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STATUS AND CONSERVATION OF THE RIO GRANDE SILVERY MINNOW, *HYBOGNATHUS AMARUS*

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ABSTRACT—The Rio Grande silvery minnow (*Hybognathus amarus*) was formerly one of the most widespread and abundant species in the Rio Grande basin of New Mexico, Texas, and Mexico, but recent surveys indicated that its current range has been much reduced. In the Pecos River, New Mexico, *H. amarus* had declined by 1968, coincident with establishment of non-native plains minnow (*Hybognathus placitus*). Hybridization and competition with *H. placitus* were probable mechanisms of extirpation of *H. amarus* from the Pecos River. In the lower Rio Grande, Texas, downstream of the Pecos River, extirpation of *H. amarus* around 1961 was probably related to construction and operation of Amistad Reservoir and introduction of non-native fishes. Local populations of *H. amarus* (e.g., Rio Grande near Big Bend, Texas) were considered extirpated just after 1960. *Hybognathus amarus* survives only in New Mexico in 5% of its original range from Cochiti Reservoir downstream to Elephant Butte Reservoir. Conservation measures are necessary as continued habitat and flow modifications, introduction of non-native fishes, and lack of refugia threaten survival of *H. amarus*.

Fish assemblages in most arid regions of North America have been affected by man-caused disturbances such as water development, habitat alteration, and introduction of non-native species. Over half of the cyprinid taxa recently listed as endangered, threatened, or of special concern were from desert streams in the American Southwest or West (Williams et al., 1989). Included as a species of special concern was the Rio Grande silvery minnow (*Hybognathus amarus*), an endemic of the Rio Grande basin in New Mexico, Texas, and Mexico. *Hybognathus amarus* was only recently recognized as a distinct species (Pflieger, 1980; Smith and Miller, 1986; Hlohowskyj et al., 1989; Williams et al., 1989; Cook et al., in press) and its present distribution and biology are poorly understood.

Hybognathus amarus was formerly distributed from northern New Mexico in the Rio Grande and Pecos River to the Gulf of Mexico (Pflieger, 1980). Evidence from collections suggested that it was one of the most abundant species in the basin, but *H. amarus* has not been recently collected from many portions of its range (Hubbs et al., 1977; Hatch et al., 1985; Propst et al., 1987; Bestgen et al., 1989; Bestgen and Platania, 1990, Platania, in press). Habitat and flow alterations and introduction of non-native fish species have been implicated in decline or extinction of cyprinids and other fishes in the Rio Grande basin (Hubbs et al., 1977; Hatch et al., 1985; Bestgen et al., 1989; Williams et al., 1989; Bestgen and Platania, 1990). Our purpose is to review the status of *H. amarus* throughout the Rio Grande basin and to discuss factors that may be limiting its current distribution and abundance.

MATERIALS AND METHODS—The Rio Grande basin drained portions of southern Colorado, eastern and central New Mexico, and the boundary region between western Texas and Mexico before emptying into the Gulf of Mexico. Warm and coolwater riverine habitats varied in size from 10 to 250 m wide dependent upon river stage and were generally shallow, braided, and sandy-bottomed. Some reaches were constrained by canyon walls or incised streambanks and were correspondingly deeper and swifter. Water was generally turbid except at low flow, and maximum summer water temperatures ranged from 25 to 30°C. Downstream from large mainstream dams, flow was generally clear and cool, and cobble and gravel substrate was more

common. Flows in this arid region were highest in the spring following snowpack melt but, in some reaches, were reduced to near zero during May through September when most available streamflow was diverted for irrigation. Discharge throughout most mainstream reaches of the study area was highly regulated by dams, and flows had declined from historic levels.

In the early 1950s, the Low-flow conveyance canal was constructed along the Rio Grande, New Mexico, from near San Acacia downstream to Elephant Butte Reservoir. This canal was designed to carry all middle Rio Grande discharge <63 m^3/s to Elephant Butte Reservoir (United States Geological Survey, 1889–1988). Accordingly, flows bypassed the mainstream in all but the highest flow periods. Conveyance canal operations were suspended in the mid-1970s; high flows and the rising level of Elephant Butte Reservoir restricted its recent use. Flows are still present in downstream reaches of the conveyance canal (annual discharge 3 to 60 m^3/s, gage no. 08358300), mostly as a result of groundwater seepage and irrigation return, but water is clearer and cooler than in the Rio Grande. Other details describing the Rio Grande and Pecos River in New Mexico can be obtained from Hatch et al. (1985), Bestgen et al. (1989), Bestgen and Platania (1990), and Platania (1991).

Collections were made in the Rio Grande and Pecos River drainages, New Mexico, from 1986 to 1989. In the Rio Grande, Texas, collections were made from El Paso downstream to Falcon Reservoir in 1988 and 1990, except that no samples were taken in Big Bend National Park. Collections were made primarily with small mesh (1.6 to 6.4 mm) seines of various lengths; a backpack electrofishing unit was occasionally used in small, clear streams. We attempted to sample all available habitats (e.g., pools, riffles, runs, and backwaters) at each site; area seined was measured, and fish density (number per square meter) was calculated. Specimens were fixed in 10% formalin, preserved in alcohol, and deposited at the Museum of Southwestern Biology (MSB), Division of Fishes, University of New Mexico.

Data describing the historic distribution and abundance of *H. amarus* in New Mexico were obtained from the Fish Database of the New Mexico Department of Game and Fish, published and unpublished literature, museum specimens, and communications with other workers. The institutional code for the fish collection at Eastern New Mexico University, Portales, is ENMU; other museum codes follow Leviton et al. (1985).

RESULTS—Historic populations of *H. amarus* were known or presumed to be present throughout most of the Rio Grande basin (Fig. 1). Past collections document the occurrence of *H. amarus* in portions of the Rio Grande and Pecos River in New Mexico, and the Rio Grande, Texas, near Big Bend National Park and downstream of Amistad Reservoir. The historic and present status of *H. amarus* in each of these four reaches will be discussed.

Rio Grande, New Mexico—In the Rio Grande drainage, New Mexico, *H. amarus* occurred in the Chama River and throughout the Rio Grande to nearly El Paso, Texas, and in the downstream portion of the Jemez River. Upstream of present-day Cochiti Reservoir, there were few historic records of *H. amarus*; only 38 specimens from four collections were known between 1874 and 1978. Despite extensive collections, we did not find *H. amarus* in this area, and, if the species remains, it is present in very low numbers. Despite perennial flows, several other cyprinids of the Rio Grande disappeared from this reach by 1960 (Bestgen and Platania, 1990). Channel modifications may have eliminated preferred habitat of *H. amarus* in this reach.

The middle Rio Grande, New Mexico, from present-day Cochiti Reservoir downstream to Elephant Butte Reservoir, supported large numbers of *H. amarus* between 1926 (first collection in the area) and 1960. *Hybognathus amarus* was most abundant in collections made just downstream of low-head diversion dams, and collections of >100 specimens from such localities were common. *Hybognathus amarus* was not documented in the lower portion of the middle Rio Grande probably due to a seasonally desiccated streambed and lack of collection effort.

A series of collections made in the middle Rio Grande from 1977 to 1978 showed that *H. amarus* was as common as in the 1926–1960 period. Additionally, 1,418 *H. amarus* were collected at 11 sites in the Low-flow conveyance canal from 1977 to 1978. Most of those specimens were young-of-year. We do not know if these fish were spawned and hatched in the canal or were transported into the canal from the Rio Grande as eggs or larvae. Large numbers of other species, which included young-of-year, were also collected suggesting that reproduction occurred within the canal.

During our survey, collections showed that the 186-km reach of the middle Rio Grande, New Mexico, from Cochiti Reservoir to Elephant Butte Reservoir, supported the only remaining *H. amarus*. Even there, however, the distribution of the species declined; only 23 *H. amarus* were found among 9,000 specimens collected from 1987 to 1989 in the 24-km reach from Cochiti Reservoir downstream. Clear water discharged from Cochiti Reservoir scoured most of the sand from the

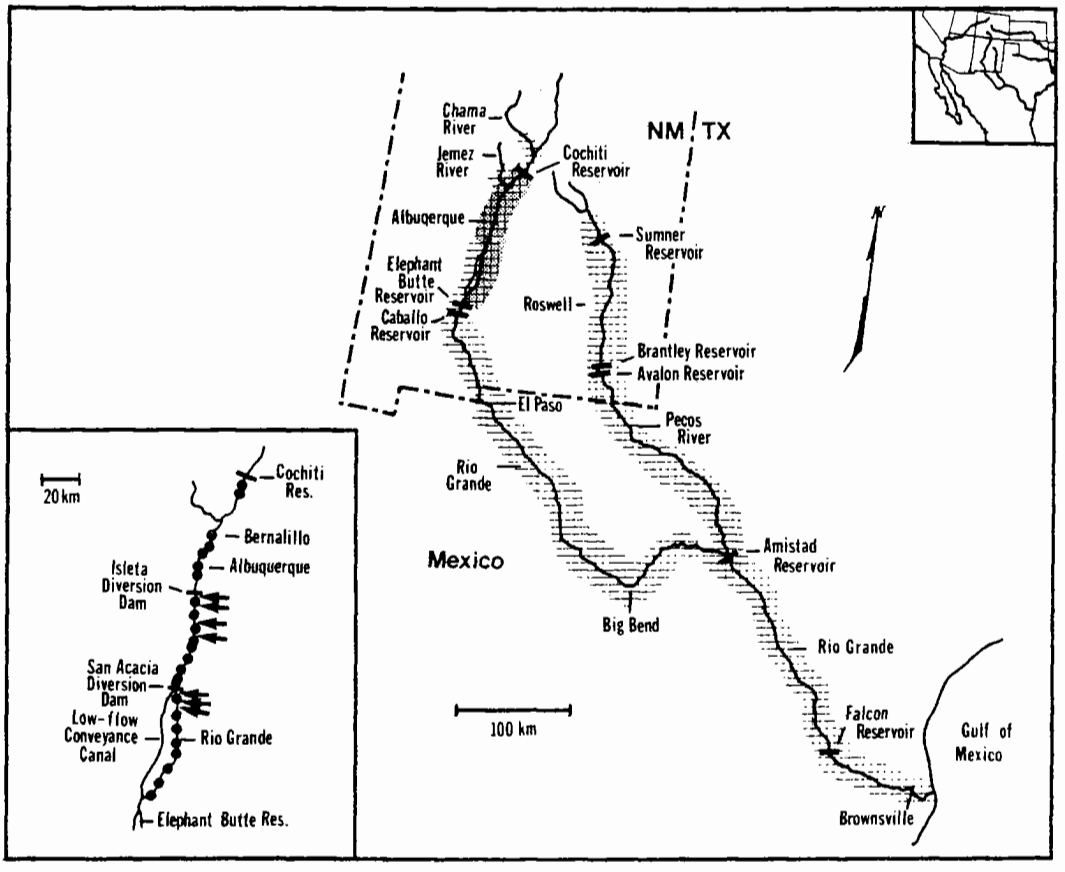

FIG. 1—Distribution of *Hybognathus amarus* in the Rio Grande basin. Cross-hatching indicates historic occurrence, and stippling represents distribution during 1986 to 1989. Inset of the middle Rio Grande, New Mexico, shows collection localities of *H. amarus* during 1986 to 1989; arrows indicate sites where >100 were collected.

channel, an alteration that may exclude *H. amarus*. Habitat was mostly cobble-bottomed riffles and runs; shallow, braided runs over sand substrate were uncommon. Most of the *H. amarus* collected in this reach were captured in low-velocity habitats that had sand substrate.

Hybognathus amarus occurred regularly in our collections downstream of Bernalillo in mainstream habitat of the Rio Grande. Generally, however, <20 adult specimens/collection were taken at sites from Bernalillo to Isleta (Table 1). Despite the presence of adequate habitat, *H. amarus* was usually absent in collections made in or just downstream of Albuquerque, and the fish fauna there was relatively depauperate.

Downstream from Isleta to Elephant Butte Reservoir, collections of >50 *H. amarus* were common in mainstream habitat of the Rio Grande. Our largest collections of *H. amarus* were made below Isleta and San Acacia diversion dams in late summer when most discharge from the Rio Grande was diverted into canals. Densities of *H. amarus* sometimes exceeded $2/m^2$ just below diversion dams.

Our collections suggested that *H. amarus* no longer inhabited the Low-flow conveyance canal, despite the abundance of specimens taken there as recently as 1978. Overall, we found low species diversity and fish density in the conveyance canal, and species composition was unlike that found in collections made in 1977 to 1978.

Flow conditions influenced the habitat in which *H. amarus* was found. When flows were not severely reduced by agricultural water diversions, *H. amarus* was found throughout most of the middle Rio Grande, New Mexico; typical habitat was

TABLE 1—Abundance of *Hybognathus amarus* (total specimens, number per square meter of habitat seined, and percent composition in collections) in summer and winter collections in reaches of the middle Rio Grande, New Mexico, 1987 to 1988. Number of collections per season and reach is given parenthetically.

	Summer			Winter		
Reach	No. of specimens	No./m²	% of collection	No. of specimens	No./m²	% of collection
Bernalillo to Isleta	15 (3)	0.01	2.4	27 (3)	0.03	5.9
Isleta Diversion Dam	808 (1)	2.07	47.0	20 (1)	0.03	15.9
Isleta to San Acacia	636 (11)	0.08	10.2	861 (6)	0.29	25.0
San Acacia Diversion Dam	2,277 (1)	7.35	58.0	42 (2)	0.03	3.3
San Acacia to Elephant Butte	812 (11)	0.17	25.5	178 (9)	0.03	12.9

shallow and braided runs over shifting sand substrate. During extreme low-flow periods, *H. amarus* was found in short, flowing reaches below diversion dams or were restricted to a few isolated pools. Habitat below diversion dams was usually >1 m deep, and had mixed sand, gravel, and cobble substrate. Isolated pools that supported fish were typically >1 m deep and adjacent to undercut, shaded stream banks.

In the Rio Grande, New Mexico, from Caballo Reservoir to the New Mexico-Texas border, only four collections and 16 *H. amarus* were known from the period between 1938 and 1944. Construction and operation of Elephant Butte and Caballo reservoirs in 1916 and 1938, respectively, severely altered discharge patterns and reduced flows. This river reach has been highly modified and channelized to expedite irrigation water deliveries, and non-native species such as bullhead minnow (*Pimephales vigilax*) dominated the depauperate fish fauna.

Pecos River, New Mexico and Texas—Hybognathus amarus was historically present in the mainstream Pecos River, New Mexico, from Santa Rosa downstream to the New Mexico-Texas border, and in the Rio Felix, a small tributary south of Roswell. Collection records suggested that reductions of *H. amarus* in the Pecos River first occurred upstream of Sumner Reservoir. *Hybognathus amarus* was known from only one (MSB 1161, n = 34, 1939) of five collections made in that reach from 1939 to 1955, and it was not subsequently collected. Use of fish toxicants after closure of Sumner Reservoir in 1937 and lack of recruitment from downstream reaches due to dam construction were blamed for reductions of native fishes in this area (Hatch et al., 1985).

Hybognathus amarus was historically common in the middle Pecos River, New Mexico, from Sumner Reservoir to Avalon Reservoir, and was the second-most abundant species in six collections made there between 1939 and 1955. In the Rio Felix, just upstream from its confluence with the Pecos River, *H. amarus* was especially common in collections. Five collections of *H. amarus* from the Pecos River, made from 1963 to 1965 just downstream of Sumner Reservoir (ASU 1308, n = 118), near Roswell (KU 8362, n = 28; KU 8318, n = 35; KU 8068, n = 145), and downstream of McMillan Reservoir (KU 8070, n = 7; McMillan Reservoir, now inundated by Brantley Reservoir), suggested that *H. amarus* was widespread and common at that time.

Cowley (1979, ENMU records) discovered the introduction of plains minnow (*Hybognathus placitus*) into the Pecos River drainage, New Mexico, from collections made as early as 1968 and also recognized the disappearance of native *H. amarus*. The last known collections of *H. amarus* from the Pecos River drainage were near Roswell in 1968 (ENMU NMCH68-010.02; n = 26; MSB 2636, n = 1). These collections also included the first verified specimens of *H. placitus* from the Pecos River.

We found two specimens of *Hybognathus* in a collection made in 1964 just downstream of Sumner Reservoir (ASU 1308) that had basi-occipital processes intermediate in width between the narrow process of *H. placitus* and the wide process of *H. amarus* (Bailey and Allum, 1962; Niazi and Moore, 1962). These two specimens may be *H. amarus* × *H. placitus* hybrids which suggests that introduction of *H. placitus* may have occurred prior to 1964. No hybrid specimens were found in other collections from the Pecos River made from 1963 to 1965. *Hybognathus placitus* has been

found throughout the historic range of *H. amarus* from Santa Rosa downstream to the New Mexico-Texas border since the early 1970s and is one of the most abundant species in the Pecos River, New Mexico (Hatch et al., 1985; Bestgen et al., 1989).

In the lower Pecos River, New Mexico, downstream of Avalon Reservoir, *H. amarus* was historically uncommon; only 14 specimens in two collections were known. The preponderance of pool habitat and intrusions of saline water (United States Geological Survey, 1889-1988) were probably responsible for paucity of *H. amarus* in this reach.

The only *H. amarus* known from the Pecos River drainage, Texas, were nine specimens collected from a Pecos River drainage canal near Fort Stockton in 1928 and 68 specimens taken from the Pecos River just upstream of its confluence with the Rio Grande in 1940. It is not unreasonable to assume, however, that *H. amarus* historically inhabited more of the Pecos River in Texas, because it was abundant upstream and downstream. Streamflow reductions that began before 1900 and the high salinity of the Pecos River (United States Geological Survey, 1889–1988) probably excluded *H. amarus* from this reach.

Big Bend, Texas—Twenty-three *H. amarus* in seven collections (1938 to 1960) were known from the Rio Grande and its tributaries near Big Bend National Park, Texas, which suggested that this population was geographically restricted and small. The last documented collections of *H. amarus* from that area were made in 1960 (OSUS 5491, $n = 2$; OSUS 11852, $n = 2$). Collections made in the Rio Grande upstream and downstream of Big Bend in 1977 by Hubbs et al. (1977) and ourselves in 1988 and 1990 did not document the species, but extirpation of *H. amarus* from the Big Bend National Park area needs confirmation. Desiccation of the Rio Grande in the vicinity of El Paso as early as 1900 (Lee, 1907) and canyon habitat downstream of Big Bend may be a partial explanation for the absence of *H. amarus*.

Lower Rio Grande, Texas—In the lower Rio Grande, Texas, *H. amarus* formerly occurred from the confluence of the Pecos River (present-day Amistad Reservoir) to the Gulf of Mexico (Pflieger, 1980). The type locality of *H. amarus* (USNM 149, $n = 1$) is the Rio Grande near Brownsville, Texas (Girard, 1856; Hubbs and Ortenburger, 1929). Subsequent collections indicated that *H. amarus* was moderately common (UMMZ 170193, 1940, $n = 231$; UMMZ 170205, 1940, $n = 128$) and one of the most widespread species of fish in the lower Rio Grande (Trevino-Robinson, 1959). The last known collection of *H. amarus* in this reach was just downstream of Falcon Reservoir in 1961 (TCWC 1104.1, $n = 1$), but time of extirpation is difficult to assess because of lack of collections. *Hybognathus amarus* was absent in our collections made in 1990 from the Rio Grande between Amistad and Falcon reservoirs. Absence of *H. amarus* downstream of Falcon Reservoir has been substantiated by numerous collections (R. J. Edwards, pers. comm.). We can find no evidence that *H. amarus* ever inhabited larger tributaries (e.g., Rio Salado, Rio Conchos) of the Rio Grande in Mexico (S. Contreras-Balderas, pers. comm.).

DISCUSSION—The widespread reduction of *H. amarus* in the Rio Grande basin is attributable to several different factors. In the Pecos River, New Mexico, genetic and morphological evidence suggested that hybridization contributed to the demise of *H. amarus*, but the extent is unknown. Alleles with a possible *H. amarus* origin were found in five of 20 *H. placitus* collected from the Pecos River, New Mexico, in 1988 (Cook et al., in press). The probable introduction site of *H. placitus* was just downstream of Sumner Reservoir. This was also the site of introduction of the Arkansas River shiner (*Notropis girardi*; Bestgen et al., 1989). The wide distribution and abundance of *H. placitus* in the Pecos River also suggested that competitive interactions might have been important in the extirpation of *H. amarus*. Altered habitat and flow conditions may also have favored reproductive success of *H. placitus* over *H. amarus*.

Habitats which historically supported small, outlier populations of *H. amarus* (e.g., upstream reaches of the Rio Grande and Pecos River, New Mexico, Big Bend area, Texas) may have relied on continuous ingress from upstream and downstream reaches to supplement populations. When these avenues of dispersal were cut off by dams or desiccated streambeds, populations dwindled and were eventually extirpated. Congeneric Mississippi silvery minnow (*Hybognathus nuchalis*), which was formerly widespread and abundant in tributaries as well as the mainstream of the Tennessee River system, disappeared from that drain-

age following closure of mainstream dams (Etnier et al., 1979; Sheldon, 1988). Habitat dissection may be an especially important mechanism in the extirpation of fishes from arid-land stream ecosystems, and the capability of dispersing to secure habitats may be critical to survival.

The reduction of *H. amarus* from the downstream portion of the Rio Grande in Texas was difficult to interpret because of lack of collections during periods of declines. Habitat and flow alterations associated with construction of reservoirs, irrigation, pollution, high salinity (0.5 to 20 ppt), and introduced fishes probably played a role in the extirpation of *H. amarus* (R. J. Edwards, pers. comm.).

Remaining populations of *H. amarus* in the Rio Grande, New Mexico, continue to decline. Degradation of stream substrate below Cochiti Reservoir is ongoing, and the ultimate downstream extent of this habitat altering process is unknown. As recently as 1984, 97 *H. amarus* were collected about 24 km downstream of Cochiti Reservoir at San Felipe Pueblo (Platania, 1991), but we did not collect any there in 1987 or 1990. Closure of Cochiti Reservoir in 1973 and subsequent water release patterns have supplemented historic summer low flows in the middle Rio Grande (Bestgen and Platania, 1990), but portions of that reach downstream of diversion dams still dry annually. During extreme low-flow events, lack of pools, small pool size, and high water temperature reduce survival of fishes. The extent of fish mortality in these habitats is probably related to duration of low flows. The effectiveness of avian and aquatic predators on resident fishes is likely enhanced in isolated pools and non-native piscivores such as white crappie (*Pomoxis annularis*) pose a substantial predation threat. Poor water quality in the Rio Grande near Albuquerque, especially during low flows, may be a problem as low numbers of *H. amarus* and an overall reduced fish community were found there.

Habitat below diversion dams is an extremely important refugium for fishes of the Rio Grande during periods of low flow. Similar to Koster (1957), we found that *H. amarus* and other species of fish were seasonally extremely abundant below diversion dams. Fishes seemingly moved upstream into habitat below diversion dams during periods of low flow. During periods of higher flows and in winter, densities of fish below diversion structures were much lower and similar to upstream and downstream reaches. The extent of such presumed movements is unknown, but this interesting and presumably important phenomenon needs investigation. These small refugia were not secure, however, as routine maintenance and repair of diversion dams altered habitat and substrate.

Reasons for the disappearance of *H. amarus* and other species of fish from the Low-flow conveyance canal remain speculative, and further research is needed. The large population that formerly existed may have been dependent on recruitment of eggs, larvae, and adult fishes from the Rio Grande to the canal. Proposed re-initiation of canal operations could have extreme consequences for mainstream populations of *H. amarus,* as the Rio Grande would dry annually in some reaches downstream of Isleta.

Absence of *H. amarus* from riverine habitat in canyons or from reaches that have been channelized or otherwise constrained may be due to the species' apparent preference for shallow, braided, sandy-bottomed habitat. Restriction of channel width by dikes, canyon walls, or the leveeing effect of dense stands of non-native riparian trees decreases stream sinuosity and meandering, enhances scouring of fine substrate, and creates more homogeneous and deeper run-type habitat.

The widespread use of *H. placitus* as bait, the generalized ecology and explosive dispersal ability of this species when introduced outside of its native range, and the proximity of the Pecos River to remaining *H. amarus* in the Rio Grande requires that stricter controls on interbasin transport of non-native fishes be implemented. Bait dealers and fishermen should be encouraged to gather bait within the same areas they intend to sell bait or fish, respectively, thereby, avoiding transport between drainages and potential problems associated with interactions between native and non-native species.

Hybognathus amarus was once one of the most widespread and abundant species in the Rio Grande basin, but its distribution has been reduced by 95% (United States Geological Survey river mile designations). Anticipated additional modifications to existing habitat, and current lack of other suitable habitats for the species, suggest limited prospects for survival of *H. amarus* unless the middle Rio Grande, New Mexico, is protected. Protection of *H. amarus* through provision of adequate flows, minimization of habitat alter-

ations, and suppression of negative interactions with non-native species may be necessary for *H. amarus* to survive.

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