# EFFECTS OF SMALL GREEN SUNFISH (*LEPOMIS CYANELLUS*) ON RECRUITMENT OF GILA CHUB (*GILA INTERMEDIA*) IN SABINO CREEK, ARIZONA

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# EFFECTS OF SMALL GREEN SUNFISH (*LEPOMIS CYANELLUS*) ON RECRUITMENT OF GILA CHUB (*GILA INTERMEDIA*) IN SABINO CREEK, ARIZONA

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ABSTRACT—Young-of-year Gila chub (*Gila intermedia*) were abundant in upstream reaches of Sabino Creek, Arizona, devoid of green sunfish (*Lepomis cyanellus*), but were absent in downstream areas occupied by green sunfish. We examined potential reasons for this pattern by studying piscivory and habitat use of small green sunfish (<75 mm TL), the dominant size-class in Sabino Creek. In one piscivory experiment, we greatly reduced numbers of green sunfish prior to spawning by Gila chub, but there was no recruitment of young-of-year Gila chub. In a second experiment, three sizes-classes of green sunfish (45–55 mm TL, 62–65 mm TL, and 76–84 mm TL) readily consumed two size-classes of young-of-year Gila chub (15–20 mm TL and 21–25 mm TL) in instream enclosures. Green sunfish predation rates were strongly size-dependent, with larger size-classes consuming notably more young-of-year Gila chub than smaller size-classes. Shallow habitats may provide refugia for young-of-year Gila chub in the presence of large (>150 mm TL) green sunfish. However, even small green sunfish were highly predacious on young-of-year Gila chub, and our habitat study demonstrated that both taxa occupied similar mesohabitats. Co-occurrence of Gila chub and green sunfish in Sabino Creek seems to be the result of periodic downstream movement of adult Gila chub from reaches devoid of green sunfish. Young life stages of Gila chub apparently do not persist in sections of Sabino Creek occupied by green sunfish.

RESUMEN—Juveniles del año de charalito de Gila (*Gila intermedia*) abundaban río arriba de Sabino Creek, Arizona, carente de robalo verde (*Lepomis cyanellus*), pero no estaba río abajo en áreas ocupadas por *Lepomis cyanellus*. Analizamos las razones probables para este patrón al estudiar la piscivoría y el uso de hábitat de *Lepomis cyanellus* pequeños (<75 mm LT), la clase dominante en Sabino Creek. En un experimento de piscivoría, redujimos notablemente el número de *Lepomis cyanellus* antes del desove de *Gila intermedia*, pero no se observó reclutamiento de juveniles de *Gila intermedia*. En un segundo experimento, tres clases de tamaño (45–55 mm LT, 62–65 mm LT, y 76–84 mm LT) de *Lepomis cyanellus* consumieron fácilmente dos clases de tamaño (15–20 mm LT y 21–25 mm LT) de *Gila intermedia* en jaulas en el riachuelo. Las tasas de depredación por *Lepomis cyanellus* fueron altamente dependientes del tamaño, con las clases de tamaño grande consumiendo notablemente más juveniles del año de *Gila intermedia* que clases de tamaño pequeño. Los hábitats poco profundos pueden proporcionar refugio para los juveniles del año de *Gila intermedia* en presencia de *Lepomis cyanellus* grandes (>150 mm LT). Sin embargo, incluso pequeños *Lepomis cyanellus* depredaban altamente los juveniles del año de *Gila intermedia*, y nuestro estudio del hábitat demostró que ambos taxa ocupaban similares mesohábitats. La coexistencia de *Gila intermedia* y *Lepomis cyanellus* en Sabino Creek parece ser el resultado de los movimientos periódicos río abajo de los adultos de *Gila intermedia* desde áreas libres de *Lepomis cyanellus*. Las etapas juveniles de *Gila intermedia* aparentemente no persisten en las áreas de Sabino Creek ocupadas por *Lepomis cyanellus*.

Gila chub (*Gila intermedia*) is endemic to streams of the upper Gila River basin in New Mexico, Sonora, and Arizona (Rinne, 1976). This chub is most abundant in deep pools with extensive cover (Minckley, 1973; Griffith and Tiersch, 1989), and the loss of such conditions is associated with decreases in its range and abundance (Hendrickson and Minckley, 1984; Meffe, 1985). Gila chub is listed as endangered in New Mexico, is present in low densities in two ciénegas of the San Pedro River in Sonora, Mexico (Varela-Romero et al., 1992), and is listed as a species of special concern in Arizona. Gila chub currently occupies 23 isolated streams and ciénegas in central and southern Arizona, and all populations except one (Ciénega Creek, Pima and Santa Cruz counties) are considered imperiled (Weedman et al., 1996).

Green sunfish (*Lepomis cyanellus*) has successfully colonized areas far outside its native range (Lee, 1980), in part because of its ability to thrive in a wide variety of environments (Werner and Hall, 1979). Green sunfish is the most piscivorous member of the genus (Carlander, 1977; Werner, 1977) and has been implicated in the decline of several native fishes in the American Southwest (Marsh and Langhorst, 1988; Fausch and Bramblett, 1991; Lohr and Fausch, 1996). Although the piscivorous food habits of large green sunfish (≥150 mm total length, TL) are well documented (Carlander, 1977; Lemly, 1985; Lohr and Fausch, 1996), little is known regarding the level of piscivory by smaller green sunfish. The objectives of our study were to investigate piscivory and habitat use of small green sunfish (<75 mm TL) co-occurring with Gila chub.

METHODS AND MATERIALS—Sabino Creek, Pima Co., Arizona, originates in the Santa Catalina Mountains (elevation 2,440 m) and drains a canyon-bound area of 92 $km^2$ (United States Geological Survey, 1992). The study area was in the lower reaches of the stream (elevation <1,088 m) where green sunfish and Gila chub were the only fishes present. Stream width rarely exceeded 10 m, depth was generally <0.5 m, substrate ranged from sand to boulder-bedrock, and vascular aquatic vegetation was generally absent. Seasonally heavy rainfall, snow melt, and drought resulted in erratic annual flows. Mean discharge for 1905–1911, 1933–1974, and 1990–1992 was 0.37 $m^3$ $sec^{-1}$ with instantaneous discharge ranging from 0 to 219 $m^3$ $sec^{-1}$ (United States Geological Survey, 1992).

Sabino Creek flows over nine solid stone bridges (1.5 to 2.5 m high) that act as barriers to upstream movement by fish. Gila chub occurred from a natural waterfall (4 m high) about 1.6 km upstream from bridge 9 to a point 0.5 km downstream from bridge 1; green sunfish were present throughout the creek downstream from a waterfall barrier near bridge 9 (Fig. 1). Although green sunfish were stocked into the small lake created by Sabino Dam soon after its completion in 1938 (Lazaroff, 1993), this species was not present upstream from the bridges (also completed in the 1930s) until about 1982 (Dudley, 1995). Recent and heavy recreational use of Sabino Canyon may have resulted in the transport of green sunfish upstream from these bridges.

To study piscivory, we reduced the density of green sunfish in three experimental pools between bridges 3 and 9 from April to July 1994. Green sunfish were captured in minnow traps and by electrofishing with removal efforts lasting 6 to 9 days per pool. Recruitment of young-of-year Gila chub was monitored at least weekly throughout the study period by use of both bank and underwater observations in the three removal pools, in three control pools where green sunfish were not removed, and in pools containing only Gila chub.

A second experiment was conducted from 7 to 16 June 1994. Plastic fish enclosures (62 by 34 by 31 cm) were equipped with lids that provided shade and prevented escape of fish. Two panels (24 by 17 cm) were cut from each enclosure and the openings covered with 0.83-mm mesh aluminum screen that allowed free flow of water through the enclosure but blocked escape of fish. Enclosures were placed in Sabino Creek just upstream from bridge 8 and anchored at depths between 15 and 20 cm. One green sunfish and 10 young-of-year Gila chub were placed together in each trial. We tested three size-classes of green sunfish (45–55 mm TL, 62–65 mm TL, and 76–84 mm TL) and two size-classes of young-of-year Gila chub (15–20 mm TL and 21–25 mm TL). Each green sunfish and young-of-year Gila chub combination was replicated three times with the exception of the largest green sunfish and smallest Gila chub combination (two trials). Fish remained together for 15–18 h overnight, including dusk and dawn. Newly-captured green sunfish from between bridges 8 and 9 and young-of-year Gila chub from upstream of bridge 9 were used for each trial. We conducted three control trials with only young-of-year Gila chub in enclosures to determine if individuals were escaping or dying and decomposing overnight.

Habitat use and availability data were collected from May to July 1994 at 11 sites between 0.5 km downstream from bridge 1 and 1 km upstream from bridge 9. We marked locations of green sunfish and Gila chub with numbered washers while snorkeling slowly upstream. Water depth and velocity were measured at each fish location. Water velocity (0.6 column depth from surface) was measured with a Marsh-McBirney flow meter mounted on a top-set rod. Visual estimation using a modified Wentworth classification (Cummins, 1962) was used to classify predominant substrate (silt, sand, gravel, cobble, boulder, or bedrock) at each fish location. Habitat availability was estimated by measuring depth, velocity, and substrate size every 50 cm along at least four

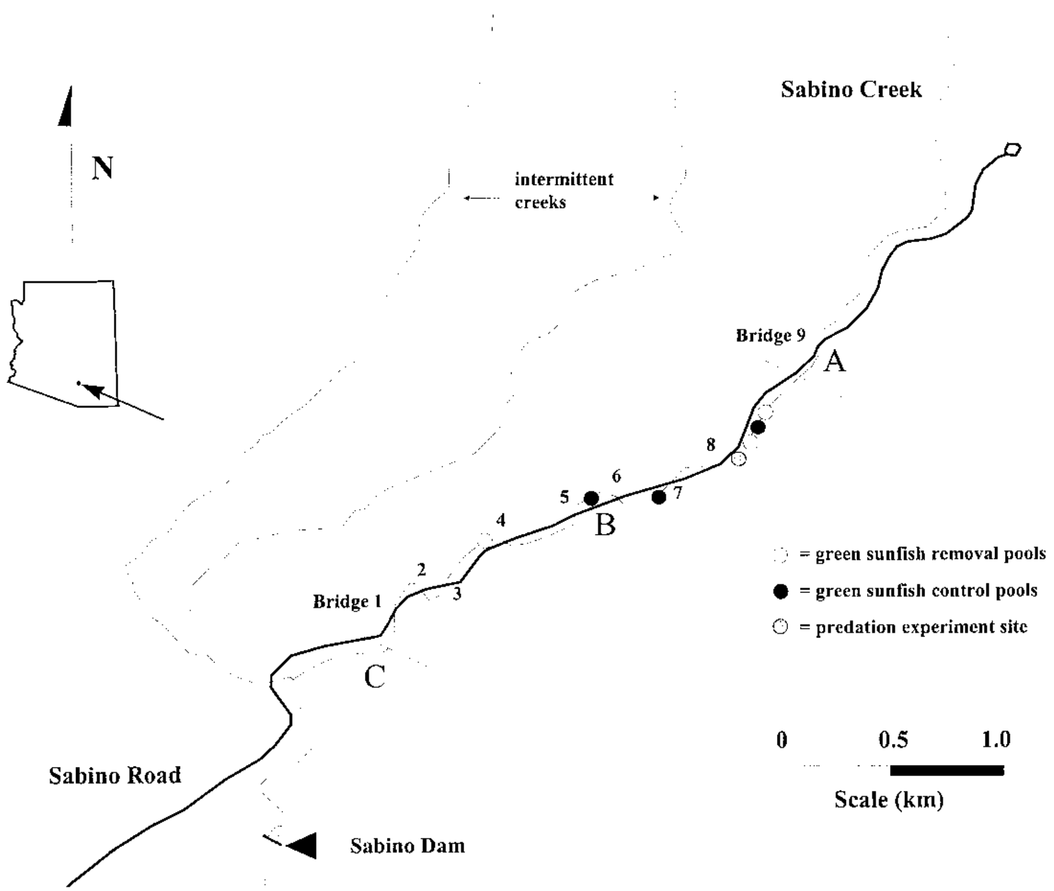


FIG. 1—Study area in Sabino Creek, Arizona (A = reach with Gila chub only, B = reach with Gila chub and green sunfish, C = reach with green sunfish only).

equally spaced transects across the stream, perpendicular to the direction of flow and ≤4 m apart.

Nonparametric statistics were used, due to nonnormal distribution of data, to test for differences between habitats available and occupied. A two-sample Mann-Whitney-Wilcoxon procedure (Zar, 1984), with chi-square approximation (NPAR1WAY procedure; SAS Institute Inc., 1989), was used to test for differences between water depth and velocity use and availability. A chi-square test of independence (Zar, 1984) was used to test for differences between substrate size use and availability.

RESULTS—Pools were connected by surface flow for the first 3 weeks of green sunfish removal experiments, but declining water levels isolated those pools (width <5 m and maximum depth <1 m) by late May 1994, precluding re-invasion by green sunfish. Nearly all green sunfish were removed after pools became isolated, making capture more feasible. We reduced the density of green sunfish by more than 90% in experimental pools (density before, $\bar{X} = 4.34 \pm 0.47/m^2$; density after, $\bar{X} = 0.31 \pm 0.07/m^2$) by removing a cumulative 1,626 individuals (Fig. 2). About 86% of the green sunfish removed from and all observed sunfish remaining in experimental pools were <75 mm TL. There was no recruitment of Gila chub in experimental pools or in control pools (green sunfish not removed) despite spawning behavior by adult Gila chub in those pools from May through July 1994. However, young-of-year Gila chub were abundant in reaches upstream from bridge 9 during this time. We found young-of-year green sunfish in two experimental pools, but did not find any in the third pool before it dried in late June 1994.

In the cage piscivory study, all three size-clas-

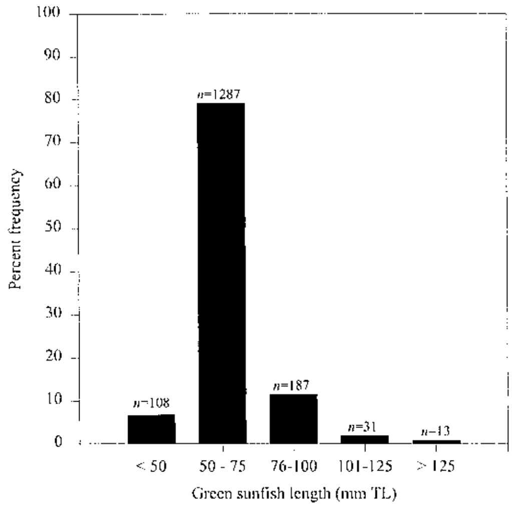


FIG. 2—Relative frequencies of green sunfish size-classes removed from three pools in Sabino Creek, Arizona ($n$ = number of individuals).

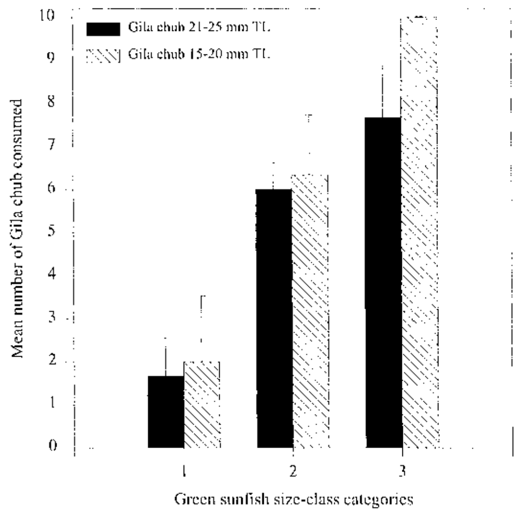


FIG. 3—Mean number (±1 *SE*) of young-of-year Gila chub, out of 10, consumed by green sunfish (category 1, range = 45–55 mm TL; category 2, range = 62–65 mm TL; category 3, range = 76–84 mm TL) in instream enclosures in Sabino Creek, Arizona.

ses of green sunfish consumed both size-classes of Gila chub (Fig. 3). In three of six trials, the smallest size-class of green sunfish did not consume Gila chub. Conversely, the two larger size-classes of green sunfish consumed between 60 and 100% of the 10 young-of-year Gila chub made available. No Gila chub escaped during the control trials and the only Gila chub that died was easily recognizable at the end of the trial.

Nearly all young-of-year Gila chub and small green sunfish (<75 mm TL) used depths ≤20 cm. Depths occupied by Gila chub and green sunfish were shallower ($\chi^2$ = 12.43; *df* = 1; $P < 0.001$ and $\chi^2$ = 19.23; *df* = 1; $P < 0.001$, respectively) than depths commonly available in pools. Although current was available, both taxa used shoreline areas with no measurable water velocity. Both Gila chub and green sunfish occurred over small substrates (e.g., sand) more frequently ($\chi^2$ = 22.86; *df* = 4; $P < 0.001$ and $\chi^2$ = 18.60; *df* = 4; $P < 0.001$, respectively) than expected based on substrate availability.

DISCUSSION—Smaller size-classes of nonindigenous predaceous fish, including green sunfish, may diminish recruitment of native fish by foraging efficiently in shallow nursery areas (Lemly, 1985; Marsh and Langhorst, 1988; Ruppert et al., 1993). Predation by green sunfish has been hypothesized to cause declines in the distribution and abundance of Gila chub (Minckley et al., 1977). However, previous studies did not provide direct evidence to corroborate the effect of predation by green sunfish on recruitment of Gila chub.

Gila chub were not recruited in areas of Sabino Creek occupied by green sunfish, despite a >90% experimental reduction in the density of green sunfish. Abundant young-of-year Gila chub were observed in the early 1980s (prior to the recent upstream presence of green sunfish) in areas currently containing green sunfish and no young-of-year Gila chub (D. W. Lazaroff, United States Forest Service, pers. comm.), thus physical factors apparently were not limiting to young-of-year Gila chub in these areas prior to the presence of green sunfish. This assumption was also supported by habitat studies conducted by Dudley (1995) which indicated no differences in available habitat in areas where young-of-year Gila chub were and were not present. Our predation experiments demonstrated that small green sunfish are capable of consuming young-of-year Gila chub; this could account for the absence of young life stages of Gila chub in areas where the species now co-occur. The vulnerability of young-of-year Gila chub to predation probably increased as pools in Sabino Creek became isolated during summer.

Despite the predatory impact of green sunfish, Gila chub continue to co-occur with green sunfish in downstream reaches of Sabino Creek. However, autumnal densities of Gila chub in areas downstream from bridge 8 were consistently $<0.1/m^2$ compared with autumnal densities of about $1.5/m^2$ in areas where Gila chub occurred alone (Dudley, 1995). Nearly all Gila chub occupying reaches of Sabino Creek with green sunfish were adults (i.e., individuals >100 mm TL), and Gila chub <40 mm TL were never found in areas with green sunfish. Larger Gila chub were probably relatively invulnerable to predation because of their size. Bestgen and Propst (1989) noted a similar pattern in Turkey Creek, New Mexico, where they found all life stages of roundtail chub (*Gila robusta*) in reaches immediately upstream from barrier falls that prevented invasion by smallmouth bass (*Micropterus dolomieu*) but found only a few adult roundtail chub and no smaller individuals downstream from the falls.

Co-occurrence of Gila chub and green sunfish in Sabino Creek, Arizona, is apparently maintained, in part, by periodic downstream movement of Gila chub from upstream areas devoid of green sunfish. Gila chub probably persist in Sabino Creek only because a waterfall barrier has prevented upstream movement of green sunfish above bridge 9. Introduction of green sunfish into upstream refugia, through transport by humans or passage above barriers, could cause the loss of young life-stages of Gila chub throughout Sabino Creek. Conservation of remaining populations of Gila chub in the American Southwest would benefit greatly from the prevention of further introductions of nonindigenous fishes, such as green sunfish, and their elimination from currently occupied areas.

The annual flow regime of Sabino Creek provides the opportunity for elimination of green sunfish from this system. During summer low-flow periods, when the stream consists mainly of isolated pools separated by long reaches of dry streambed, Gila chub could be removed temporarily and the pools treated with fish toxicant to eliminate green sunfish. Elimination of green sunfish from lower Sabino Creek could allow for reestablishment of young life stages of Gila chub in those areas.

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