12-2010

Population Characteristics of Central Stonerollers in Iowa Streams

Scott M. Bisping

Jesse R. Fischer

Michael C. Quist

Andrew J. Schaefer

The Prairie Naturalist 42(3/4):109–115; 2010

Population Characteristics of Central Stonerollers in Iowa Streams

SCOTT M. BISPING, JESSE R. FISCHER[1], MICHAEL C. QUIST, AND ANDREW J. SCHAEFER

Department of Natural Resource Ecology and Management, Iowa State University, Ames, IA USA, 50011

ABSTRACT The central stoneroller (*Campostoma anomalum*) is a herbivore that can have substantial effects on algal communities, nutrient dynamics, and energy flow in streams. Despite its importance in lotic ecosystems, little is known about its population dynamics in streams of the Great Plains. Our objective was to describe age structure, age-specific mortality, and growth rates of central stonerollers in three Iowa streams. We sampled fish from 41 reaches during June–August 2007. We sampled 466 central stonerollers, of which we aged 192. Fish varied in length from 32 to 130 mm and in age from age 0 to 4 years. Over 75% of the central stonerollers were age 2 or younger. Total annual mortality varied from 53.5 to 65.5% across the 3 streams and averaged 64.4% for all streams. Age-specific mortality was approximately 35% between ages 1 and 2, but increased to approximately 50% and above for older ages. Central stonerollers grew approximately 75 mm during their first year and approximately 10–20 mm per year in subsequent years. Size structure, age structure, mortality, and growth were similar to other central stoneroller populations in the Great Plains. Our results provide important insight for the management and conservation of streams, and provide a foundation for future research on factors influencing small-bodied, nongame fishes in stream ecosystems.

KEY WORDS central stoneroller, fish population dynamics, growth, Iowa, mortality

The central stoneroller (*Campostoma anomalum*) is a widely-distributed species in North America; it occurs throughout central and eastern regions of the United States and Canada (Lee et al. 1980). Central stonerollers are often most abundant in small streams with moderate to high channel gradients, well-defined riffle habitats with large rocky substrate (e.g., gravel, cobble), and permanent flow (Pflieger 1997). The trophic ecology of central stoneroller has been extensively studied. Central stonerollers are herbivorous and may consume up to 27% of their body weight in benthic algae per day (Fowler and Taber 1985). In addition to algae, a variety of food items often are consumed by central stonerollers. For instance, Evans-White et al. (2003) found that algae contributed most (47%) to the diet of central stonerollers in a Kansas stream, followed by detritus (30%), animal matter (21%), and terrestrial vegetation (2%).

Most studies on central stonerollers have primarily focused on their role in aquatic food webs. Specifically, central stonerollers can significantly reduce algal biomass (Power et al. 1985, Stewart 1987, Power et al. 1988, Gelwick and Matthews 1992), decrease algal spatial and temporal variability (Gelwick and Matthews 1997), and may alter algal community composition (Power and Matthews 1983, Power et al. 1988). Consequently, the central stoneroller is a primary driver of ecosystem processes (e.g., benthic community composition, nutrient and energy dynamics) in streams where they occur (Power et al. 1988, Matthews 1998). Despite their importance to the structure and function of lotic food webs, little research has been conducted on their population dynamics.

Understanding the population dynamics of central stonerollers is critical for effective management and conservation, and for predicting the potential consequences of biotic interactions (e.g., introduction of nonnative species) and environmental alterations (e.g., climate change, changes in land use). In particular, growth and mortality are important population-level dynamics that influence the structure and function of central stoneroller populations. Growth provides an integrated evaluation of environmental conditions (e.g., prey availability, thermal conditions, habitat suitability) and genetic factors, and has direct and indirect effects on recruitment dynamics, trophic interactions, and mortality (DeVries and Frie 1996). An understanding of mortality also is critical for management and conservation. Mortality results from factors such as predation (Brant et al. 1987), disease (Post 1987), and starvation (Chick and Van Den Avyle 1999). As such, knowledge of mortality rates is critical for understanding the influence of abiotic and biotic mechanisms on central stoneroller populations. Due to their importance in stream ecosystems and lack of information on their population dynamics, our objective was to describe growth and mortality of central stonerollers in three Iowa streams.

STUDY AREA

Watershed areas of all study streams were approximately 70 km^2 and typical of most streams in central Iowa. Land use in the watersheds was dominated by row crop agriculture (Isenhart et al. 1997). Bear Creek has undergone extensive riparian habitat enhancement since 1990; primarily plantings of multi-species riparian buffers along more than 23 km of stream (see Schultz et al. 1995 and Isenhart et al. 1997 for a detailed description of conservation buffer practices on Bear Creek). Adjacent

[1] Corresponding author email address: fischer@iastate.edu

watersheds and streams, including Keigley Branch and Long Dick Creek, were nearly identical to Bear Creek except that they were not the focus of riparian restoration prior to (since 1990) or during our study. Despite focused restoration on portions of Bear Creek, all 3 streams were characterized by natural and artificial riparian buffers with similar instream physical habitat (see Fischer et al. 2010).

METHODS

We sampled central stonerollers from 41 reaches in three streams located in central Iowa during June–August 2007; we sampled 20 reaches from Bear Creek, 10 reaches from Keigley Branch, and 11 reaches from Long Dick Creek. We sampled central stonerollers using a Smith-Root Model LR-20 backpack-mounted DC electrofisher (Smith-Root, Inc., Vancouver, Washington, USA). At each reach, we made 1 upstream pass with 2 netters using dip nets with 6-mm ace mesh. Sample reach length was 35 times the mean stream width (Lyons 1992; Simonson et al. 1994) or 300 m, whichever was longer. We measured central stonerollers to the nearest mm (total length) and removed asterisci otoliths from 10 fish per cm length group for age and growth analysis. We placed otoliths in microcentrifuge tubes and subsequently transported samples to the Iowa State University fisheries laboratory for processing. Once in the laboratory, we mounted otoliths on glass slides (i.e., convex or distal-side facing up) with thermoplastic cement and read samples under a microscope equipped with a digital camera linked to an image analysis system (Image-Pro Plus, Media Cybernetics, Silver Spring, Maryland, USA). We aged otoliths using a single reader; however, we read a random subsample of otoliths (n = 30) using 2 readers to assess accuracy of our aging technique. We measured annuli and radii from all otoliths using the image analysis system. We estimated mean back-calculated lengths at age (MBCL) using the Dahl-Lea method (DeVries and Frie 1996): $L_i = L_c \times (S_i/S_c)$, where L_i was the length at annulus i, L_c was the length at capture, S_i was the otolith radius at annulus i, and S_c was the otolith radius at capture.

We compared size structure of central stonerollers using a Kolmogrov-Smirnov two-sample test (Neumann and Allen 2007). We estimated age structure of central stoneroller populations at each reach using an age-length key (DeVries and Frie 1996; Bettoli and Miranda 2001). We estimated total annual mortality using a weighted catch curve (Miranda and Bettoli 2007). We estimated mortality for each stream and also by pooling age structure data across streams (Ricker 1975; Miranda and Bettoli 2007). We estimated age-specific mortality rates (e.g., mortality between age 1 and age 2, mortality between age 2 and age 3) by calculating changes in the relative frequency of individuals in successive age groups for each reach (Ricker 1975). We estimated average MBCL at age and age-specific mortality rate across reaches for each stream. The standard error and 95% confidence interval for MBCL at age were estimated using pooled variance. Our study was conducted with the approval of Iowa State University's Institutional Animal Care and Use Committee (project identification #4-06-6109-I).

RESULTS

Central stonerollers varied in length from 32 to 130 mm (n = 466) across all reaches and length-frequency distributions were similar among streams (Fig. 1). Specifically, central stoneroller length distributions were similar between Bear Creek and Kiegley Branch (Kolmogrov-Smirnov, D_{max} = 0.18, P = 0.31, n = 52 and 74), Bear Creek and Long Dick Creek (K-S, D_{max} = 0.14, P = 0.59, n = 52 and 66), Kiegley Branch and Long Dick Creek (K-S, D_{max} = 0.10, P = 0.87, n = 74 and 66). Age and growth were estimated from a subsample of 192 central stonerollers, including 52 from Bear Creek, 74 from Keigley Branch, and 66 from Long Dick Creek. Central stonerollers varied in age from 0 to 4 years (Fig. 2). No age-0 fish were collected from Keigley Branch, a single age-0 fish was sampled in Bear Creek, and 13 were sampled from Long Dick Creek. Only 7 age-4 central stonerollers were sampled; 2 from Keigley Branch and 5 from Long Dick Creek. Approximately 75% of the fish were age 1 and 2 across all streams.

Total annual mortality of age-1 and older central stonerollers was 50.3% in Bear Creek, 55.0% in Keigley Branch, and 61.7% in Long Dick Creek. When streams were pooled, total annual mortality was 64.4%. Age-specific mortality averaged approximately 35% between age 1 and 2 for all streams (Fig. 2). Age-specific mortality increased to 50% between age 2 to 3 across all streams and approximately 85% for age 3–4 for Keigley Branch and Long Dick Creek. Mean back-calculated length at age was similar across streams (Table 1). Growth was fastest during the first year of life where fish grew approximately 75 mm. Annual growth increments declined thereafter to approximately 20 mm per year for all but the oldest central stonerollers.

DISCUSSION

Use of population characteristics (i.e., age, growth, mortality) obtained from age determination has been critical to the management and conservation of sport fishes and large-bodied species of conservation concern. However, small-bodied fish research has commonly focused on assemblage characteristics (e.g., richness, composition) due to lack of techniques or the high cost and labor intensive methods associated with collecting age data from individual fish. As such, the description of small-bodied fish population characteristics is important to understanding stream ecosystems. Our study demonstrated that central stoneroller size structure, mortality, growth were similar to other Great Plains populations.

Reported maximum lengths of central stonerollers vary considerably among studies. For instance, Lennon and Parker (1960) reported that the maximum length of central stonerollers in streams from Great Smoky Mountains National Park (GSMNP) was 226 mm. Moreover, Gunning and Lewis (1956) reported a maximum length of approximately 170 mm in Roaring Springs Creek, Illinois. Our results are most similar to those of Quist and Guy (2001) and Evans-White et al. (2003), who reported a maximum length of approximately 140 mm in Kansas streams.

Table 1. Mean (SE, 95% confidence limits) back-calculated length (mm) at age of central stonerollers sampled from three streams in central Iowa, 2007.

		Age (years)			
Stream	*n*	1	2	3	4
Bear Creek	52	77 (1.8, 74–81)	97 (1.8, 93–100)	112 (2.2, 107–116)	
Keigley Branch	74	74 (2.5, 69–79)	95 (2.1, 91–99)	113 (2.3, 108–117)	120 (7.3, 101–138)
Long Dick Creek	66	75 (1.3, 72–78)	95 (1.7, 92–98)	103 (1.6, 100–106)	108 (4.6, 97–121)

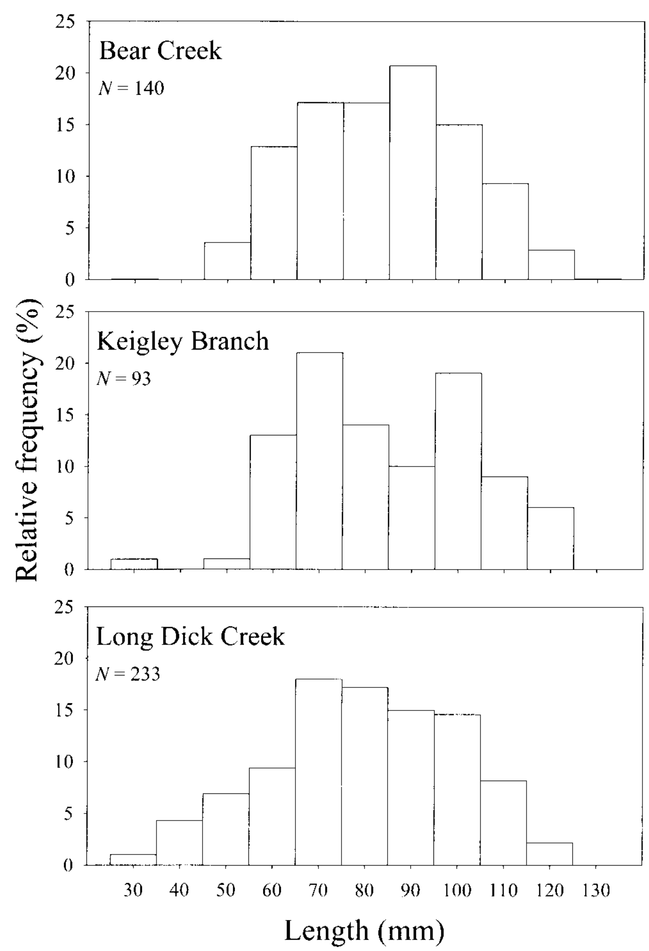

Figure 1. Length-frequency distributions of central stonerollers sampled from three streams in central Iowa, 2007.

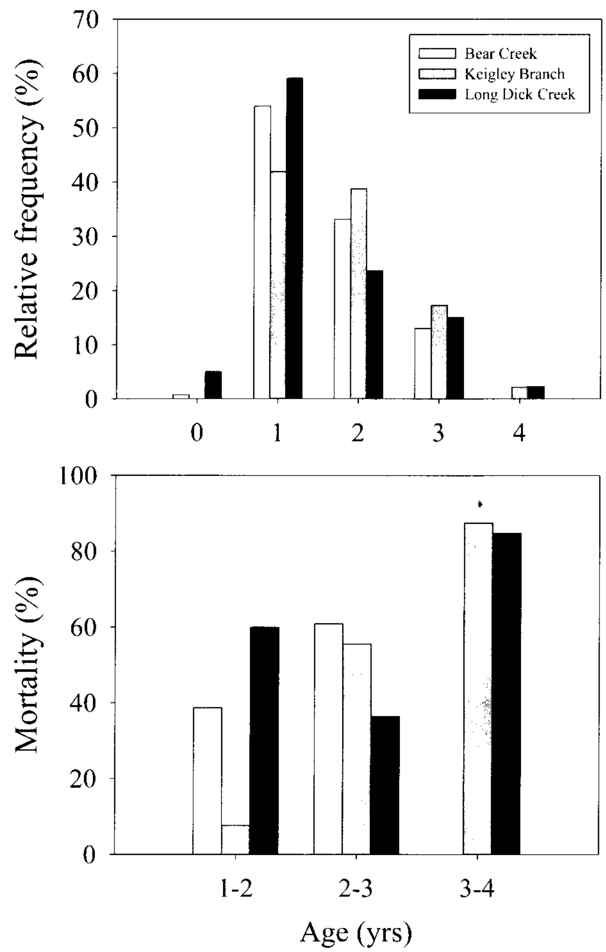

Figure 2. Relative frequency of different ages (top panel) and age-specific mean (SE) total annual mortality (lower panel) of central stonerollers sampled from three streams in central Iowa, 2007.

Similar to maximum length, age structure varies among studies. Quist and Guy (2001) reported central stonerollers up to age 3 in Kansas streams with 97% of the fish less than age 2. Gunning and Lewis (1956) reported that central stonerollers in an Illinois stream varied from age 0 to 3 and that 77% were age 1 and 2. While the age structure of central stoneroller populations in the current study is similar to that reported in Quist and Guy (2001) and Gunning and Lewis (1956), it is most similar to the age structure of populations reported by Lennon and Parker (1960). The authors reported that central stonerollers varied in age from 0 to 5 and that most fish (55–87% depending on stream) were less than age 3.

Although the mortality estimate of 61% by Quist and Guy (2001) is similar to that observed in the current study, patterns of age-specific mortality were quite different. Specifically, Quist and Guy (2001) found that age-specific mortality increased from approximately 80% between age 1 and 2 to nearly 100% for subsequent age intervals. Thus, once central stonerollers live past age 1 in central Iowa streams, survival is higher than for central stonerollers in Kansas streams. The streams studied by Quist and Guy (2001) were located on Fort Riley Military Reservation and experience high levels of anthropogenic and natural disturbance (e.g., high sediment delivery, highly variable discharge, low instream cover; Quist et al. 2003). While the mechanisms related to the observed patterns in age-specific mortality are unknown, one possibility is that environmental conditions in Iowa streams are not as deleterious to the survival of central stonerollers (i.e., at least those older than age 1) as those studied by Quist and Guy (2001) in Kansas. Specifically, increased sediment delivery coupled with high canopy coverage (i.e., > 80%) and increased abundance of creek chubs (*Semotilus atromaculatus*) in the streams studied by Quist and Guy (2001) may have increased mortality of adult central stonerollers by reducing the quality and quantity of food resources and predation.

Growth of central stonerollers in Iowa streams was similar to that of fish in Roaring Springs Creek, Illinois (Gunning and Lewis 1956) and Kansas streams (Quist and Guy 2001; Fig. 3). In contrast, growth of central stonerollers in GSMNP was higher than other central stoneroller populations, particularly at older ages (Lennon and Parker 1960). Few studies have described factors (e.g., habitat characteristics) contributing to growth of central stonerollers. However, the importance of benthic algae in their diet (e.g., Fowler and Taber 1985; Evans-White et al. 2001) suggested that any factor resulting in high production of benthic algae should result in fast growth rates of central stonerollers. Recent research suggests that stream reaches in Iowa without extensive riparian vegetation have low canopy cover and high nutrient delivery to streams (e.g., Isenhart et al. 1997; Fischer et al. 2010). These areas also appear to result in fast growth of herbivorous fishes; presumably through increased algal production (e.g., increased nutrient availability and solar irradiance). However, the faster growth for all ages of central stonerollers observed by Lennon and Parker (1960) in Tennessee streams suggested that other factors (e.g., climate) may have been important to small-bodied fish population characteristics. For instance, Marsh-Matthews and Matthews (2000) found latitudinal gradients (e.g., annual temperature, bank stability, terrestrial vegetation type) were important determinants of fish assemblage composition in Midwestern streams. As such, the observed growth of central stonerollers in central Iowa streams may be conducive to faster rates of growth and lower mortality associated increased food availability compared to Kansas (Quist and Guy 2001) and Illinois (Gunning and Lewis 1956) populations. However climatic conditions (e.g., growing degree days) may be responsible for the reduced rate of growth compared to those observed in Tennessee stream central stoneroller populations (Lennon and Parker 1960).

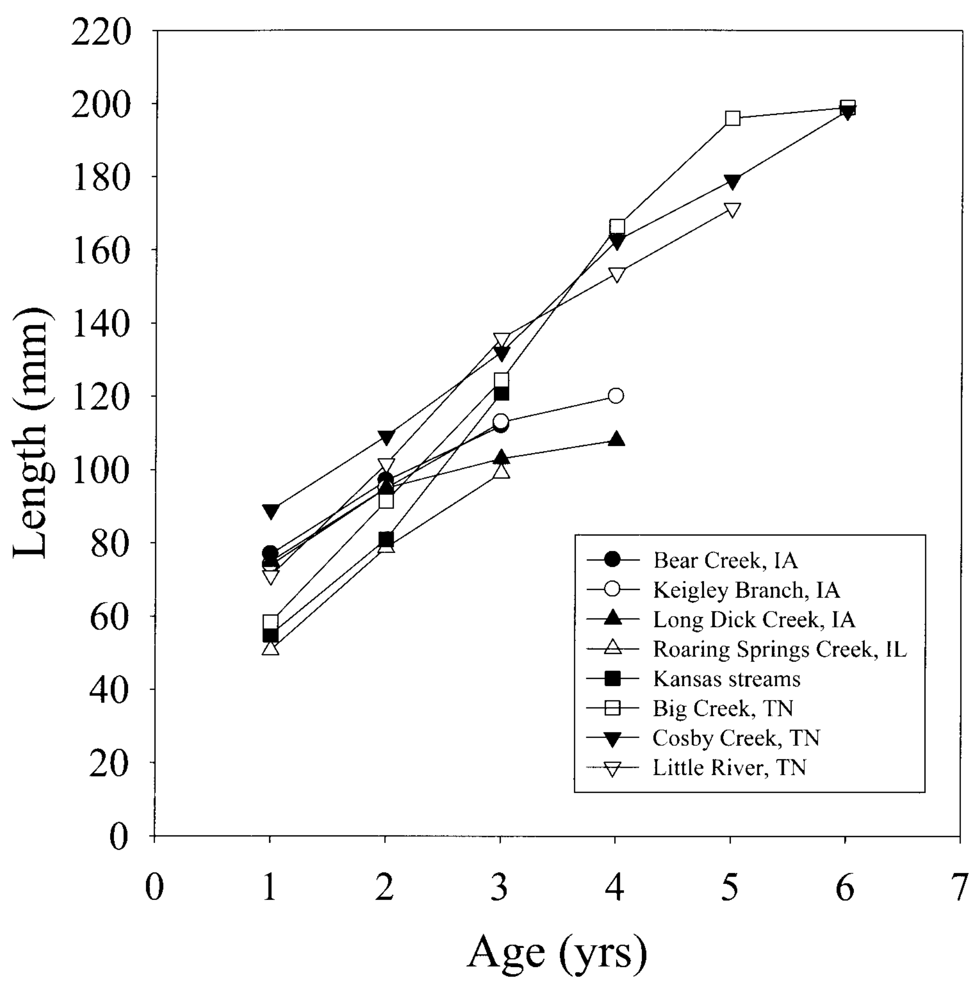

Figure 3. Mean total length at age (mm) for central stonerollers sampled from central Iowa (current study), Illinois (Gunning and Lewis 1956), Kansas (Quist and Guy 2001), and Tennessee (Lennon and Parker 1960).

MANAGEMENT IMPLICATIONS

Given the importance of central stonerollers to stream ecosystem function, understanding their population dynamics should be a high priority in systems where they are abundant. For instance, coupling age-structured population models with food web models is becoming more common because they can provide insight on ecosystem impacts of nonnative species, climate change, or alterations to important system inputs (e.g., nutrient delivery). Consequently, the availability of data on age structure, mortality, and growth of fishes (particularly small-bodied, nongame fishes) will be increasingly important to aquatic ecologists and management biologists. Our study provides such data as well as a foundation and framework for further observational and experimental research on the mechanistic processes influencing stream fish populations.

ACKNOWLEDGMENTS

We thank J. Lore, T. Giorgenti, M. Spurgeon, T. Neebling, and S. Wigen for assistance with data collection. Support for this project was provided by the U.S. Geological Survey, Iowa Water Center, Iowa Department of Natural Resources, and Iowa State University–Department of Natural Resource Ecology and Management.

LITERATURE CITED

Bettoli, P. W., and L. E. Miranda. 2001. Cautionary note about estimating mean length at age with subsampled data. North American Journal of Fisheries Management 21:425–428.

Brandt, S. B., D. M. Mason, D. B. MacNeill, T. Coates, and J. E. Gannon. 1987. Predation by alewives on larvae of yellow perch in Lake Ontario. Transactions of the American Fisheries Society 116:641–645.

Chick, J. H., and M. J. Van Den Avyle. 1999. Zooplankton variability and larval striped bass foraging: evaluating potential match/mismatch regulation. Ecological Applications 9:320–334.

DeVries, D. R., and R. V. Frie. 1996. Determination of age and growth. Pages 483–512 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, second edition. American Fisheries Society, Bethesda, Maryland, USA.

Evans-White, M. A., W. K. Dodds, L. J. Gray, and K. M. Fritz. 2001. A comparison of the trophic ecology of the crayfishes (*Orconectes nais* (Faxon) and *Orconectes neglectus* (Faxon)) and the central stoneroller minnow (*Campostoma anomalum* (Rafinesque)): omnivory in a tallgrass prairie. Hydrobiologia 462:131–144.

Evans-White, M. A., W. K. Dodds, and M. R. Whiles. 2003. Ecosystem significance of crayfishes and stonerollers in a prairie stream: functional differences between co-occurring ominivores. Journal of the North American Benthological Society 22:423–441.

Fischer, J. R., M. C. Quist, S. L. Wigen, A. J. Schaefer, T. W. Stewart, and T. M. Isenhart. 2010. Assemblage and population level responses of stream fish to riparian buffers at multiple spatial scales. Transactions of the American Fisheries Society 139:185–200.

Fowler, J. F., and C. A. Taber. 1985. Food habits and feeding periodicity in two sympatric central stonerollers (Cyprinidae). American Midland Naturalist 113:217–223.

Gelwick, F. P., and W. L. Matthews. 1992. Effects of an algivorous minnow on temperate stream ecosystem properties. Ecology 73:1630–1645.

Gelwick, F. P., and W. L. Matthews. 1997. Effects of algivorous minnows (*Campostoma*) on spatial and temporal heterogeneity of stream periphyton. Oecologia 112:386–392.

Gunning, G. E., and W. M. Lewis. 1956. Age and growth of two important bait species in a cold-water stream in southern Illinois. American Midland Naturalist 55:118–120.

Isenhart, T. M., R. C. Schultz, and J. P. Colletti. 1997. Watershed restoration and agricultural practices in the Midwest: Bear Creek of Iowa. Pages 318–334 *in* J. E. Williams, C. A. Wood, and M. P. Dombeck, editors. Watershed restoration: principles and practices. American Fisheries Society, Bethesda, Maryland, USA.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. 1980. Publication #1980-12, North Carolina Biological Survey, North Carolina State Museum of Natural History, Raleigh, North Carolina, USA.

Lennon, R. E., and P. S. Parker. 1960. The stoneroller, *Campostoma anomalum* (Rafinesque), in Great Smoky Mountains National Park. Transactions of the American Fisheries Society 89:263–270.

Lyons, J. 1992. The length of stream to sample with a towed electrofishing unit when fish species richness is estimated. North American Journal of Fisheries Management 12:198–203.

Marsh-Matthews, E., and W. J. Matthews. 2000. Geographic, terrestrial and aquatic factors: which most influence the structure of stream fish assemblages in the midwestern United States? Ecology of Freshwater Fish 9:9–21.

Matthews, W. L. 1998. Patterns in freshwater fish ecology. Kluwer Academic Publishers, Norwell, Massachusetts, USA.

Miranda, L. E., and P. W. Bettoli. 2007. Mortality. Pages 229–277 *in* C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland, USA.

Neumann, R. M., and M. S. Allen. 2007. Size structure. Pages 375–421 *in* C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland, USA.

Pflieger, W. L. 1997. The fishes of Missouri, revised edition. Missouri Department of Conservation, Jefferson City, Missouri, USA.

Post, G. 1987. Textbook of fish health, revised and expanded edition. T.F.H. Publications, Neptune City, New Jersey, USA.

Power, M. E., and W. J. Matthews. 1983. Algae-grazing minnows (*Campostoma anomalum*), piscivorous bass (*Micropterus* spp.), and the distribution of attached algae in a small prairie-margin stream. Oecologia 60:328–332.

Power, M. E., A. J. Stewart, and W. J. Matthews. 1988. Grazer control of algae in an Ozark Mountain stream: effects of short-term exclusion. Ecology 69:1894–1898.

Power, M. E., W. L. Matthews, and A. J. Stewart. 1985. Grazing minnows, piscivorous bass, and stream algae: dynamics of a strong interaction. Ecology 66:1448–1456.

Quist, M. C., and C. S. Guy. 2001. Growth and mortality of prairie stream fishes: relations with fish community and instream habitat characteristics. Ecology of Freshwater Fish 10:88–96.

Quist, M. C., P. A. Fay, C. S. Guy, A. K. Knapp, and B. N. Rubenstein. 2003. Effects of military training on terrestrial and aquatic communities on a grassland military installation. Ecological Applications 13:432–442.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191, Ottawa, Canada.

Schultz, R. C., J. P. Colletti, T. M. Isenhart, W. W. Simpkins, C. W. Mize, and M. L. Thompson. 1995. Design and placement of a multi-species riparian buffer strip system. Agroforestry Systems 29:201–226.

Simonson, T. E., J. Lyons, and P. D. Kanehl. 1994. Quantifying fish habitat in streams: transect spacing, sample size, and a proposed framework. North American Journal of Fisheries Management 14:607–615.

Stewart, A. J. 1987. Responses of stream algae to grazing minnows and nutrients: a field test for interactions. Oecologia 72:1–7.

Submitted 9 February 2010. Accepted 10 November 2010. Associate Editor was Brian G. Blackwell.