Physical habitat utilization of fish in a Sonoran Desert stream, Arizona, southwestern United States

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Abstract – The physical habitat utilization of 7 species of native fishes in a Sonoran Desert stream, Aravaipa Creek, Arizona is described. The species occupied significantly different depths and velocities of water. Longfin dace (*Agosia chrysogaster*), speckled dace (*Rhinichthys osculus*) and loach minnow (*Tiaroga cobitis*) used similar depths and velocities. Two of the three larger species (Sonora sucker [*Catostomus insignis*] and roundtail chub [*Gila robusta*]) used areas of greater depth and reduced velocity. Desert sucker (*Catostomus clarki*) grouped with loach minnow and speckled dace in the velocity of water occupied, but utilized deeper waters. The spikedace (*Meda fulgida*) aligned very closely with desert sucker in use of all 3 physical habitat variables.

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Un resumen en español se incluye debrás del texto principal de este articulo.

Introduction

Deserts are characterized by both the lack of precipitation and perennial streamflow and appear as unlikely environments for fish. Generally, the fish fauna of the western United States is depauperate, but many species in the West and the Southwest, specifically, are uniquely adapted to survive in hostile environments (Soltz & Naiman 1978; Naiman & Soltz 1981). These species have evolved strategies to survive cycles of flood and drought (Minckley & Meffe 1987) and changing hydrologies (Hubbs & Miller 1948). However, humans have superimposed marked changes in the hydrologic regime of the Southwest through dams, diversions and groundwater mining (Miller 1961; Rinne 1984; Rinne & Minckley 1991). The combination of natural cycles, alteration of habitat by humans and the introduction of non-native fish (Rinne in press) has caused a dramatic decline in this valuable resource (Johnson & Rinne 1982; Rinne & Minckley 1991; Minckley & Deacon 1991). Quantitative information on habitat requirements for many desert fishes are lacking. Most recovery plans for listed species acknowledge the importance of habitat protection.

Studies were initiated in spring 1983 to determine the physical habitat requirements of the loach minnow (*Tiaroga cobitis*) and spikedace (*Meda fulgida*) in streams they occupy in Arizona and New Mexico, including Aravaipa Creek. During sampling, locational and physical habitat data also were collected on the other 5 native species inhabiting this stream. This article describes the physical habitat utilization of these species in Aravaipa Creek.

Material and methods

Study area and fish

Aravaipa Creek is an Upper Sonoran Desert (Lowe 1964; Dunbier 1968; Brown 1982) stream in southeastern Arizona. It contains 7 (longfin dace, *Agosia chrysogaster*; speckled dace, *Rhinichthys osculus*; loach minnow, *T. cobitis*; spikedace, *M. fulgida*; Sonora sucker, *Catostomus insignis*; desert sucker, *Catostomus clarki*; and roundtail chub *Gila robusta*; see Fig. 1) of the 17 native fishes that historically inhabited the Gila River Basin, Arizona-New Mexico (Rinne & Minckley 1991). All 7 species are Cypriniforms; 2 are suckers and 5 are minnows, and the spikedace and loach minnow are listed as threatened species (United States Fish and Wildlife Service 1986a, 1986b).

Aravaipa Creek was described by Barber & Minckley (1966) and Minckley (1981). It contains an extensive database spanning 30 years. In general, it is a low-gradient (< 1%), narrow (3–5 m),

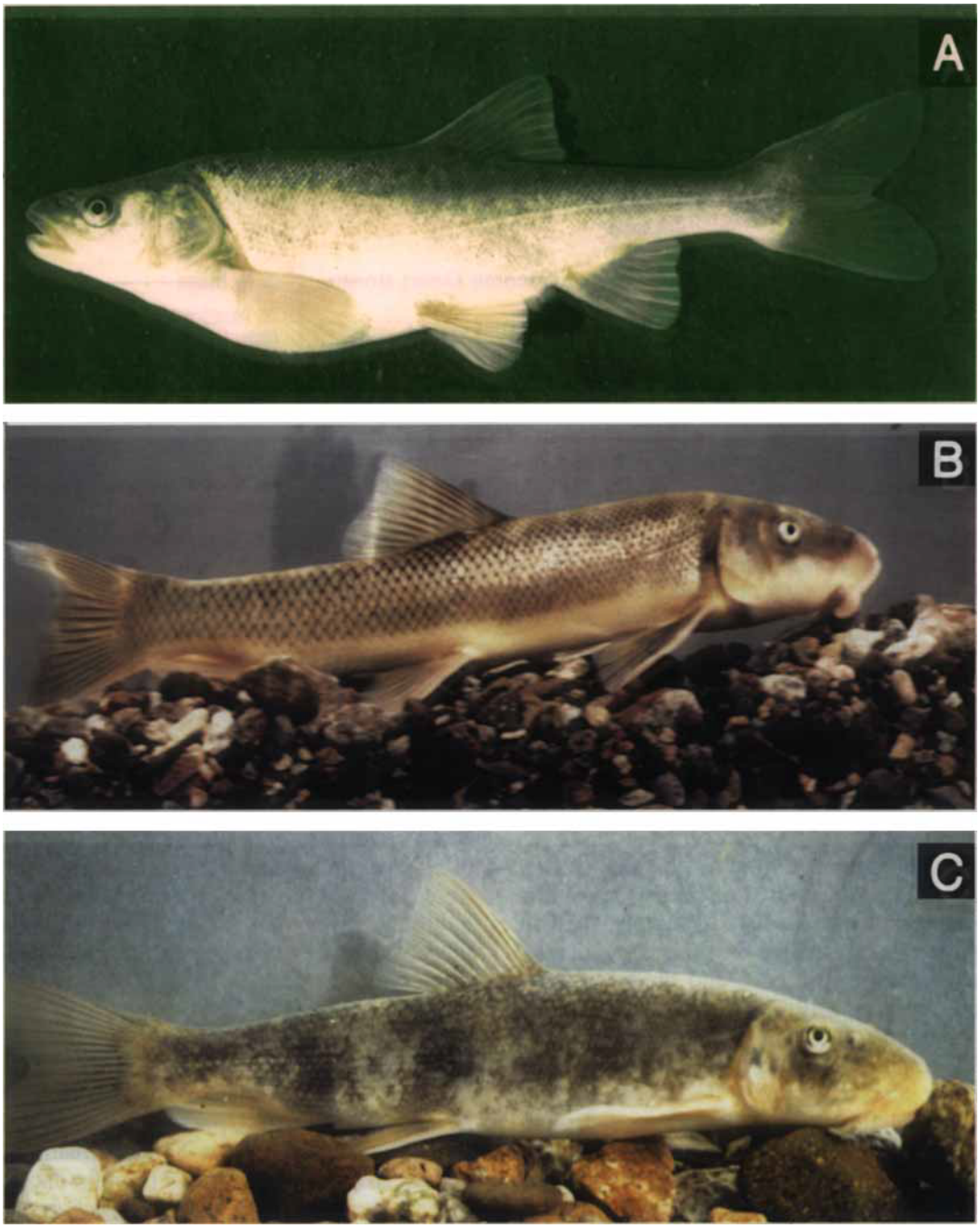

Fig. 1. Native fish of Aravaipa Creek. **A.** Roundtail chub (17.5 cm, TL). **B.** Sonora sucker (19.5 cm, TL). **C.** Desert sucker (21 cm, TL). **D.** Longfin dace (86 mm, TL). **E.** Speckled dace (67 mm, TL). **F.** Loach minnow (62 mm, TL). **G.** Spikedace (70 mm, TL).

often braided, hydrologically stable stream, with a gravel-pebble substrate. Modal discharge ranges between 0.5 and 1.0 $m^3 \cdot s^{-1}$, with greatest flows in winter months; however, late summer convectional storms are capable of producing sudden, periodically violent, flash floods. A central, canyon-bound reach separates more open, upper and lower reaches of the stream. The perennial reach of the stream lies within the riparian deciduous forest and woodland biome (Minckley & Brown 1982).

Methods

All data were collected in the upper reach of Aravaipa Creek. Habitat transects were randomly located and a maximum of 10 transects was sampled in a respective reach of stream. For detailed methods see Rinne (1985) and below.

Fish were immobilized by direct-current electrofishing gear and then captured by a 1-m-wide block seine positioned 1–2 m downstream (Rinne 1985).


D


E


F


G

To preclude significant displacement of individuals, transects were marked and sampling did not commence until 15 min had elapsed. To further reduce displacement, each fish sample was taken quickly; the net operator entered the stream first with the electrofishing gear operator immediately (1–2 s) following. Captured fish were enumerated, measured and returned alive to the streams. Only data on juvenile (≥ 1 years) and adult fish are reported here.

The physical habitat characteristics of the approximately 1- to 2-m^2 sample areas were measured using a meter transect method and habitat sampler (Rinne 1985). All areas were measured for habitat whether or not fish were present. With this apparatus, comprising 2 laboratory ring stands and a 1.2-m bar graduated into 5-cm intervals, one set (velocity, depth, substrate) of 21 measurements was made at each sample area. These 21 data points for each habitat variable were averaged prior to statistical analysis.

To better define the actual values of velocity habitation, the velocity was measured 5 cm above the substrate with a direct-reading flow meter. The depth was recorded with a metal meter rule modified by width reduction at the zero end to facilitate more accurate depth estimation among pebble/cobble substrate. Substrate, visually classified into one of 5 classes (sand, <2 mm; gravel, 3–16 mm; pebble, 17–64 mm; cobble, 65–256 mm; and boulder, >256 mm), was recorded at each 5-cm interval of the graduated bar. Classification was based on substrate class "hit" by the tip of modified meter rule. Substrate indices (Rinne 1985) were calculated (Table 1). Aravaipa Creek was sampled 5 times between April 1983 and July 1984 to include winter ($n=90$), spring ($n=94$) and summer ($n=142$) seasons. Because no difference in habitat use was detectable among seasons, the data were combined for analysis.

Results

The results of analysis of variance (ANOVA) indicated differences ($P<0.0001$, $F=32.5$, df $=273$) between depths occupied by the 7 species. Tukey's multiple range test indicated that the loach minnow and speckled and longfin dace used similar, shallower (12–16 cm) depths (Fig. 2). By comparison, the loach minnow and speckled dace were taken in the shallowest (14–15 cm) riffles of greater velocity (about 40 cm·s^{-1}) over pebble/cobble substrate. The longfin dace was also grouped with spikedace and desert sucker in deeper (16–22 cm) waters. The longfin dace and spikedace were most often captured in shallow (<20 cm) riffles characterized by moderate (35 cm·s^{-1}) velocities over pebble/gravel substrate (Table 1, Fig. 2).

The desert sucker occupied waters characterized by similar velocity and substrate as the loach minnow and speckled dace, but riffles in which individuals were captured were slightly deeper. In constrast, the roundtail chub and Sonoran sucker

Table 1. Comparative physical habitat utilization of Aravaipa Creek fish

Species	n	Depth (cm)	Velocity (cm·s^{-1})	Substrate class
longfin dace	136	16.5	34.0	3.1
Sonora sucker	61	30.5	24.4	2.7
roundtail chub	36	33.2	15.8	2.4
spikedace	96	19.4	34.5	3.1
desert sucker	163	20.5	38.1	3.4
speckled dace	83	15.6	38.5	3.5
loach minnow	156	14.2	41.3	3.7

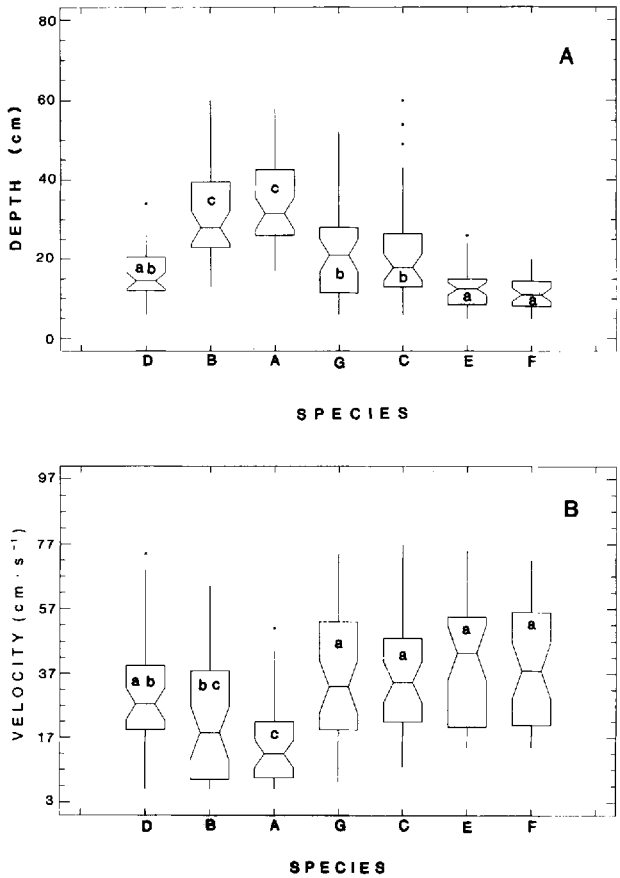

Fig. 2. Notched box plots of depths (**A**) and velocities (**B**) of water occupied by the 7 native fish (same letter notations as in Fig. 1) in Aravaipa Creek. Similarity of use is shown by degree of overlap of notches. Notches are 95% confidence limits of the median and, if non-overlapping, indicate significance at that level. Lines are the range of data, middle horizontal bars the medians, outer horizontal bars are upper and lower quartiles. Outlying values are indicated by solid dots. Small case letters indicate similarity of depth and velocity use as grouped by Tukey's multiple range test.

utilized pool areas of greater depth (30.0 cm), lower velocity (15–25 $cm \cdot s^{-1}$) and sand/gravel substrates. These two species occupied the deepest (32–34 cm) areas or pools in Aravaipa Creek.

Similar to depth analyses, the 7 species used waters of different velocities (ANOVA; $P < 0.0001$, $F = 10.6$, $df = 273$). The Sonora sucker and roundtails were combined to use the lowest velocity waters (15–22 $cm \cdot s^{-1}$) in pools. The longfin dace, spikedace, desert sucker, loach minnow and speckled dace were grouped (by Tukey's multiple range test) within waters of greater velocity (30–41 $cm \cdot s^{-1}$). The desert sucker and longfin dace were categorized by Tukey's test into an intermediate velocity group (22–30 $cm \cdot s^{-1}$; Fig. 2).

In summary, the loach minnow, speckled dace and desert sucker all used riffle habitat with swift, turbulent flows over gravel-pebble substrate. By comparison, the spikedace and longfin dace used riffle habitat with more smooth, laminar flow of moderate velocity over gravel-sand substrate. Finally, the Sonora sucker and roundtail chub occupied pool habitat characterized by slower to zero velocity and sand substrate.

Discussion

Physical habitat

The loach minnow and speckled dace mirrored each other in physical habitat utilization. Minckley (1973) subjectively characterized the loach minnow as inhabiting "gravelly riffles" and stated that speckled dace "usually live in water less than 0.5 m deep". Vives & Minckley (1991) reported loach minnow nests in substrate of "cobble, gravel, and coarse sand". Propst, Bestgen & Painter (1988) reported loach minnow spawning on "rocks" in a stream in New Mexico. Although no size was provided for "rocks", their descriptions would imply cobble (substrate index 4). Rinne (1989) suggested that the loach minnow utilized gravel to cobble substrates based on availability in streams across its range in Arizona and New Mexico. Mueller (1984) recorded speckled dace spawning in substrates 10–55 mm in size in the San Francisco River, New Mexico.

The two suckers were markedly separated spatially in Aravaipa Creek and, based on observations of the author and others, in other streams in the Southwest by water depth and velocity. The Sonora sucker more commonly inhabits pools characterized by slow current and smaller (sand/fine gravel) substrate materials. By comparison, the desert sucker occupied primarily riffle habitat characterized by laminar flow over pebble/gravel substrate. The desert sucker did use riffle habitat similar to the loach minnow and speckled dace.

The use of physical habitat by spikedace in Aravaipa Creek transcended all species but the pool-dwelling Sonora sucker and roundtail chub. The roundtail chub is secretive and is often found in pools along canyon walls, with undercuts sculptured by degradation processes inherent in periodic spates in this stream. Rinne (1991) reported spikedace as occupying slower-moving waters (25.0 $cm \cdot s^{-1}$) in streams across its geographic range in the Southwest. Generally, this threatened species of minnow occupied habitat based on availability. In Aravaipa Creek, the species is often found in eddying currents and "shear zones" between confluent riffles (Rinne 1991).

Biological and behavioral considerations

Differential physical habitat use by the 7 species in Aravaipa Creek could be explained by either their respective evolutionary histories or interspecific (competitive) interactions. Although no specific data of this nature were collected during this study, the abundance of literature on this stream and its fish suggest that both are tenable hypotheses.

For example, the speckled dace, loach minnow and desert sucker occupy essentially the same physical habitat in Aravaipa Creek. Cursory underwater observations in Aravaipa Creek suggest that the loach minnow is more of a substrate interstices dweller whereas the speckled dace characteristically occupies substrate surface to open water. Behaviorally, the loach minnow is similar in niche to the riffle-inhabiting darters of the eastern United States. The 3 species could segregate ecological niches in Aravaipa Creek and perhaps in other streams where they co-exist through differing food habits (Schreiber & Minckley 1981). The desert sucker feeds almost predominantly by scraping filamentous algae and diatoms from substrate materials in Aravaipa Creek (Rinne & Minckley 1991). The speckled dace is differentiated from the algae-scraping desert sucker by feeding primarily on invertebrates. The food habits of the speckled dace overlapped widely (80%) with the longfin dace, spikedace and loach minnow in Aravaipa Creek (Schreiber & Minckley 1981), but the first 2 species are separated by physical habitat use. Only the food habits of the roundtail chub overlapped less than 80% with loach minnow in Aravaipa.

The loach minnow fluctuates markedly in population numbers in this low desert stream (Minckley 1981). The overlap of both food habits and physical habitat use between this threatened minnow and the desert sucker and speckled dace suggest that density-independent factors such as space and perhaps food may be important in delimiting populations of this rare species.

The longfin dace has been suggested as "the most successful, highly adaptable, cyprinid fish native to the deserts of the American Southwest" (Minckley 1973). In Aravaipa Creek the longfin dace was most ubiquitous in terms of presence, distribution, food habits (Schreiber & Minckley 1981) and physical habitat use. Although it requires sand and fine to coarse gravel substrates to construct spawning nests (Minckley & Barber 1971; Kepner 1982; Rinne & Minckley 1991), it apparently is capable of utilizing a wide array of habitats across its geographic and altitudinal range. The longfin dace and spikedace occupied a similar physical habitat in Aravaipa Creek. The spikedace is primarily an invertebrate feeder compared with the mostly algae and occasional invertebrate diet of the longfin dace.

Finally, the roundtail chub and Sonora sucker occupy pools in Aravaipa Creek. Minckley (1973) characterized the Sonora sucker as a "pool dweller". This sucker shares these lentic habitats with the roundtail chub through feeding behavior and food resource use. The roundtail chub is the top carnivore in this low desert ecosystem, preying on larvae and juveniles of the other species as they occupy pools through innate life history characteristics or displacement by increased flows. Larger-sized food items found in the stomachs of the roundtail in Aravaipa substantiates its large predatory nature (Schreiber & Minckley 1981). The Sonora sucker occupies these same habitats but adults are removed from predation by size that may equal or exceed that of the chub. The Sonora sucker feeds on bottom-dwelling invertebrates residing in lentic habitats compared with the open water feeding behavior of the roundtail chub.

Conservation and management implications

Aravaipa Creek is "a jewel in the desert" in terms of natural riparian and fisheries resources. Over 95% of historic riparian-stream habitats in the Southwest have been lost through damming, diversion, agriculture, water mining and wood cutting (Minckley & Rinne 1982). This low desert stream not only has the greatest percentage of the historic native fish fauna of the Gila River Basin intact, but is accompanied by an extensive database spanning 30 years. It is protected, in part, by the U.S. Bureau of Land Management as a primitive area. Private land holdings by the Defenders of Wildlife also increase the security of this unique aquatic habitat. It also has instream flow designations to sustain surface waters for habitat for these native species.

Despite these apparent safety mechanisms, resource agencies must be ever viligant of this stream and its existing native fish fauna. This isolated canyon area must have its upstream aquifer protected. Overappropriation or use of the headward Sulphur Springs Valley aquifer must be guarded against. Maintenance of flow in this stream is highly critical because of the habitation of shallow riffle areas by 5 of the 7 fish species. In event of reduction in flow, intermittent surface flow could result. Only the chub and Sonora sucker would have a higher probability of surviving under such conditions. Natural cycles of abundance of the federally listed spikedace and loach minnow, combined with any significant loss of flow, could negatively impact or even extirpate these species from this stream.

Invasion of non-native fishes either from stock or domestic livestock watering tanks upstream or the Gila River downstream is an equal or greater threat. The red shiner (*Cyprinella lutrensis*) is present in the Gila River and has been suggested as a potential competitor for native species. Rinne (1991) demonstrated similarity of habitat use by the red shiner and spikedace. This species has recently (1990) been reported in the lower reaches of Aravaipa Creek.

Resumen

Este trabajo describe la utilización del habitat físico por siete especies de peces del río Aravaipa (Desierto de Sonora, Arizona). Las especies ocupan profundidades y velocidades de agua significativamente distintas. Tres especies, longfin dace (*Agosia chrysogaster*), speckled dace (*Rhinichthys osculus*) y loach minnow (*Tiaroga cobitis*) utilizan profundidades y velocidades similares. Dos de las tres especies de mayor tamaño (Sonora sucker [*Catostomus insignis*] y roundtail chub [*Gila robusta*]) utilizan areas de mayor profundidad y menor velocidad. Por otro lado, desert sucker (*Catostomus clarki*) se agrupa con loach minnow y speckled dace en la velocidad de agua ocupada pero utiliza aguas más profundas mientras que spikedace (*Meda fulgida*) se aproxima mucho a *C. clarki* en el uso de las tres variables del hábitat físico.

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