

Taylor and Miller 1990). Although the interactions (e.g., hybridization or competition) between the silvery minnow and the introduced plains minnow are believed by some to be one of the primary causes for the extirpation of the silvery minnow in the Pecos River, this hypothesis is unsubstantiated (Hatch *et al.* 1985; Bestgen *et al.* 1989; Cook *et al.* 1992). Currently, New Mexico State University is conducting research on the plains minnow and silvery minnow to determine if the two species hybridize. These studies are ongoing and results should be available in 2003 (C. Caldwell, U.S. Geological Survey, Biological Resources Division pers. comm. 2002).

Within its native range, the plains minnow is sympatric (occurs at the same localities) with other species of *Hybognathus*, but is separated ecologically from them. For example, the plains minnow is found in the main river channel where the substrate is predominantly sand, whereas related species such as the western silvery minnow (*Hybognathus argyritis*) predominate in backwaters and protected areas with little to no current and sand or silt substrate (Pflieger 1997). Consequently, if the silvery minnow and plains minnow do not hybridize, they may be ecologically segregated and able to co-exist.

The plains minnow and silvery minnow appear to have little in the way of behavioral or physiological isolating mechanisms and may hybridize (Cook *et al.* 1992); yet the combined effects of habitat degradation (i.e., modification of the flow regime, channel drying, water diversion, and stream channelization) may be another potential explanation for the silvery minnow's extirpation from the Pecos River (Bestgen and Platania 1991; C. Hoagstrom, pers. comm. 2001). We acknowledge that no conclusive data exist to determine the cause of extirpation of the silvery minnow from the Pecos River.

The silvery minnow has also been extirpated from the Rio Grande downstream of Elephant Butte Reservoir, NM, to the Gulf of Mexico, Texas (TX), including the river reach within Big Bend National Park (Hubbs *et al.* 1977; Bestgen and Platania 1991). Reasons for the species' extirpation in the lower Rio Grande are also uncertain. The last documented collection of a silvery minnow in the Big Bend area was 1961, but reexamination of that specimen revealed it was a plains minnow (Bestgen and Propst 1996). Therefore, the last silvery minnow from the lower Rio Grande was apparently collected in the late 1950s (Trevino-

Robinson 1959; Hubbs *et al.* 1977; Edwards and Contreras-Balderas 1991).

Prior to measurable human influence on the middle Rio Grande, starting in the 1300's, (Biella and Chapman 1977), the Rio Grande was a perennially flowing, aggrading river with a shifting sand substrate. In general, the river was slightly sinuous and braided, and freely migrated across the floodplain. Strong evidence now suggests that the middle Rio Grande started drying up on a fairly regular basis only after the development of Colorado's San Luis Valley in the 1870's. Prior to this, there are only two examples of its flow ceasing, during prolonged, severe droughts in 1752 and 1861. Over the past century, and particularly in the last few decades, the middle Rio Grande has been frequently dewatered, particularly in the river reach from Isleta Diversion Dam to the San Acacia Diversion Dam (Isleta reach) and the reach from San Acacia Diversion Dam to Elephant Butte Reservoir (San Acacia reach) (Middle Rio Grande Conservancy District (MRGCD) 1999; Scurlock and Johnson 2001; Scurlock 1998).

Decline of the species in the middle Rio Grande probably began in 1916 when the gates of Elephant Butte Dam were closed. Construction of the dam signaled the beginning of an era of dam construction on the mainstem Rio Grande that resulted in five major mainstem dams within the silvery minnow's historic range (Shupe and Williams 1988). These dams (Cochiti, Elephant Butte, Caballo, International Amistad, and International Falcon) allowed manipulation and diversion of the river's flow. Often this manipulation severely altered the flow regime and likely precipitated the decline of the silvery minnow (Bestgen and Platania 1991). Water management and use has resulted in a large reduction of suitable habitat for the silvery minnow. Lack of water is likely the single most important limiting factor for the survival of the species (Service 1999). Agriculture accounts for 90 percent of the water consumption in the middle Rio Grande (Bullard and Wells 1992). The average annual diversion of water in the middle Rio Grande by the MRGCD was 535,280 acre-feet (af) for the period from 1975 to 1989 (U.S. Bureau of Reclamation (BOR) 1993). The silvery minnow historically survived low flow periods because such events were infrequent and of lesser magnitude, and there were no diversion dams to restrict free movement of silvery minnows in the river (59 FR 36988). Concurrent with construction of the mainstem dams was an increase in the abundance of non-native fish (largemouth bass (*Micropterus*

*salmoides*), smallmouth bass (*M. dolomieu*)) as these species were stocked into the reservoirs created by the dams (e.g., Cochiti Reservoir) (Sublette *et al.* 1990). Once established, these species often completely replaced the native fish fauna (Propst *et al.* 1987; Propst 1999).

Development of agriculture and the growth of cities within the historic range of the silvery minnow resulted in a decrease in the quality of river water caused by municipal and agricultural runoff (i.e., sewage and pesticides) that may have also adversely affected the range and distribution of the silvery minnow. Historically there were four other small native fish species (speckled chub (*Macrohybopsis aestivalis*); Rio Grande shiner (*Notropis jemezianus*); phantom shiner (*Notropis orca*); and Rio Grande bluntnose shiner (*Notropis simus simus*)) within the middle Rio Grande that had similar reproductive attributes, but these species are now either extinct or extirpated (Platania 1991).

The various life history stages of the silvery minnow require shallow waters with a sandy and silty substrate that is generally associated with a meandering river that includes sidebars, oxbows, and backwaters (C. Hoagstrom, pers. comm. 2001; Bestgen and Platania 1991; Platania 1991). However, physical modifications to the Rio Grande over the last century—including the construction of dams, levees, and channelization of the mainstem—have altered much of the habitat that is necessary for the species to persist (Service 1999). Channelization has straightened and shortened mainstem river reaches; increased the velocity of the current; and altered riparian vegetation, instream cover, and substrate composition (BOR 2001a). Adult silvery minnows occur in shallow braided runs over sand substrate, but rarely in habitat with substrate of gravel or cobble (Platania 1991; Dudley and Platania 1997; Platania and Dudley 1997; Remshardt *et al.* 2001).

The silvery minnow is a pelagic spawning species; i.e., its eggs flow in the water column. The silvery minnow is the only surviving small, native pelagic spawning minnow in the middle Rio Grande, and its range has been reduced to only 5 percent of its historic extent. Although the silvery minnow is a hearty fish, capable of withstanding many of the natural stresses of the desert aquatic environment, most individual silvery minnows live only one year (Bestgen and Platania 1991). Thus, a successful annual spawn is key to the survival of the species (Platania and Hoagstrom 1996; Service 1999; Dudley and Platania 2001, 2002b). The