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Abstract—We examined contents of alimentary canal from pond-reared Rio Grande silvery minnows (*Hybognathus amarus*; $n = 183$) to determine frequency of occurrence for foods consumed among small (9–20 mm), medium (21–35 mm), and large fish (36–75 mm). Among 183 fish, 19% ($n = 34$) of alimentary canals were empty. Of those with food items ($n = 149$), insects were the most common and were present in 66% of fish, followed by formulated feed (60%), diatoms (40%), cladocerans (36%), rotifers (35%), filamentous algae (32%), bryozoan statoblasts (19%), copepods (11%), protozoa (9%), plant material (9%), ostracods (6%), detritus (5%), and sand (4%). Among size groups, small and medium fish consumed a greater variety of foods than large fish. Information on contents of alimentary canal of pond-reared Rio Grande silvery minnows will aid in refining culture techniques for this federally listed endangered species.

Resumen—Examinamos los contenidos de los estómagos de los peces *Hybognathus amarus* ($n = 183$) provenientes de criaderos para determinar la frecuencia de ocurrencia de tipos de comida consumidos por peces pequeños (9–20 mm), medianos (21–35 mm), y grandes (36–75 mm). Entre 183 peces, 19% ($n = 34$) de los estómagos estuvieron vacíos. Entre los que tenían comida ($n = 149$), insectos fueron más comunes, encontrándose en 66% de los peces, seguidos por alimento comercial (60%), diatomas (40%), cladóceros (36%), rotíferos (35%), algas filamentosas (32%), briozoos estatoblastos (19%), copépodos (11%), protozoarios (9%), material de plantas (9%), ostrácodos (6%), detritus (5%), y arena (4%). Entre grupos de tamaño, los peces pequeños y medianos consumieron una variedad mayor de comida que los peces grandes. Información sobre contenidos de estómagos de *H. amarus* provenientes de criaderos ayudará a refinar técnicas de cultivo para esta especie listada federalmente como en peligro de extinción.

The Rio Grande silvery minnow *Hybognathus amarus* historically occurred in the Rio Grande from Espanola, New Mexico, to the Gulf of Mexico, and in the Pecos River from Santa Rosa, New Mexico, to the Rio Grande (Bestgen and Platania, 1991). Local and widespread fragmentation of rivers by diversions of water and reservoirs, dewatering of mainstem reaches, introductions of congener plains minnow *H. placitus*, and nutrient enrichment are likely causes of range-wide reductions in occurrence and abundance (Bestgen and Propst, 1996). Consequently, this once widespread and abundant fish was extirpated from the Pecos River and the Rio Grande in Texas by the 1960s (Bestgen and Platania, 1991; Hubbs et al., 1991), prompting listing of the fish as an endangered species (United States Department of the Interior, 1994). Currently, the Rio Grande silvery minnow occurs only in a 280-km section of the Rio Grande between Cochiti Reservoir and Elephant Butte Reservoir in New Mexico (United States Fish and Wildlife Service, 1999, 2007). However, persistence of Rio Grande silvery minnows in this section of the Rio Grande is tenuous because of introductions of exotic fish and continued degradation of water quantity and quality (Bestgen and Propst, 1996). As such, wild stocks are supplemented by hatchery-reared fish.

The primary goal of the Rio Grande silvery minnow recovery plan (United States Fish and Wildlife Service, 1999, 2007) is to prevent extinction of the Rio Grande silvery minnow in the middle Rio Grande; captive propagation is the main tool for achieving this goal. Dexter National Fish Hatchery and Technology Center (Dexter, Chaves County, New Mexico) is a 267-ha facility with specific responsibilities for the propagation, culture, and research of threatened and endangered aquatic species. Propagation of the Rio Grande silvery minnow began at Dexter National Fish Hatchery and Technology Center in 2001 with an emphasis placed on development and refinement of captive-propagation and rearing techniques. As of 2008, Dexter National Fish Hatchery and Technology Center produced ca. 300,000 Rio Grande silvery minnows/year and, along with other facilities, has released >1,000,000 hatchery-reared fish into a 280-km section of the Rio Grande. In December 2008, Rio Grande silvery minnows from Dexter National Fish Hatchery and Technology Center (250,000 age 0 and 150,000 age 1) were used for a historic reintroduction into the Big Bend reach of the Rio Grande in Texas and Mexico, with plans to stock an additional 100,000 fish/year through 2012.

To increase production, part of the rearing process includes raising larval fish in outdoor earthen and lined ponds for ≤1 year. Wild age-0 Rio Grande silvery minnows are believed to be opportunistic feeders based on ratios of stable isotopes, consuming algae and probably invertebrates (Pease et al., 2006; Magaña, 2007). However, information on specific foods consumed is unknown but necessary to ensure adequate food supply is maintained in the rearing ponds. The purpose of this study was to collect baseline data on diets of hatchery-raised, juvenile Rio Grande silvery minnows by identifying foods, both natural and formulated feed, ingested by small, medium, and large-sized fish of age-0 that were reared in the ponds. Information gained will enable better management of ponds before and during stocking of fish.

Materials and Methods—We assessed contents of alimentary canals from two cohorts of fish reared at Dexter National Fish Hatchery and Technology Center in 2002 and 2005. The 2002 cohort was hatched from eggs taken from the Rio Grande at San Marcial, Socorro County, New Mexico, on 18–19 May 2002, and from eggs spawned from wild-caught adults at Dexter National Fish Hatchery and Technology Center on 18 May 2002. The 2005 cohort was hatched from eggs spawned 4–17 May 2005 at Dexter National Fish Hatchery and Technology Center and New Mexico State University A-Mountain Native Fish Rearing Facility, Dona Aña County. Fry were stocked into grow-out ponds after fry achieved vertical swimming, which was 3–5 days post-hatching at water temperatures of 20–23°C. Among the 2002 cohort, 7 to 16 fish were harvested weekly during 4–24 June 2002 and 40 fish were harvested once in November 2002 from four ponds. An additional five fish were harvested from one pond in March 2003 after the pond was drained. Among the 2005 cohort, ≤10 fish were harvested twice in June, July, and August 2005, and once in September 2005 from eight ponds. Collections from the 2 cohort years covered the time when fish were maintained in ponds before being harvested for stocking events in autumn and spring. All harvested fish were immediately euthanized and fixed in 10% formalin.

In the laboratory, we recorded total length (mm) and weight (g) for each fish. The alimentary canal from the esophagus to the anus was extracted. Contents of alimentary canals were removed, sorted, and identified to the lowest practical taxon. Contents were expressed as percentage occurrence, the percentage of fish by size in which the food item was present. Percentage occurrence is a rapid method for quantifying food items in fish but does not indicate preference or importance of food items consumed (Bowen, 1996). Size groups consisted of small (total length, 9–20 mm), medium (21–35 mm), and large fish (36–75 mm). For the 2002 cohort, formulated feed and detritus were classified as one food item. For the 2005 cohort, formulated feed and detritus were separated into two food items. The ratio of formulated feed to occurrence of detritus in the 2005 cohort was then used to estimate these two food items for the 2002 cohort. Renkonen similarity indices were used to assess similarity in occurrences of food items among size groups (Krebs, 1999).

Before stocking, ponds were fertilized with alfalfa pellets and granular inorganic 0-45-0 (super phosphate) to stimulate phytoplankton and zooplankton production. Formulated feed was offered to fish beginning at day 20–30 post-hatching to supplement natural foods. Rates and frequency of feeding were based on water temperature, percent of body weight, and estimated biomass (Piper et al., 1982) in each pond.

Results and Discussion—Contents of alimentary canals were assessed among 2002 cohort fish (n = 88) and 2005 cohort fish (n = 95) for a total of 183 fish. Collectively, alimentary canals were empty in 34 (18.6%) fish. Among size groups, percentage of empty alimentary canals was 6.3% in small fish, 5.1% in medium fish, and 45% in large fish. Although relatively fewer large fish had food items in their stomachs and intestines, most large fish appeared healthy and had substantial amounts of adipose tissue surrounding the alimentary canal, suggesting adequate nutrition was available in the hatchery ponds. Fulton condition factors (100,000 * weight * total length^{-3}) averaged 1.12 (range,

Table 1—Percentage occurrence of food items in small (9–20 mm), medium (21–35 mm), and large (36–75 mm) Rio Grande silvery minnows *Hybognathus amarus* (n = 149), which were reared in hatchery ponds, and the total percentage occurrence of food items in all fish.

Food item	Size of fish: Small (n = 60)	Size of fish: Medium (n = 56)	Size of fish: Large (n = 33)	Total for all fish (n = 149)
Plant material	15.6	11.9		9.3
Diatoms	45.3	66.1	8.3	39.9
Filamentous algae	28.1	44.1	23.3	31.7
Protozoa (*Volvox*)	8.3	9.3	11.4	9.4
Insects	98.4	78.0	20.0	66.1
Diptera	45.3	33.9	6.7	29.0
Tricoptera	1.6			0.5
Odonata			1.7	0.5
Unidentified	51.6	44.1	11.7	36.1
Cladocera	53.1	45.8	6.7	35.5
Copepoda	12.5	11.9	10.0	11.5
Ostracoda	9.4	8.5		6.0
Rotifera	34.4	54.2	16.7	35.0
Ectoprocta (Bryozoan)	28.1	20.3	6.7	18.6
Formulated feed	54.7	79.7	45.0	59.6
Detritus	14.1			4.9
Sand	6.3	6.8		4.4

0.59–1.79) for small fish, 1.25 (0.89–1.64) for medium fish, and 1.04 (0.61–1.35) for large fish.

Among those with food items (n = 149), insects were most common and occurred in 66% of fish, followed by formulated feed (60%), diatoms (40%), cladocerans (36%), rotifers (35%), filamentous algae (32%), bryozoan statoblasts (19%), and copepods (12%; Table 1). Among small fish, insects (i.e., Diptera, Tricoptera, and unidentified) were the most common food items, present in 98% of fish, followed by formulated feed (55%), cladocerans (53%), diatoms (45%), rotifers (34%), filamentous algae (28%), and bryozoan statoblasts (28%). Among medium fish, formulated feed (80%) and insects (i.e., Diptera and unidentified; 78%) were the most common food items followed by diatoms (66%), rotifers (54%), cladocerans (46%), filamentous algae (44%), and bryozoan statoblasts (20%). Among large fish, formulated feed was the most common food item and was present in 45% of fish, followed by filamentous algae (23%), insects (i.e., Diptera, Odonata, and unidentified; 20%), and rotifers (17%). Sand was in small and medium fish (<4% of fish), but absent in large fish. Diatoms were in all fish, but were most prevalent in medium fish. Sand and diatoms in contents of alimentary canals typically indicate benthic-feeding behaviors (Wilde et al., 2001; Cowley et al., 2006).

Percentage occurrence in contents of alimentary canals was more similar between small and medium fish (Renkonen Similarity Index = 82%) than medium and large fish (74%) and small and large fish (66%). Small and medium fish consumed a greater variety of foods compared to large fish, suggesting perhaps a more generalist feeding behavior in small and medium fish. Ontogenetic shifts in diet are typical in herbivorous fishes and suggest differences in habitat or nutritional requirements between small and large conspecifics (Balon, 1985; Gerking, 1994). We cannot infer from our assessment of contents of alimentary canals that small and medium fish inhabited different areas in the ponds than larger fish, but similar Fulton condition factors among size groups weakly support differences in nutritional requirement between small and large conspecifics. Alternatively, differences observed in diversity of food items consumed might depend on time of collection; small and medium fish were harvested during summer, whereas large fish were harvested in September, November, and March.

Taxonomic occurrences within contents of alimentary canals of age-0 Rio Grande silvery minnows reared in hatchery ponds were variable, but contents were similar to those predicted for wild-caught larval conspecifics (Pease et al., 2006; Magaña, 2007) and to those reported for adult conspecifics and congeners. Adult Rio Grande silvery minnows are benthic foragers, consuming diatoms, organic detritus, and other smaller items under turbid conditions (Hlohowskyj et al., 1989; Cowley et al., 2006; Shirey et al., 2008). Plains minnows *H. placitus*, a species often in shallow and turbid streams similar to Rio Grande silvery minnow, also are benthic feeders and consume algae and diatoms (Miller and Robison, 1973). Two species, brassy minnow *H. hankinsoni* and Mississippi silvery minnow *H. nuchalis*, are benthic feeders and consume detritus, algae, and diatoms (Starrett, 1950; Becker, 1983); contents of alimentary canals of the brassy minnow also included aquatic insects and zooplankton (Trautman, 1981). Consumption of animal tissue, such as aquatic insects and zooplankton, by adult *Hybognathus* might simply be incidental ingestion while feeding on algae and detritus (Gerking, 1994; Goldstein and Simon, 1999). This is further supported by presence of unique pharyngeal structures in adult *Hybognathus*, adapted primarily for filtering and masticating small food items (Hlohowskyj et al., 1989).

One of the goals of propagation efforts is to produce large numbers of healthy Rio Grande silvery minnows that will survive and reproduce after supplemental stocking in the middle Rio Grande and repatriation into other reaches of the Rio Grande and into the Pecos River (United States Fish and Wildlife Service, 2007). Results of this study will assist hatchery personnel at Dexter National Fish Hatchery and Technology Center and other hatcheries in development of cost-effective protocols to manage ponds for desirable phytoplankton, zooplankton, and macroinvertebrates, to determine optimum densities for stocking fish, and to minimize supplementation of formulated feed. As such, poor water quality and disease associated with overstocking and overfeeding of fish can be avoided. In addition, a greater understanding of diet of larval fish in hatchery ponds might provide insight into what further research on foraging habits of the Rio Grande silvery minnow is needed.

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