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AUTUMN SPAWNING AND OTHER REPRODUCTIVE NOTES ON LOACH MINNOW, A THREATENED CYPRINID FISH OF THE AMERICAN SOUTHWEST

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The loach minnow (*Tiaroga cobitis* Girard) is a small (<70 mm SL), darter-like, rare cyprinid fish endemic to the Gila River basin of Arizona and New Mexico and of Sonora, Mexico (Minckley, 1973, 1980). It is listed as threatened by the United States Fish and Wildlife Service (1986) and endangered by the states of Arizona and New Mexico. Reasons for its decline are cited as habitat alteration and establishment of non-native fishes (Minckley and Deacon, 1968). Data on its biology are therefore important in formulating management and protection strategies. Information on habitat use, diet, age, growth, and reproduction may be found in Minckley (1965, 1973), Schreiber (1978), Schreiber and Minckley (1981), Britt (1982), Rinne (1985, 1989), and Abarca (in press). The species has been considered a spring spawner (Britt, 1982; D. L. Propst et al., in litt.). We report autumn spawning of *T. cobitis,* heretofore unknown, and provide additional notes on its reproductive habits.

Collections and observations were made in Aravaipa Creek, a tributary of the San Pedro River in Arizona, which was described by Barber and Minckley (1966) and Bruns and Minckley (1980). On 25 September 1988, a short reach of Aravaipa Creek was temporarily diverted into an irrigation canal, drying a riffle upon which two loach minnow nest cavities were discovered. Prior to drying, depths on the riffle varied from 5 to 30 cm, and currents were turbulent and moderate in velocity; substrate was cobble, gravel, and coarse sand. Water temperature was 23°C between 0900 and 1030 h.

Entrances of both nest cavities faced downstream. Nest cavities were located beneath rocks embedded in the bottom on their upstream sides and slightly elevated on the downstream sides. The rocks were 8 to 10 cm thick and measured 16 by 12 and 18 by 14 cm on their lower surfaces. One cavity measured approximately 2.5 cm wide, 1.2 cm high, and 8.0 cm long; its walls and floor were of coarse sand with a scattering of pea-sized gravel. The second was destroyed when its overlying rock was removed.

Observations on nests of *T. cobitis* were made in the same area in March 1979, and 13 cavities that contained eggs were studied. All were beneath rocks (Table 1): 11 (84.6%) in shear zones at the edges of riffles, two (15.4%) within riffles. Ten cavities (76.2%) opened into eddying currents on the downstream sides, and three (23.8%) had entryways on the shoreward sides in the turbulent zone between "shooting" flow passing over a rock and eddying currents downstream. Cavities were longer than wide. All cavities were in fine to coarse sand; water depths over nest rocks averaged 10.8 cm (Table 1). Entrances varied in dimensions but were apparently narrower than cavity widths. The entrances typically collapsed as rocks were lifted and were unmeasurable.

Unconsolidated substrates in Aravaipa Creek are mobilized during floods to depths of centimeters or even meters, depending on the severity of a discharge event. After scour and deposition, sorting and compaction of stream-bed sediments occur over days and weeks, forming riffles armored by gravel and cobble embedded in underlying sand. The means by which nest cavities are formed in such substrates are unknown. Natural depressions and holes beneath rocks are dissimilar to those occupied by *T. cobitis,* so either some form of direct excavation or alteration of natural cavities must occur. In aquaria, loach minnows use their snouts to push aside gravel when searching for food as well as to enlarge cavities beneath rocks (S. P. Vives, pers. obser.).

Eggs were attached to a roof formed by the overlying rock and at or near the back of the cavity in the 15 nests examined. The eggs were in adherent, single-layered masses ($n = 9$) or pendulous, multilayered masses ($n = 6$) hanging toward the floor. All egg masses were longer than wide and had sand adhering to and incorporated within them on surfaces which contacted the cavity walls. The two collected in 1988 contained

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TABLE 1—Characteristics of 13 nest cavities and rocks forming ceilings of the cavities of *Tiaroga cobitis* in Aravaipa Creek, Arizona, 1979; means ± 1 *SD* and ranges in centimeters.

Nest characteristic	Mean	Range
Cavity		
Height	2.3 ± 0.9	1.8–4.7
Width	2.7 ± 1.0	2.0–5.7
Length	9.0 ± 1.1	6.4–10.7
Ceiling rock		
Thickness	7.8 ± 3.4	4.5–24.0
Least width	13.4 ± 4.4	8.3–26.3
Depth	10.8 ± 3.8	5.8–19.4

approximately 90 and 125 eggs, but counts were made after transport to aquaria, and some had already hatched. Each mass was uniform in coloration and developmental stage and appeared to be the result of a single spawning episode. Britt (1982) and D. L. Propst et al. (in litt.) reported average numbers of loach minnow eggs per rock as 63 (range of nine to 260, $n = 25$) and 52 (range of four to 250, $n = 80$), respectively.

In 1988, two loach minnows (50 to 60 mm standard length, SL), a male and female, both in breeding coloration (see Minckley, 1965), were within one nest cavity. A large male (approximately 65 mm SL), also in spawning colors, was alone in the other (D. A. Hendrickson, pers. comm.). It is possible that these fish took refuge as water levels receded during diversion and drying, but the pair persisted in returning to the nest site before and after the rock forming the cavity roof was removed from the nest site. No systematic search was made, but presence of numerous males in apparent breeding condition suggested that additional nests were also there.

Loach minnows have only recently been reported as hole-nesters (W. L. Minckley, in litt.; Britt, 1982), and nothing has been published on possible care-giving by either sex. D. L. Propst et al. (in litt.) noted males darting from beneath rocks that were later found to have attached eggs. In 1979, males were seen darting in and out of nine of 13 nests in Aravaipa Creek, and one nest cavity contained a pair of individuals. Both above-water and snorkel observations showed males resting on cavity floors with their heads oriented toward or protruding from entryways. Males sporadically fanned the egg mass with the pectoral fins, possibly aerating or cleaning the egg mass. Males often exited the cavity (up to several times per minute), re-entered head-first, and turned around to again position themselves at or near the entrance. On two occasions, an approach by another fish (speckled dace, *Rhinichthys osculus,* in one instance and a male loach minnow in the other) elicited flaring of the operculars and "flashing" of the brilliant red branchiostegal region and lower head, plus "threatening," side-to-side head movements. The male lunged from its cavity entrance for about half its body length, retreated, and lunged again, three and seven times, respectively, only to retire to the entryway when the interlopers passed.

Minckley (1973) reported loach minnows spawning in late winter and early spring in Arizona, with young-of-the-year taken in February and March. He later found (pers. obser.) the principal breeding period to last from March to June, with some reproduction in December, January, and February. Britt (1982) plotted gonosomatic indices peaking in April 1979 and with minimal values in August 1979 in the Gila River, New Mexico; eggs were found in April, May, and early June. In that same area, D. L. Propst et al. (in litt.) recorded a peak gonosomatic index and spawning in April 1984 and believed reproduction occurred over a 2- to 3-week period. No gonosomatic index was given for August, and small sample size resulted in equivocal data for September. These indications of spring spawning and a short, discrete reproductive season raise the questions of whether loach minnows spawn in autumn only under special circumstances, some proportion of the population regularly spawns in autumn after summer monsoons and flooding cease, or the species spawns continuously over summer and into autumn.

A bimodal pattern of winter rains, spring drought, summer monsoons, and autumn drought (Lowe, 1964) results in flooding in January and February and August and September in streams of the sub-tropical Sonoran Desert, separated by discharges in March to June and October to December that remain at or near base flows. Water temperatures are similar in spring and autumn, typically attaining >20°C in at least part of the habitat at almost any time of the year (W. L. Minckley, pers. obser.). Conditions for spawning may thus be as favorable in September as in spring. Summer floods have further been proposed as providing cues for reproductive activities by a number of southwestern fishes (Koster, 1957;

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John, 1963; Deacon and Minckley, 1974; Kepner, 1982; Mueller, 1984). Climatic conditions have been implicated in prolonging spawning or causing gonadal recrudescence in several species of minnow (Farringer et al., 1979; Lehtinen and Echelle, 1979; Lehtinen and Layzer, 1988). A number of small cyprinids are also known to have multiple clutches over a single season (Heins and Rabito, 1986). The discovery of *T. cobitis* nests during or shortly after a period of flooding (a spate occurred 12 days before the nests were located in September 1988; United States Geological Survey discharge data) suggests that some individuals, given correct conditions, may remain reproductively capable throughout summer. Additional study is needed to understand what factors serve as cues for autumn reproduction and whether or not it is a common phenomenon.

Our observations place this species in the guild of hole-nesting fishes with male guarding (Balon, 1975). Hole-nesting with male parental care is rare in North American minnows. Others using this reproductive mode are *Pimephales* sp. (Breder and Rosen, 1966), *Opsopeodus emiliae* (C. E. Johnston, pers. comm.), and *Codoma ornata* (Minckley and Vives, 1990). This breeding mode is more common in other groups of freshwater fishes, e.g., catfishes (Ictaluridae), darters (Percidae: Etheostomatinae) and sculpins (Cottidae; Breder and Rosen, 1966). Phylogenetic relationships are yet to be resolved, but *T. cobitis* is believed to be related to a "*Rhinichthys*-like" stock of western cyprinids (Minckley, 1980). No species of *Rhinichthys* is a demonstrated hole-nester, although males of some species excavate nest depressions on riffles and at least temporarily guard them (Breder and Rosen, 1966). The possibility also exists that female *T. cobitis* may play a guarding role, based on an observation in 1988 of both a male and female within, and repeatedly returning to, a nest site in which eggs were near hatching. If such is the case, the species is unique among cyprinids, since nest guarding by both sexes is known only in a few native freshwater North American fishes and not at all in cyprinids (Blumer, 1982). *Tiaroga cobitis* is, thus, a potentially important species for the study of the evolution of nesting and parental care.

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GEOGRAPHIC DISTRIBUTION OF THE CYTOTYPES OF *CHAETODIPUS NELSONI CANESCENS* (RODENTIA: HETEROMYIDAE)

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Chaetodipus recently was elevated to the generic status from within the genus *Perognathus,* based on morphological and biochemical data (Hafner and Hafner, 1983). However, relationship among and within species of *Chaetodipus* remain unresolved.

Chaetodipus nelsoni (Merriam, 1894) occurs from northern Jalisco, Mexico, to southern New Mexico. Two subspecies have been described: *C. n. canescens* (Osgood, 1900) which occurs from New Mexico to southern Coahuila and southern Chihuahua and *C. n. nelsoni* (Merriam, 1894) which occurs south of southern Coahuila and Chihuahua to northern Jalisco (Hall, 1981). Two cytotypes having diploid numbers (2n) of 48 and 46 have been described (Patton, 1970). These cytotypes both lie within the range of *C. n. canescens*: one (2n = 48) reported from the Davis Mountains and the other (2n = 46) from southern Coahuila. The number of autosomal arms or fundamental number (fn) of 58 is common to both cytotypes. The difference between the cytotypes is probably due to a Robertsonian event (Patton, 1970). This study was initiated to further delineate geographic ranges of the two cytotypes identified by Patton (1970).

Specimens were collected in Sherman live traps and karyotyped using techniques of Patton (1967), as modified by Robbins and Baker (1978). Voucher specimens were deposited in the Angelo State Vertebrate Natural History Collection. Localities and diploid numbers from this study and that of Patton (1970) were as follows: Texas, Val Verde Co., ¼ mi. N, ¼ mi. E Langtry, 2n = 48 (2 males), this study; Brewster Co., 55 mi. S Marathon, 2n = 48 (1 male), this study; Jeff

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