

Size-Specific Habitat Segregation and Intraspecific Interactions in Banded Sculpin (*Cottus carolinae*)

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Abstract - The purpose of this study was to investigate patterns of size-specific habitat use by banded sculpin (*Cottus carolinae*) in Brawley's Fork (Cumberland River Basin, TN). In a survey of three riffle and three pool habitats in a first order stream, adults were found almost exclusively in the pools, while young-of-the-year (YOY) were found almost exclusively in the riffles; juveniles were found in both habitat types. In-stream habitat-choice chambers were used to examine the velocity and depth preferences of juveniles and YOY sculpin and to determine the influence of adult presence on habitat selection of juveniles and YOY. Size-specific habitat segregation is not related to velocity differences between pool and riffle habitats. None of the size classes demonstrated a velocity preference, and the presence of adults did not affect the velocity use of the juveniles or YOY. However, adults showed a strong preference for deep habitat, YOY tended to prefer shallow habitat, both when alone and when in the presence of an adult, and juveniles strongly preferred deep habitat when no adult was present, but chose shallow habitat in the presence of an adult. The ontogenetic habitat shift from riffles to pools by juvenile sculpin may be explained by a change in predation risk as sculpin grow. The most significant predation risk to smaller sculpin is posed by larger piscivorous fish, which primarily inhabit deeper pool habitats. The greatest risk of predation for larger sculpin is posed by piscivorous mammals, reptiles, and birds, and this risk is minimized by the fishes' use of deeper pool habitats. The timing of this habitat shift appears to be a function of the density of adult sculpin, which are potential competitors/predators of the juvenile sculpin.

Introduction

Size-specific habitat segregation by stream fishes is a well-documented phenomenon (Mahon and Portt 1985, Mullen and Burton 1995, Schlosser 1982). Typically, larger fish are found more frequently in pools while smaller fish are found more frequently in riffles and raceways. Several studies show the significance of interspecific interactions, such as predation, in determining patterns of size-specific habitat use in fishes (e.g., Brown and Moyle 1991, Harvey 1991, Power 1984, Schlosser 1987); however, few studies have examined the role played by intraspecific interactions on these patterns. Freeman and Stouder (1989) report that depth preferences of juvenile mottled sculpin (*Cottus bairdi* Girard) are affected by the presence of adult conspecifics. Mullen and Burton (1998) found that intraspecific

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competition explains size-specific velocity segregation in longnose dace (*Rhinichthys cataractae* Valenciennes), but intraspecific interactions do not sufficiently explain size-specific segregation according to substrate size. Spina (2000) found insufficient evidence to conclude that intraspecific competition influenced size-specific habitat use patterns in rainbow trout (*Oncorhynchus mykiss* Walbaum).

Cottus Carolinae Gill, the banded sculpin, is a widespread benthic fish commonly found in variably sized streams in the Southeastern US (Etnier and Starnes 1993). Little is known about the basic ecology and habitat preference of this fish, and no information is available regarding size-specific habitat use. Banded sculpin are found in various velocities of water throughout life, but generally prefer riffle habitats of gravel and rubble (Etnier and Starnes 1993, Greenberg and Holtzman 1987). They are cryptic in nature and their coloring mimics the common substrate. Banded sculpin are primarily nocturnal ambush predators that seek refuge under rocks during the day (Greenberg and Holtzman 1987). The diet of small banded sculpin includes immature aquatic insects such as caddisflies, mayflies, and midge larvae; as adults, they switch to a diet dominated by crayfish, fish (including darters), large stoneflies, salamanders, and dobsonfly (*Corydalus*) (Etnier and Starnes 1993, Phillips and Kilambi 1996). Cannibalism in the congener *C. bairdi* has been demonstrated when fish size differs by 40 mm or more (Downhower and Brown 1979), and young-of-the-year (YOY) *C. carolinae* have been found in the stomach of one conspecific adult (D. Mullen, pers. observ.).

The purpose of this study was to add to knowledge of the basic ecology of *C. carolinae* by exploring size-specific habitat use and to examine the role of intraspecific interactions in affecting habitat choice of these fish. Two hypotheses were tested. The first hypothesis was that adults would occur more frequently in pool habitats and smaller sculpin would occur more frequently in riffle habitats. The second hypothesis was that adults would affect habitat selection of smaller sculpin.

Methods

Field-site description

This study was conducted during September and October 2003 in Brawley's Fork (Cumberland River Basin, Cannon County, TN), a large, spring-fed, first order stream. Summer discharge is about 0.5 m³ per second. The substrate is dominated by pebble (16–64 mm), cobble (64–256 mm), and boulder (> 256 mm), as defined by Cummins (1962), with a few limestone outcrops and root masses primarily associated with the pool margins.

Habitat survey

Three pools and three riffles were selected for an initial habitat survey. All habitats were separated by at least 5 m of stream channel. Within each

habitat, ten points were chosen haphazardly (by toss of a heavy object) for measurements of depth, velocity, and dominant substrate. Depth measurements were taken with a meter stick. Velocity measurements were taken at 0.6 total depth with a Swiffer Instruments Model 1700 Current Meter. The meter malfunctioned after six measurements in the first riffle, resulting in limited data for riffle velocities and no velocity data for the pools. Current was not visually apparent in the pools and was apparent in the riffles. The dominant substrate type at each point was determined by placing a 0.1-m² PVC frame on the stream bed and recording the substrate type that made up the largest portion of the area within the frame. Percent of each substrate type for each habitat was calculated from these data.

Size-specific habitat use was measured on the same day (between 8 and 10 a.m.) that the habitat measurements were taken. A Coffeltt Mark X Backpack electrofisher was used to sample the sculpin populations in each of the three riffles and pools. One pass was made through each habitat and all sculpin were measured for total length and released. Blocking seines were not used to prevent movement between habitats; however, all habitats were at least 5 m apart and sculpin were observed to seek shelter in the substrate rather than flee the area during electrofishing. These data ($n = 174$) were pooled (and supplemented with a sample of 136 sculpin from a nearby area of the stream containing a mixture of riffles and pools) to generate a size frequency distribution that was used to assign age classes. Size ranges were determined for young-of-the-year (YOY; 24–33 mm total length [TL]), juveniles (age 1–2 yrs., 34–68 mm TL) and adults (age 2+ yrs., > 68 mm TL).

Adult effects

Four in-stream habitat choice chambers were used to determine the effect of adult sculpin on habitat use (specifically depth and velocity preferences) of YOY and juvenile sculpin. Chambers were 1 m x 1 m square, 0.5 m deep, and consisted of a lumber frame with plywood sides and 6.35-mm hardware cloth covering the front, bottom and back, (Fig. 1) similar to those described

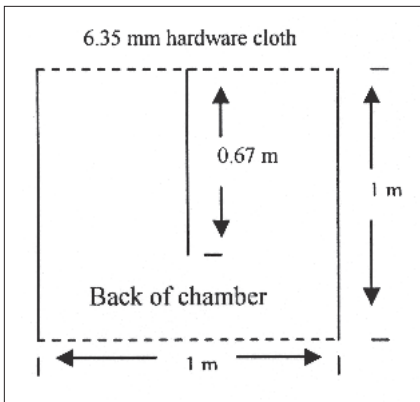


Figure 1. Design of habitat choice chambers. Chambers were situated in the stream so that water flowed through each channel from front to back.

by Freeman and Stouder (1989). Window screening was added over the hardware cloth before trials with YOY sculpin began to prevent escape of these small fish. A 0.67-m length of plywood extended 2/3 of the length down the middle of the chambers from the front towards the back. This divided the chamber into two equal sides with an open area in the back so sculpin could easily move between sides.

Velocity study

Chambers were placed in riffles for the velocity experiment. Two chambers were anchored in each of two riffles. Both sides of each chamber were filled with small cobble from the surrounding stream to cover the bottom, and one large rock (about 15 cm in diameter) was placed in the center of each side to serve as a refuge. Stream rocks were arranged in a V-shape pattern upstream of each chamber to direct the majority of the stream flow towards one side of the chamber, creating a fast-flowing side and a slow-flowing side. Velocity category (slow or fast) was assigned to sides of each chamber in an alternating pattern to eliminate directional bias, and the chambers were staggered within the riffles to avoid flow interference. The velocity in each side of each chamber was determined by measuring the time required for a small rubber ball to float from the front to the back of the chamber. A mean velocity from three trials was calculated for each side of each chamber following each observation.

The following procedure was conducted with adults (ranging from 89–140 mm TL) and juveniles (39–50 mm TL) and repeated with adults and YOY (26–33 mm TL). Sculpin of the appropriate age class were obtained by electrofishing and placed in the center of the downstream end of each chamber. Chambers 1 and 3 received one adult and 1 juvenile (or YOY) sculpin and chambers 2 and 4 received one juvenile (or YOY) sculpin each. All fish were allowed to acclimate in the chambers overnight prior to observation. Because chamber flow was affected by debris accumulating on the front screen, the debris was removed continuously for two hours prior to observations, which were conducted between the hours of 8 and 10 a.m. Initial observation attempts involved observing the fish from downstream of the chambers following the approach of Freeman and Stouder (1989); however, due to the cryptic nature of banded sculpin, no behavior or movement could be observed (the sculpin could not be located without disturbing the chambers). Subsequent observations involved separating the two sides with a removable partition, locating the individual fish, and recording the habitat (fast or slow) that each fish occupied. After the first observations, the adults were captured and moved to the even-numbered chambers and all fish were allowed to acclimate overnight. Observations were repeated as above, giving two observations of each juvenile (or YOY), one with an adult and one without an adult. After the second observation all fish were released and the process was repeated twice more to achieve 12 total observations with and without an adult for each age class of fish. Due to a flooding event and

inability to find YOY on a few occasions, additional observations were conducted to achieve a sample size close to 12. To aid in locating small sculpin, after the first two runs, all juvenile and YOY fish were anesthetized with MS 222 and a 5-cm length of blue and yellow thread was sewn through the caudal peduncle prior to introduction to the chambers. The four chambers varied with respect to average velocity and the fast velocities slowed as creek levels fell throughout the experiment.

Depth study

After the velocity studies, the four chambers were placed in one large pool for the depth study. Depth category (shallow or deep) was assigned in an alternating pattern from chamber 1 to chamber 4. The shallow side was filled with pebble and cobble from the stream bed giving a depth of ≈ 10 cm (range 7–15 cm over the course of the study). A slope behind the divider connected the shallow side to the deep side which had minimal covering of the same substrate and a depth of ≈ 30 cm (range 27–35 cm over the course of the study). Sculpin acquisition and placement in the chambers mirrored the velocity experiment. Observations were conducted between the hours of 7 and 10 AM following the overnight acclimation period. There was no two-hour chamber maintenance prior to the depth observations. Average depth of each side was calculated as the mean of three measurements, at the front, middle and back of each side after fish observations were completed. Three two-day runs were conducted with additional replicates to achieve a sample size near 12 for each age class. The juvenile and YOY fish were marked with colored thread as described previously.

Data analysis

Contingency table analysis was used to test for independence between size class and habitat use in the survey. The results of this analysis were used to make hypotheses about the effects of adults on the depth and velocity preference of juvenile and YOY sculpin, which were then tested using one-tailed Fisher exact tests. Chi-square goodness-of-fit analysis was used to test for adult depth and velocity preferences in the presence of a smaller conspecific. Observations from studies with juvenile and YOY sculpin were combined for this analysis and only the first observation made on each adult sculpin was used in order to ensure independence of data. This approach could potentially miss an adult effect on the smaller fish in cases where the adults were not selective of habitat but the smaller fish avoided the side of the chamber occupied by the adults. In cases where the adults were not selective of habitat, and the Fisher exact test failed to reject the null hypothesis, a chi-square goodness-of-fit test was used to determine if the smaller fish were avoiding the side of the chamber occupied by the adult. All goodness-of-fit tests were conducted using the Yates correction for continuity (Zar 1984).

Results

Habitat survey

Riffle and pool habitats differed by depth, velocity, and substrate size (Table 1). Since the mean velocity reported for the riffles represents a small sample size and water levels fell over the course of this study, the 0.99 m/sec riffle velocity and mean depths for the pool and riffle habitats reported in Table 1 are overestimates of the average velocities and depths in this section of Brawley’s Fork during the study period. Size-specific habitat use varied among age classes; YOY sculpin were found almost exclusively in the riffle habitats, adults were found almost exclusively in pool habitats, and juveniles were found in both habitats (Fig. 2).

Velocity Study

Velocity for the YOY treatments ranged from 0 to 0.09 m/s in the slow channels and from 0.19 to 0.51 m/s in the fast channels. In all cases, there was at least a 0.19 m/s difference between channels in any given chamber. Adults (10 of 13) tended to prefer the slow channels, although this trend was not significant (chi square = 2.67, P = 0.097). The adults did not significantly affect the velocity preference of YOY fish (Fig. 3). In the presence of an adult, YOY were more often found in the same velocity as the adult (67% of the observations), but this trend was not significant (chi-square = 0.44; P = 0.51). In the YOY-only treatment, fish with thread attached used both fast (3 observations) and slow habitats (3 observations), while YOY without thread utilized slow habitats (4 observations). This indicates that fish with a thread attached to their caudal peduncle were not prevented from using the

Table 1. Characteristics of 3 riffle and 3 pool habitats of Brawley’s Fork, Cannon County, TN, on 9/04/03.

Characteristic	Riffle	Pool
Mean depth	18.1 cm	47.5 cm
Mean velocity	0.99 m/sec	Equipment failure
Substrate*	53% C, 33% P, 14% B	23% C, 50% P, 10% B, 17% O
Total area	210 m ²	267 m ²

*C = cobble, P = pebble, B = boulder/outcrop, and O = others

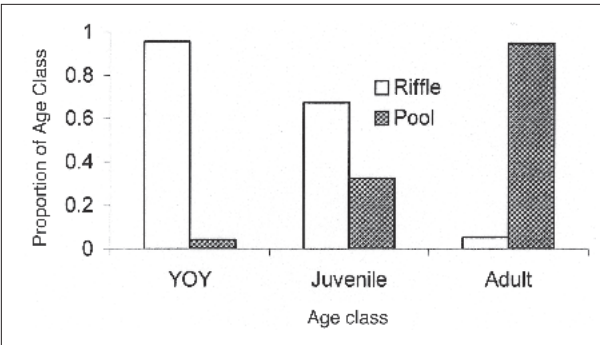


Figure 2. Proportional habitat use by age class of *C. caroliniae* (YOY N = 23, juvenile N = 132, adult N = 19). Contingency table analysis of independence between age class and habitat use was significant ($X^2 = 39.5, P < 0.001$).

fast-flowing water as a result of the thread. Habitat selection was not significantly influenced by the attachment of thread (Fisher exact test, $P = 0.17$).

Velocity measurements for juvenile treatments ranged from 0.04 to 0.19 m/s in the slow channel and from 0.24 to 0.86 m/s in the fast channel. In all cases there was at least a 0.2 m/s difference between velocity channels in the chambers. There was no significant effect of adults on juvenile habitat use (Fig. 3). In treatments where juveniles and adult sculpin were together, the juveniles were found as frequently in the same side of the chamber as the adult as they were in the opposite side (chi-square = 0.08; $P = 0.78$).

Depth Study

Depth for YOY treatments ranged from 0.07 to 0.12 m for the shallow channel and from 0.28 to 0.34 m for the deep channel. Adults were more frequently found in the deep channel of treatment cages; this trend was significant (chi square = 4.92; $P = 0.027$). Adults had no effect on depth choice of YOY fish (Fig. 4). The YOY sculpin showed a non-significant trend toward use of the shallow habitat both with and without adults.

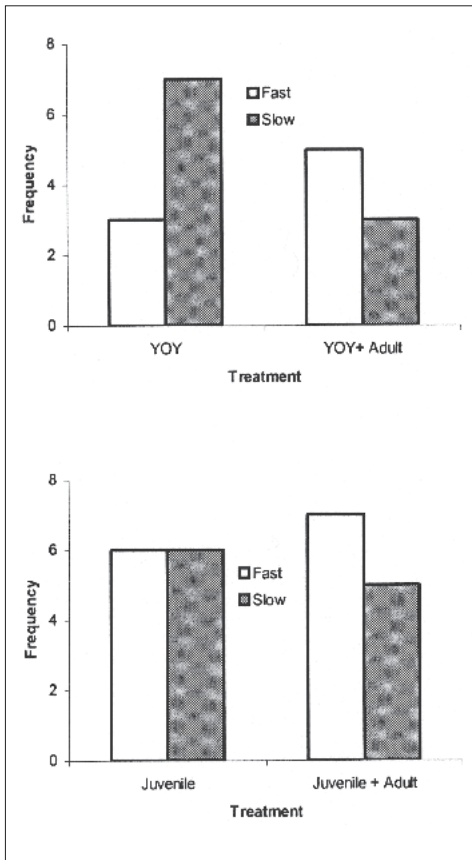


Figure 3. Young-of-the-year and juvenile velocity choice in the presence and absence of adults. There was no significant difference in velocity choice between treatments for YOY sculpin (Fisher exact test, $P = 0.18$) or juvenile sculpin (Fisher exact test, $P = 0.50$).

Depth measurements of treatment cages in the juvenile studies ranged from 0.09 to 0.15 m in the shallow channel and from 0.27 to 0.35 m in the deep channel. The presence of adults did affect the juveniles' depth choice; juvenile fish occurred more frequently in the deep channel when adults were absent and in the shallow channel when the adults were present (Fig. 4).

Discussion

Banded sculpin in Brawley's Fork exhibit a strong pattern of size-specific habitat segregation. Adults occur almost exclusively in the pool habitats, while YOY occur almost exclusively in the riffle habitat. Juvenile sculpin occupy both habitats. Since this study was conducted during the morning hours and others report that banded sculpin are nocturnal foragers (Greenberg and Holtzman 1987), the results and conclusions of this study reflect the refuge habitat use and not necessarily the feeding habitat use of banded sculpin.

The results from the habitat choice experiments indicate that adult sculpin have a strong preference for the deeper pool habitat and that the habitat

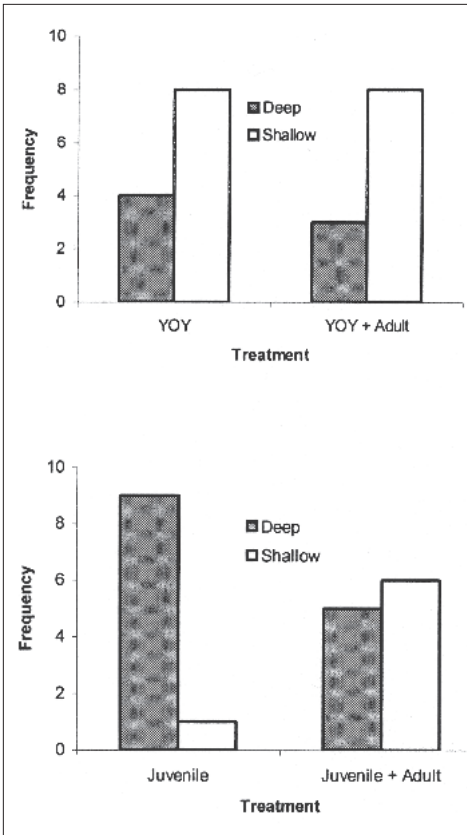


Figure 4. Young-of-the-year and juvenile depth choice in the presence and absence of adults. There was no significant difference in depth choice between treatments for YOY sculpin (Fisher exact test, $P = 0.55$), but there was a significant difference in depth choice between treatments for juvenile sculpin (Fisher exact test, $P = 0.043$).

preference of YOY sculpin is not affected by the presence of adults. The presence of adults does, however, affect the habitat preference of juveniles. Juveniles are more likely to use the pool habitat in the absence of adults. Adult banded sculpin may represent a potential predator to the juveniles and/or a potential competitor for refuges in the pools. In all cases, the size difference between the juveniles and adults used in this study exceeded the 40 mm TL size difference necessary for cannibalism in the mottled sculpin (Downhower and Brown 1979). Despite this effect, approximately 33% of juveniles captured in the habitat survey were found in the pool habitat. The ability of these juveniles to use the pool habitat despite the presence of adults is probably a function of juvenile size (comparison of the mean juvenile sizes between the two habitats indicates that the pool juveniles were larger than the riffle juveniles; 47.3 mm TL vs. 40.8 mm TL respectively, $t = 5.18$, $P < 0.0001$) and low adult densities. Only 19 adults were captured in the habitat survey, compared to 132 juveniles, despite the fact that the total area of pool habitat sampled was greater than the total riffle area (Table 1).

Pool/riffle habitat segregation between the age classes is probably not related to velocity differences between those habitats. All three age classes readily used the fast side of the habitat choice chambers, and although the adults tended to prefer the slow side, this tendency was not significant. The boulders and cobbles in the riffle habitat (and large cobble in the habitat choice chambers) provide refuge from the current for bottom oriented fish such as sculpin. Facey and Grossman (1990) report that mottled sculpin are able to hold position on the bottom of the stream against velocities less than 8 body lengths per second without incurring an energetic cost. In all but one case, the velocity in the fast side of the chamber was less than 8 times the body length of the adult sculpin.

Adult preference for the pool habitat is not likely a function of food availability. The major adult food items described by Etnier and Starnes (1993), Phillips and Kilambi (1996), and Starnes and Starnes (1985) such as small fish, including darters (Mahon and Portt 1985), small crayfish (Englund and Krupa 2000), and large stone flies (Gore and Judy 1981) are all more typically abundant in the shallower areas and riffles of stream. Adult sculpin may be using the pool habitat as a daytime refuge and foraging in the shallower habitats at night.

Predation risk from avian, mammalian, and/or reptilian predators is the most likely explanation for the depth preference of the adult sculpin. Despite their cryptic coloration, sculpin are susceptible to predation by piscivorous birds such as Belted Kingfishers (*Megaceryle alcyon* Linnaeus) and Great Blue Heron (*Ardea herodias* Linnaeus), both of which are common in the study area (D. Mullen, pers. observ.). Kingfishers forage effectively in stream riffles (Davis 1982) and are known to prey on sculpin (Salyer and Lagler 1946). Great Blue Heron forage in water less than 0.5 m deep (Short and Cooper 1985) and are known to prey on a similar species of sculpin (*Leptocottus armatus* Girard) (Krebs 1974). Lonzarich and Quinn (1995),

however, found that mortality (presumably from avian predators) of coast range sculpin (*Cottus aleoticus* Gilbert) in artificial pools was independent of depth. But the shallowest pools used in their study were 0.25 m deep, deeper than our deepest riffle measurement in this study. Mammalian predators, such as raccoons (*Procyon lotor* Linnaeus) are more effective at foraging on crayfish in shallow water (Englund and Krupa 2000) and also include fish in their diet. Northern Water Snakes (*Nerodia sipedon* Linnaeus) are also common in the study area (D. Mullen, pers. observ.) and feed on sculpin (Brown 1958). Unfortunately, there are no data available on foraging efficiency and depth for these snakes.

Young-of-the-year sculpin were absent from the pools in the habitat survey but demonstrated only a weak, non-significant preference for the shallow habitat in the experimental chambers (Fig. 4). Predation risk from pool dwelling piscivorous fish might explain this pattern. The pool habitats in the study stream contained numerous adult creek chub (*Semotilus atromaculatus* Rafinesque). Adult creek chub are predominantly piscivorous and prey on small fish between 10 and 60 mm TL (Moshenko and Gee 1973, Newsome and Gee 1978) and may represent an important threat to the YOY sculpin in the pools. In addition, many of the major food items of small banded sculpin listed by Etnier and Starnes (1993) and Phillips and Kilambi (1996), such as mayflies and caddisflies, prefer the faster velocities of the riffle habitat (Gore and Judy 1981).

As they grow, banded sculpin in Brawley's Fork undergo an ontogenetic niche shift from the shallow, riffle areas to the deeper, pool areas of the stream sometime between their first and second year of life. Since the primary food items of both small and large sculpin are typically more abundant in shallow water and riffles, this shift is probably best explained by a change in predation risk from piscivorous fish to avian and terrestrial predators as the sculpin grow. The timing of this habitat shift appears to be affected by the densities of adult sculpin, which are potential predators/competitors of the juvenile sculpin.

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Literature Cited

- Brown, E.E. 1958. Feeding habits of the Northern Water Snake, *Natrix sipedon sipedon* Linnaeus. *Zoologica* 43(3):55–71.
- Brown, L.R., and P.B. Moyle. 1991. Changes in habitat and microhabitat partitioning within an assemblage of stream fishes in response to predation by Sacramento squawfish (*Ptychocheilus grandis*). *Canadian Journal of Fisheries and Aquatic Sciences* 48:849–856.

- Cummins, K.W. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. *American Midland Naturalist* 67:477–504.
- Davis, W.J. 1982. Territory size of *Megaceryle alcyon* along a stream habitat. *Auk* 99:353–362.
- Downhower, J.F., and L. Brown. 1979. Seasonal changes in the social structure of a mottled sculpin (*Cottus bairdi*) population. *Animal Behavior* 115:711–715.
- Englund, G., and J.J. Krupa. 2000. Habitat use by crayfish in stream pools: Influence of predators, depth, and body size. *Freshwater Biology* 43(1):75–83.
- Etnier, D.A., and W.C. Starnes. 1993. *The Fishes of Tennessee*. University of Tennessee Press, Knoxville, TN. 681 pp.
- Facey, D.E., and G.D. Grossman. 1990. The metabolic costs of maintaining position for four North American stream fishes: Effects of season and velocity. *Physiological Zoology* 63:757–776.
- Freeman, M.C., and D.J. Stouder. 1989. Intraspecific interactions influence size specific depth distribution in *Cottus bairdi*. *Environmental Biology of Fishes* 24(3):231–236.
- Gore, J.A., and R.D. Judy. 1981. Predictive models of benthic macroinvertebrate density for use in instream flow studies and regulated flow management. *Canadian Journal of Fisheries and Aquatic Sciences* 38:1363–1370.
- Greenberg, L.A., and D.A. Holtzman. 1987. Microhabitat utilization, feeding periodicity, home range, and population size of the banded sculpin, *Cottus carolinae*. *Copeia* 1987(1):19–25.
- Harvey, B.C. 1991. Interactions among stream fishes: Predator-induced habitat shifts and larval survival. *Oecologia* 87:29–36.
- Krebs, J.R. 1974. Colonial nesting and social feeding as strategies for exploiting food resources in the Great Blue Heron (*Ardea herodias*). *Behaviour* 51:93–134.
- Lonzarich, D.G., and T.P. Quinn. 1995. Experimental evidence for the effect of depth and structure on the distribution, growth, and survival of stream fishes. *Canadian Journal of Zoology* 73: 2223–2230.
- Mahon, R., and C.B. Portt. 1985. Local size related segregation of fishes in streams. *Archives fur Hydrobiologia* 103:267–271.
- Moshenko, R.W., and J.H. Gee. 1973. Diet, time, and place of spawning, and environments occupied by creek chub (*Semotilus atromaculatus*) in the Mink River, Manitoba. *Journal of the Fisheries Research Board of Canada* 30:357–362.
- Mullen, D.M., and T.M. Burton. 1995. Size related habitat use by longnose dace (*Rhinichthys cataractae*). *American Midland Naturalist* 133:177–183.
- Mullen, D.M., and T.M. Burton. 1998. Experimental tests of competition in stream riffles between juvenile and adult longnose dace (*Rhinichthys cataractae*). *Canadian Journal of Zoology* 76:855–862.
- Newsome, G.E., and J.H. Gee. 1978. Preference and selection of prey by creek chub (*Semotilus atromaculatus*) inhabiting the Mink River, Manitoba. *Canadian Journal of Zoology* 56:2486–2497.
- Phillips, E.C., and R.V. Kilambi. 1996. Food habits of four benthic fish species (*Etheostoma spectabile*, *Percina caprodes*, *Noturus exilis*, *Cottus carolinae*) from Northwest Arkansas streams. *Southwestern Naturalist* 41:69–73.
- Power, M.E. 1984. Depth distribution of armored catfish: Predator induced resource avoidance? *Ecology* 65:523–528.
- Salyer, J.C., and K.F. Lagler. 1946. The Eastern Belted Kingfisher, *Megaceryle alcyon alcyon* (Linnaeus), in relation to fish management. *Transactions of the American Fisheries Society* 76:97–117.

- Schlosser, I.J. 1982. Fish community structure and function along two habitat gradients in a headwater stream. *Ecological Monographs* 52:395–414.
- Schlosser, I.J. 1987. The role of predation in age- and size-related habitat use by stream fishes. *Ecology* 68:651–659.
- Short, H.L., and R.J. Cooper. 1985. Habitat suitability index models: Great Blue Heron. US Fish and Wildlife Service Biological Report No. 82 (10.99). 23pp.
- Spina, A.P. 2000. Habitat partitioning in a patchy environment: Considering the role of intraspecific competition. *Environmental Biology of Fishes* 57(4):393–400.
- Starnes, L.B., and W.B. Starnes. 1985. Ecology and life history of the mountain madtom, *Noturus eleutherus* (Pisces: Ictaluridae). *American Midland Naturalist* 114:331–341.
- Zar, J.H. 1984. *Biostatistical Analysis*, 2nd Edition. Prentice Hall, Englewood Cliffs, NJ. 718 pp.