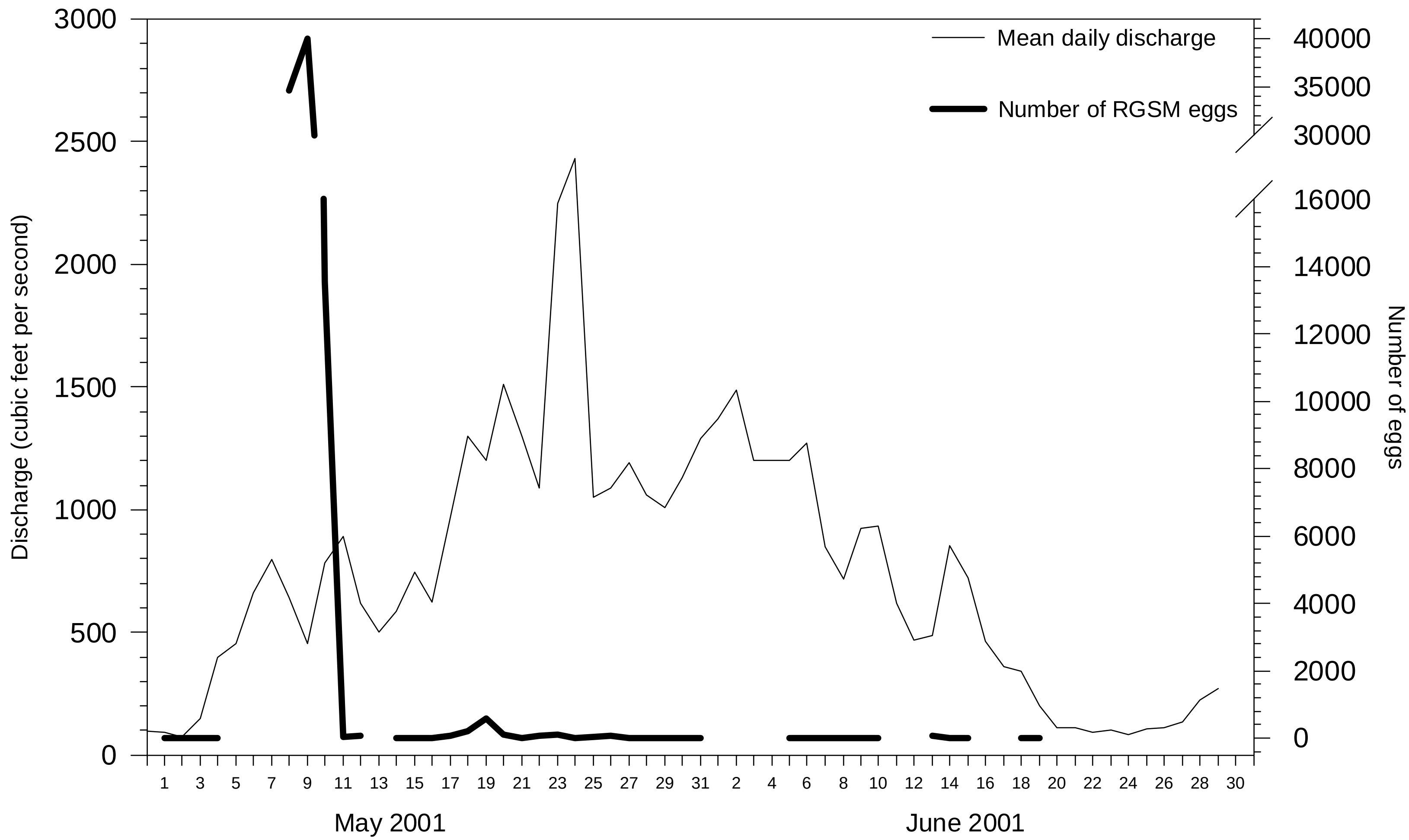

Figure 4. Number of Rio Grande silvery minnow eggs collected during the 2001 study period compared with mean daily dischange at San Marcial.

eggs but catch rates were markedly higher during this period than during the three preceding days. Catch rate on both 18 and 20 May 2001 was 17.5 eggs/100 m^3 of water sampled but cumulatively yielded only 301 eggs. Peak egg catch during this second spawning event occurred on 19 May when 577 Rio Grande silvery minnow eggs were collected at a rate of 39.2 eggs/100 m^3 of water sampled. The catch rate and number of eggs collected on 20 May 2001 was the second highest (after 8-10 May) during the study.

A small number of eggs continued to be collected after 20 May 2001 through the remainder of the month (n=289) with catch rates generally remaining below 10 eggs/100 m^3 of water sampled (range 0.08 - 11.78 eggs /100 m^3 of water sampled; mean 2.7 eggs/100 m^3 of water sampled). Collecting efforts in June yielded a total of 83 Rio Grande silvery minnow eggs, all of which were taken on 13 June 2001. None of the other 10 dates sampled between 5-19 June resulted in the collection of Rio Grande silvery minnow eggs. The final egg collecting effort occurred on 19 June 2001.

Discharge and Water Temperature

Mean daily discharge during May and June 2001 (Figure 5) was characterized by a series of gradually increasing peaks as flow rose from 75 cfs (3 May 2001) to 2,430 cfs (25 May 2001). Flow in the Rio Grande during this period was >100 cfs for all except five days (n=56) and was >1,000 cfs from 19 May through 7 June 2001 (n=20 days). Decreasing discharge, after 25 May 2001 peak, was punctuated by a series of small spikes (both magnitude and duration) during its gradual decline to about 100 cfs (end of June).

Like discharge, mean daily water temperature rose gradually throughout the study. From 11 May 2001 through the end of this study, mean daily water temperature remained >20 °C. An increase in daily fluctuations of water temperature which corresponded with decreasing discharge was noted. Daily fluctuations in water temperature were generally <5 °C during May but rose to almost 10 °C per day by the last week of June as discharge declined to <200 cfs. From 17-27 June 2001 minimum daily water temperature was never <21 °C while maximum water temperature was always >26 °C. During five of these 11 days, maximum daily water temperature was >30 °C.

Discharge prior to the principal spawning event was <100 cfs (1-3 May) but increased gradually until 8 May when it peaked at 797 cfs. A two day decline in discharge followed before discharge again rose (891 cfs). Concurrent with increasing flow in early May 2001 was a considerable increase in water temperature. Between 5-8 May mean daily water temperature increased from 14.9 °C to 19.8 °C. Conversely, mean daily water temperature during the three days of highest egg collection remained at a relatively consistent 19.7 °C (± 0.2 °C).

During the second spawning spike (17-20 May 2001) discharge increased from 625 to 1,200 cfs. Minimum and maximum daily water temperatures during this same period remained above 19 °C while mean daily water temperature was between 20.2-23.0 °C. Water levels continued their general rise from 21-25 May 2001 while mean daily water temperatures ranged between 15.5-20.0 °C.

DISCUSSION

As rivers have become increasingly fragmented, an important factor limiting the recolonization of upstream reaches is the downstream transport of reproductive products below barriers or displacement into highly degraded downstream riverine habitats and reservoirs. The potential negative impacts of dam-related modifications of flow and habitat on Great Plains stream cyprinids that employ drifting eggs and larvae as an early life history strategy have been well documented (Stanford and Ward, 1979; Cross et al., 1983; Cross et al. 1985, Cross and Moss, 1987; Winston, 1991; Luttrell et al., 1999). In the Middle Rio Grande, many of the eggs and larvae of the

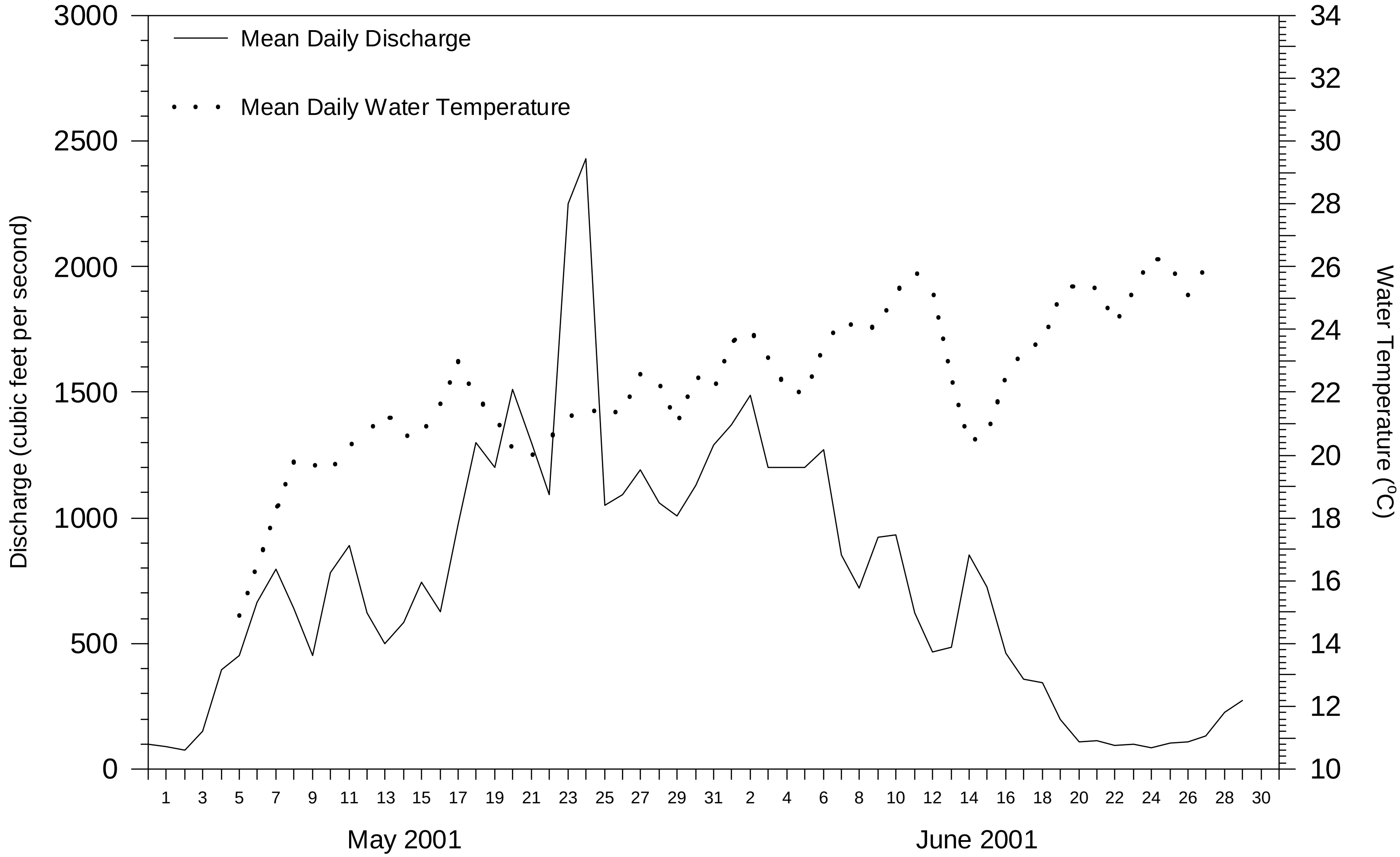

Figure 5. Mean daily discharge compared with mean daily water temperature during the 2001 study period at San Marcial.

federally endangered Rio Grande silvery minnow are rapidly displaced downstream of diversion dams and into Elephant Butte Reservoir. The loss of this reproductive effort from upstream sources is one factor that has led to the currently imperiled state of this species. Reducing the rate of downstream transport, allowing upstream passage, and salvaging eggs destined for Elephant Butte Reservoir are all options that will, to some degree, improve the current status of Rio Grande silvery minnow.

Since Rio Grande silvery minnow is the only extant species of the previously discussed reproductive guild in the Middle Rio Grande, the species-specific identification of any semibuoyant egg collected during this study is unambiguous. The only other eggs that we have captured in the Middle Rio Grande during this and previous investigations that look (to the untrained individual) remotely similar to those of Rio Grande silvery minnow are the eggs of common carp, *Cyprinus carpio.* Fortunately, there are numerous differences between the eggs of these two species that aid in identification. As the eggs of common carp are adhesive, there are usually small pieces of particulate matter attached to the chorion. Additionally, common carp eggs are smaller and more opaque than Rio Grande silvery minnow eggs, and the eyes of carp embryo become pigmented very early in development. Conversely, the egg of Rio Grande silvery minnow is clear, nonadhesive, smooth, large, and the embryo lacks discernable pigment.

Rio Grande silvery minnow and other members of its reproductive guild (Platania and Altenbach, 1998) appear to be triggered to spawn by specific environmental cues. These fishes exhibited a strong positive correlation between flow and spawning. In both 1999 and 2001, the peak spawning event by Rio Grande silvery minnow occurred soon after the initiation of spring snowmelt runoff (during the first two weeks of May). Egg catch rates in the Pecos River and Rio Grande appear most closely correlated with increased flow and not absolute water volume. This relationship has been observed throughout the Middle Pecos River from early-May until late-September. Spawning was closely correlated to sharp increases in flow from local rainstorms and egg catch rates would drop as soon as flows began to drop. This sequential pattern (increased flow, increased spawning, decreased flow, decreased spawning) occured throughout the summer in the Pecos River, NM. By late-September, the association between spawning and flow was minimal, indicating the end of the reproductive season for the five members of the rerporductive guild that occupy the Pecos River.

While spawning by Rio Grande silvery minnow appeared to be strongly associated with changes in flow and water temperature, its spawning period occurred over a very short time span. Over 98% of all eggs collected during this study arrived over a three day period. This short and concerted spawning effort occurred shortly after both flows and water temperatures increased dramatically. A second and smaller spawning effort was also strongly associated with physical changes in river conditions associated with increased flows. Substantive information to characterize the fish that participated in the second spawn has not been obtained. It would be valuable to know whether, for those individual females participating in the second event, it was their first spawn or if those individuals represented a specific age-class. The same information would be useful during years when small spawning events precede a single large reproductive effort.

Some low level of spawning occurred throughout most of the study period but its significance is unknown. While it appears that most adult Rio Grande silvery minnow were triggered to spawn during a single flow event, a lesser amount of background spawning occurred for several weeks after the main reproductive effort. Background spawning did not appear to be strongly associated with changes in river conditions although low densities of eggs precluded any definitive conclusions about proximal causes.

The highest flows during the study period occurred in late May and early June. Rapid increases in flow occurred numerous times but spawning activity remained very low and seemed only weakly correlated to these events. It appears that the majority of reproductively capable Rio Grande silvery minnow spawned on the first major flow event and that there were far few individuals available to spawn on subsequent flow events.

The downstream displacement of drifting fish eggs and larvae in aquatic ecosystems poses a unique problem for resource managers. While the most simple solution would appear to be collecting eggs from downstream localities and transporting them to rearing facilities, this method has only short term significance. Additionally, the capture of eggs using current techniques and levels of effort will result in the collection of only a miniscual fraction of the total reproductive effort that is destined for Elephant Butte Reservoir. The ability to efficiently sample even 1% of the entire volume of water that carries these reproductive propagules downstream would require a momumental effort.

Future efforts should focus on reducing the deleterious effects that changes in river connectivity, flow patterns, and habitat heterogeneity have on the downstream displacement of Rio Grande silvery minnow eggs and larvae. Eliminating diversion structures would allow upstream passage of individuals to reaches from which they were displaced. Repopulating upstream reaches of the Middle Rio Grande through natural recolonization would greatly aid in the recovery of this species. Efforts to improve degraded riverine habitats could include returning the flow regime to a more historical pattern (i.e., allowing passage of large flow events) and removing or relocating structures that inhibit the lateral movement of the Rio Grande (e.g., jetty-jacks, levees, and water conveyance ditches). The long-term recovery of Rio Grande silvery minnow will depend on taking management actions that attempt to restore the natural processes of this river.

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