

**Shortnose Gar (*Lepisosteus platostomus*) Foraging on Periodical Cicadas
(*Magicicada* spp.): Territorial Defense of Profitable Pool Positions**

ABSTRACT.—Shortnose gar foraged on spent periodical cicadas floating on the surface during a mass emergence of 13- and 17-y broods. The largest gar in each pool of an observed stream reach was positioned at the upstream pool lip. Ambient cicada drift was observed and increased feeding trials were used to investigate the observed pattern. The largest gar defended the upstream pool lip from other gar in the pool and consistently consumed more cicadas than any other single gar.

INTRODUCTION

The shortnose gar, *Lepisosteus platostomus*, is a common member of Missouri stream fish communities outside of the Ozarks (Pflieger, 1997), but has been rarely studied. Smaller than the wider ranging longnose gar, *L. osseus*, shortnose gar may reach up to 750–900 mm long with 500–700 mm typical of adults in northern Missouri. Pflieger (1997:55) describes the hunting activity of the gars as “stalking rather than active pursuit” the fish appearing “like a stick or log drifting slowly with the current.” Highly piscivorous, gars are also noted opportunists, often eating the most common prey fish available (Lagler *et al.*, 1942). Shortnose gar, however, consume more invertebrates than the other species of gar (Lagler *et al.*, 1942; Robison and Buchanan, 1988). Gar are conspicuous in streams of the Midwest, often breaking the surface to replace the air in their swimbladder, from which they can move oxygen into the bloodstream (Cross and Collins, 1995; Pflieger, 1997). Although they are readily observed, I am aware of no previous account of territory defense by a gar in natural (or artificial) conditions.

In 1998 Missouri experienced the emergence of large broods of both 13- and 17-y periodical cicadas, Homoptera: Cicadidae: *Magicicada* spp., for the first time since 1777 (Arduser, 1998). It is estimated that 1 acre of bottomland forest alone can produce 1.5 million cicadas (Arduser, 1998) during a large brood’s emergence. The synchronous emergence of the cicadas is thought to constitute “predator swamping,” where the number of emerging cicadas is so vast that predators cannot possibly consume them all (Williams *et al.*, 1993). During late May and early June 1998 central Missouri was littered with dying cicadas, a portion of which ended up drifting along the surface of streams. This study reports on the foraging of shortnose gar on these spent cicadas and the apparent defense of in-stream sites at which foraging opportunities are heightened.

MATERIALS AND METHODS

Study site.—Hinkson Creek is a fourth order stream that flows through Columbia, Missouri. The study area was 0.8 km of stream in southwest Columbia. This stream reach is characterized by a sand and gravel substrate and exposed eroding soil banks. Water clarity varied from 22.5- to 35-cm Secchi depth and water temperature was 23.65 C. Near base flow the wetted channel was 2–5 m across and pools were <1.5 m deep.

Initial observations.—In late May 1998 (during the cicada emergence) I observed groups (between 4 and 14, varying with pool size) of shortnose gar feeding on dying periodical cicadas in pools of Hinkson Creek. The gars appeared to be “patrolling” the surface, actively moving about searching for fallen prey. In every case the largest gar in any given pool was patrolling immediately below the upstream lip of the pool, whereas the smaller individuals seemed relegated to the remaining pool area.

Hypotheses.—(1) I tested the null hypothesis that the occupant of an upstream pool lip would consume drifting cicadas at rates equal to the other gar in the pool. (2) Given that the largest gar in a pool seemed to always occupy the upstream pool lip area, I tested the null hypothesis that this pattern was fortuitous, and not the result of active territory defense. (3) I tested the null hypothesis that prey presentation frequencies above ambient natural levels would yield no change in the within-pool, among-individual, dominance and positional hierarchies that seemed to prevail.

Study pool.—On 25 May 1998 I selected one pool in which to perform experimental field tests of these hypotheses. The study pool was approximately 8.5 m long and averaged 3.5 m across. The upstream lip of this pool was approximately 1.5 m wide; depth at the lip averaged 15 cm.

Feeding experiment.—I first monitored ambient undisturbed/nonmanipulated conditions for 90 min

to serve as a reference. During this period seven shortnose gar were observed in the pool. The largest gar was easily identified at all times because of its size [estimated at 550 mm total length (TL) by comparison to a measured piece of wood placed in the stream]. This largest gar only patrolled the upstream pool lip area. The remaining six gar were not able to be monitored as individuals because of the similarity in their sizes and their frequent convergence on prey items. It was possible, however, to sort them into two groups, three gars in each, mid- and small-sized (estimated at 450–475 mm and 375–400 mm TL, respectively). These mid- and small-sized gar occupied the upstream and downstream halves of the pool, respectively. All seven gar were always near the water surface, not easily disturbed and remained in the pool during the observation and feeding trials. During the 90 min of observation the natural rate of cicada drift and pattern of consumption among the gar was recorded.

Nearly spent or dead cicadas were collected ($n = 50$) and used to create a more prolific drift to present to the seven gar in the study pool. Feeding trials were conducted in succession during the evening hours (4:30–8:30 PM), the time when cicada activity seemed to peak. Cicadas were placed into the current 5 m upstream from the pool lip. Five trials of 10 cicadas each were presented to the gar at rates which markedly exceeded ambient.

Trial 1 presented one cicada every 10 seconds, for a total of 90 seconds.

Trial 2 (replicates A and B) presented a new cicada after the previous one had been captured by a gar. The trials varied in duration depending on the rate at which the gar located and captured the prey.

Trial 3 (replicates A and B) presented the next cicada after the gar had captured, consumed and re-oriented itself against the current and, in the case of the largest gar, had cleared any other gar from the pool lip area.

Further investigations.—A 7.5 m long, 13 mm mesh gill-net panel was set in a large pool approximately 0.4 km upstream from the study pool for 4 h to collect gar specimens for diet analysis. I also made subsequent visits to the reach to record observations on the numbers of gar in the study pool and the continuation of the constant surface patrol feeding behavior and upstream lip patrol by the largest gar of each pool.

RESULTS

Reference.—During the 90 min observation period 17 cicadas drifted into the pool from upstream and three cicadas fell directly into the pool from overhanging riparian vegetation. The largest gar occupied and slowly “patrolled” back and forth along the upstream lip of the pool the entire 90 minutes; no agonistic interactions were observed during this time. The largest gar consumed 11 (64.7%) of the 17 cicadas that drifted downstream. The three cicadas that fell directly into the pool were consumed by whichever of the remaining gar was closest to it. All of the six cicadas that passed through the largest gar’s territory were consumed by the three medium-sized gars occupying the upper half of the pool. No defense of territory was observed during this period. The largest gar missed cicadas by being at the opposite edge of the lip, away from the drifting cicada.

Trial 1.—The first feeding trial placed a cicada into the stream every 10 seconds; which exceeded the observed natural drift rate by a factor of 28.4. This augmentation resulted in increased feeding activity; by the time the fourth cicada reached the pool lip all six mid- and small-sized gar had moved upstream and invaded the territory of the largest gar. In response, the largest gar did attempt to defend its territory against the invading six, but was overwhelmed. The largest gar consumed only three (30%) of the cicadas during this trial (still double the 14% that might be expected from seven fish vying for 10 prey items). Individual gar did retreat from the dominant gar’s pursuit and bites at the body, but then quickly circled and rejoined the feeding.

Trial 2.—The second trial (repeated twice) differed from the first in that the next cicada was provided only after the previous cicada was captured by a gar. This reduction of the drift rate increased the largest gar’s foraging success to four (40%) and five (50%) for each trial, respectively. It was noted that once an individual captured a cicada it incurred handling time and associated costs, as the gar stopped holding position against the current and was displaced downstream an average 1.5 to 2.0 m while it manipulated and swallowed the prey. For the largest gar this allowed other individuals to infiltrate its territory (although not *en masse*, as in trial 1). This resulted in the largest gar chasing intruders from the upstream lip area. By the end of the second replicate of trial 2 the seven gar had

shifted their respective positions upstream, vacating the downstream half of the pool. This forced the largest gar upstream as well, into the faster and shallower water of the run/riffle habitat directly upstream of the study pool. Because the large gar seemed to be struggling unduly, trial 3 was delayed. The gar responded quickly and were soon (within 30 min) patrolling the same areas of the pool as during the 90 min observation period.

Trial 3.—The two replicates of trial 3 allowed the gar to fully consume the food items and reposition themselves before the next cicada was presented. Furthermore, when the largest gar consumed the cicada it was allowed time, if necessary, to clear its territory of intruders. In these two replicates the largest gar consumed seven (70%) and five (50%) of the cicadas, which on average (60%) is comparable to the observed percentage under ambient conditions.

During these feeding trials new gar behavior was observed. When an intruder slowly started to move upstream into the largest gar's territory the latter would orient itself perpendicular to the invading gar and drift downstream toward the intruder. Usually this was sufficient to cause the invader to turn and exit the area. If, however, the invader's snout made physical contact with the largest gar, the latter gar would immediately turn, snap at the body of the invader and proceed to chase it from the upstream pool lip area.

Further investigations.—The 4 h gill-net set in a separate pool captured three shortnose gar which were sacrificed and examined within 3 h of removal from the stream. The largest gar measured 741 mm TL and was a prespawn female carrying an estimated 16,442 eggs (estimated by extrapolation from five replicate 50 egg weighed subsamples), each approximately 2.5 mm in diameter. This female's stomach was empty; judging from the size of the egg mass, it would have experienced difficulty in moving large items through the gastrointestinal (GI) tract. The second gar was a male of 510 mm TL, slightly smaller than the dominant gar in the study pool. The GI tract of this gar contained cicadas exclusively—eight separate individuals were identified; as well as a large mass consisting of cicada pieces in advanced states of digestion. The third gar, also male, measured 430 mm TL. Its gut was also filled with cicadas—five separate individuals—accompanied again by a mass of cicada pieces as well as a terrestrial caterpillar, Order Lepidoptera.

DISCUSSION

Consumption rates.—Because the cicada consumption rates for the largest gar in the study pool exceeded those for the remaining individuals under all conditions, evidence did not suggest support of the null hypothesis that occupants of an upstream pool lip consume drifting cicadas at equal rates with the other pool occupants. Occupying the upstream lip of the pool was the most profitable position for gar feeding on cicadas. The largest gar's 64.7% consumption during the natural state assures that even if a second gar consumed all the remaining cicadas it would only be half that of the largest gar. The profitability of the upstream section of a pool has been discussed at length in salmonid ecology. Jenkins (1969) found that adult brown (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) both show preference for a site in the upstream area of a pool. Chinook salmon (*O. tshawytscha*) and steelhead (*O. mykiss*) were found to behave similarly in Idaho streams (Everest and Chapman, 1972). Trout and salmon tend to choose locations of moderate current located close to the faster water which contains the most drifting food items (Diana, 1995). Shortnose gar inhabit much lower gradient streams and no velocity within the observed pool itself caused the fish to actively fin-beat or struggle to maintain position. The run-riffle habitat directly upstream from the pool did, however, challenge the gar, forcing them to swim actively with large body undulations not used in the pool except when advancing toward a cicada or other gar. Fausch and White (1981) and Fausch (1984) studied salmonid position profitability and showed, under artificial stream conditions, that the fish holding the upstream site grew more rapidly. Furthermore, fish in successive positions down through the pool had successively slower growth rates. When an upstream trout was removed the next largest trout took its pool position, revealing a dominance hierarchy. The shortnose gar habitat occupation patterns I observed did not appear to be this structured.

Territorial defense.—Because the largest gar in the study pool occupied (ambient conditions) and aggressively defended (trials 2 and 3) the upstream pool lip area consistently, relegating the remaining gar to seemingly less profitable positions, the null hypothesis that this pattern of habitat use was simply a fortuitous occurrence was not supported. The perpendicular orientation of the largest gar toward

intruders was unique. Many fish perform side by side parallel "size assessments" in which the fins are erected (*e.g.*, in *Nannacara anomala*; see Jakobsson *et al.*, 1979; Krebs and Davies, 1993). The perpendicular orientation of the dominant gar toward the intruder may serve a similar ritualistic size assessment function.

Dominance hierarchy.—Because the increased prey presentation rates in the feeding experiments clearly caused changes in the activities and pool positions of the gar, support is lacking for the null hypothesis of no disruption of the pattern observed during the ambient drift.

Under natural conditions the largest gar exhibited no agonistic behavior. In contrast, during the feeding trials the largest gar repeatedly defended the upstream pool lip area; approaches by other gar were met with active chasing, regardless of whether a cicada was immediately present or not. The largest gar never left the upstream pool lip area to pursue a cicada that had drifted downstream, even when it would have had a good chance to consume it. These results suggest that a dominance hierarchy had been established and that it minimized continuing agonistic encounters (Diana, 1995). While the particular large gar observed during the feeding trials did not remain in the study pool (only smaller gars were observed during a visit 5 d later), it was not possible to determine if one of the three slightly smaller gars took its place.

An alternative explanation for the lack of agonistic encounters at the natural drift rate might be that under ambient conditions even the mid- and smaller-sized gar were receiving a favorable benefit to cost ratio, once aggression was negated (energy intake compared to cost of aggression).

Opportunism.—It was somewhat surprising that the shortnose gar were eating cicadas at all, since these fish are not considered surface-oriented foragers (Cross and Collins, 1995; Lagler *et al.*, 1942). Cicadas likely represent a novel prey item for gar, as their lifespan is similar in duration to the cicadas (Redmond, 1964; Johnson and Noltie, 1997). It is unlikely that a shortnose gar would experience two large emergences in one lifetime. In contrast, the Green and Yampa Rivers, Colorado and Utah, experience multiple mass migrations of Mormon crickets (*Anabrus simplex*) which swim across stream surfaces and are eaten by 11 fish species in that assemblage and represents a temporally available, plentiful, terrestrial, food source (Tyus and Minckley, 1988).

Results presented here raise the question whether dominant gars choose the most profitable pool position under more typical feeding conditions. Perhaps the advent of a plentiful surface resource elucidated the observed behavior, or perhaps the gar displayed an adaptive plasticity in feeding behavior. If the gar are displaying a behavioral shift in feeding, they would seem to be able to ascertain when to begin and when to stop defending a pool position. Salmonids are known to shift their behavior in this manner; Cunjack and Power (1986) observed non-aggressive aggregations of brown and brook trout (*Salvelinus fontinalis*) in thermal refugia during the non-actively foraging winter months. In apparent contrast to the observed shortnose gar, the largest brown trout seem to grow out of the pool position hierarchy, making longer (3.2–4.8 km) foraging runs at night, feeding chiefly on other fish (Jenkins, 1969).

The shortnose gar stopped surface patrolling before the end of the cicada mass die-off, although it had slowed noticeably. This may represent a case of economic resource defense (*sensu* Brown, 1964); once the gar are no longer profiting energy from the cicada food source they cease defending the territory which delivers the food items. Alternatively, because of seasonal timing, the gar may have migrated to staging areas to spawn (Johnson and Noltie, 1996) or quit feeding during the actual spawning period. Gar gather in large aggregations for 2–3 d periods to spawn, and several males often follow and flank a single female before and during the spawning act (Haase, 1969; Pflieger, 1997; Johnson, 1994).

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LITERATURE CITED

- ARDUSER, M. 1998. Coming soon to a forest near you: periodical cicadas. *Missouri Conservationist*, **59**:28.
BROWN, J. L. 1964. The evolution of diversity in avian territorial systems. *Wilson Bull.*, **76**:160–169.

- CROSS, F. B. AND J. T. COLLINS. 1995. Fishes in Kansas. University Press of Kansas, Lawrence, 315 p.
- CUNJACK, R. A. AND G. POWER. 1986. Winter habitat utilization by stream resident brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*). *Can. J. Fish. Aquat. Sci.*, **43**:1970–1981.
- DIANA, J. S. 1995. Biology and ecology of fishes. Biological Sciences Press, Cooper Publishing Group LLC, Carmel, Ind., 441 p.
- EVEREST, F. H. AND D. W. CHAPMAN. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. *J. Fish. Res. Bd. Can.*, **29**:91–100.
- FAUSCH, K. D. 1984. Profitable stream positions for salmonids: relating specific growth rate to net energy gain. *Can. J. Zool.*, **62**:441–451.
- AND R. J. WHITE. 1981. Competition between brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) for positions in a Michigan stream. *Can. J. Fish. Aquat. Sci.*, **38**:1220–1227.
- HAASE, B. L. 1969. An ecological life history of the longnose gar, *Lepisosteus osseus* (Linnaeus), in Lake Mendota and several other lakes of southern Wisconsin. Ph.D. Dissertation. Univ. of Wisconsin, Madison, 224 p.
- JAKOBSSON, S., T. RADESÄTER AND T. JÄRVI. 1979. On the fighting behaviour of *Nannacara anomala* (Pisces, Cichlidae) males. *Z. Tierpsychol.*, **49**:210–220.
- JENKINS, T. M., JR. 1969. Social structure, position choice and microdistribution of two trout species (*Salmo trutta* and *Salmo gairdneri*) resident in mountain streams. *Anim. Behav. Monogr.*, **2**:56–123.
- JOHNSON, B. L. 1994. Migration and population demographics of stream-spawning longnose gar (*Lepisosteus osseus*) in Missouri. M.S. Thesis. University of Missouri, Columbia, 140 p.
- AND D. B. NOLTIE. 1996. Migratory dynamics of stream-spawning longnose gar (*Lepisosteus osseus*). *Ecol. Freshwat. Fish*, **5**:97–107.
- AND ———. 1997. Demography, growth, and reproductive allocation in stream-spawning longnose gar. *Trans. Am. Fish. Soc.*, **126**:438–466.
- KREBS, J. R. AND N. B. DAVIES. 1993. An introduction to behavioural ecology. Blackwell Science Ltd., Oxford, England, 420 p.
- LAGLER, K. F., C. B. OBRECHT AND G. V. HARRY. 1942. The food habits of gars (*Lepisosteus* spp.) considered in relation to fish management. *Investigations of Indiana Lakes and Streams*, **2**:117–135.
- PFLIEGER, W. L. 1997. The fishes of Missouri. Missouri Department of Conservation, Jefferson City, 371 p.
- REDMOND, L. C. 1964. Ecology of the spotted gar (*Lepisosteus oculatus*) in southeastern Missouri. M.S. Thesis. University of Missouri, Columbia, 115 p.
- ROBISON, H. W. AND T. M. BUCHANAN. 1988. Fishes of Arkansas. University of Arkansas Press, Fayetteville, 536 p.
- TYUS, H. M. AND W. L. MINCKLEY. 1988. Migrating Mormon crickets *Anabrus simplex* Orthoptera Tettigoniidae as food for stream fishes. *Grt. Bsn. Nat.*, **48**:25–30.
- WILLIAMS, K. S., K. G. SMITH AND J. C. RIDDLE. 1993. Emergence of 13-Yr periodical cicadas *Cicadidae magicicada*. *Ecology*, **74**:1143–1152.
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