# Impacts of a Threadfin Shad Winterkill on Black Crappie in a North Carolina Reservoir[1]

**James R. Jackson,** *Department of Zoology, Campus Box 7617, North Carolina State University, Raleigh, NC 27695*

**Shari L. Bryant,** *North Carolina Wildlife Resources Commission, 512 North Salisbury Street, Raleigh, NC 27611*

---

*Abstract*: A total winterkill of threadfin shad (*Dorosoma petenense*) in B. Everett Jordan Lake, North Carolina, facilitated assessment of their role in the growth and condition of black crappie (*Pomoxis nigromaculatus*). Reductions in size at age and $W_r$ were observed in Age 3 and older crappie in the year of the winterkill. Reestablishment of threadfin shad in the following year led to improvements in crappie population parameters, and within 2 years of the shad winterkill, crappie growth and condition had returned to pre-kill levels. The presence of a strong gizzard shad (*D. cepedianum*) year class during the season in which crappie conditions otherwise declined established the superiority of threadfin shad as forage for crappie.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 47:511–519

---

The most common colonizers of newly impounded southern reservoirs are primarily littoral in habit, with relatively few species pre-adapted to utilize pelagic resources. Accordingly, a frequent management strategy in reservoirs has been to create or enhance sustainable fisheries in open-water areas (Kohler et al. 1986). Black crappie and white crappie (*P. annularis*) are found in the pelagic communities of many southeastern reservoirs and commonly comprise an important part of the recreational fishery. Not surprisingly, it is common practice to try to enhance crappie growth by stocking additional prey species such as threadfin shad or inland silversides, *Menidia beryllina*. Unfortunately, management of forage fishes is often conducted on a trial-and-error basis, and the need for careful evaluations of both the direct and indirect effects of forage base manipulations has been recognized as a priority in management-oriented research (Ney 1981, Noble 1981).

In a survey of system responses to shad stockings, DeVries and Stein (1990)

---

[1] This project was conducted through support of the North Carolina Wildlife Resources Commission under Federal Aid for Sportfish Restoration Projects F-23-S, F-30-1, and F-30-3, and funded in part by the North Carolina Agricultural Research Service.

found that adult crappie responded positively to threadfin shad introductions in most of the cases reviewed, though they also reported neutral and negative effects. Mosher (1984) reported improved condition in larger crappie (>200 mm) of both species following threadfin shad introduction in a Kansas lake already populated by gizzard shad, but first year improvements in growth were not sustained. Range (1973) observed improved growth in white crappie after threadfin shad were stocked into Dale Hollow Reservoir, Tennessee.

While comparisons of crappie growth and condition before and after stocking of threadfin shad typically indicate positive responses to the increased forage, we are not aware of any published results which examine the impacts of removal of threadfin shad on crappie populations. B. Everett Jordan Lake, in central North Carolina, supported reproducing populations of both threadfin shad and gizzard shad when clupeid sampling was initiated in 1987. A severe cold front in December 1989 resulted in a rapid drop in water temperatures and development of ice cover over much of the lake. The freeze resulted in a total winterkill of threadfin shad, but did not eliminate gizzard shad (Jackson et al. 1991). Threadfin shad began to reestablish during the summer of 1991, presumably invading the lake from an upstream stocking.

Our paper describes responses of black crappie populations to the winterkill and subsequent reestablishment of threadfin shad. The relative importance of threadfin shad and gizzard shad as forage to crappie is evaluated through comparison of conditions in years with both shad species (1989, 1992) and the year with gizzard shad only (1990). Given that indirect, multi-trophic level responses to the absence of threadfin shad are not likely to have become established in the short time before reinvasion occurred, results of the current study provide an opportunity to examine the direct influence of threadfin shad on crappie populations without confounding effects from other segments of the system.

The authors acknowledge the assistance of many workers from both the North Carolina Wildlife Resources Commission's (NCWRC) Division of Boating and Inland Fisheries and the Department of Zoology at North Carolina State University. Special thanks are extended to R. Jones, S. Van Horn, B. Collart, F. McBride, W. Jones, and B. Hammers of the NCWRC; and R. Noble, T. Wheeler, T. Shahady, C. Thomas and K. Hodges at NCSU.

## Methods

B. Everett Jordan Lake is a 5,720-ha flood control reservoir in the eastern piedmont of North Carolina. The dam, which began operation in late 1981, lies at the confluence of the Haw and New Hope rivers. Development of aquatic macrophytes is limited by seasonal water level fluctuations and the lake is typically turbid (average secchi depth = 0.5 m). The fish fauna is characteristic of southern systems. Important piscivores include largemouth bass (*Micropterus salmoides*) and black and white crappie. *Morone* hybrids have been stocked sporadically since 1983, but a strong population has not been established. Gizzard shad have occupied the lake since impoundment; threadfin shad were first observed in the lake in 1987.

Larval and juvenile shad were collected every 2 weeks at 9 main lake stations from April through October 1988–1990 with a 1-mm mesh neuston net mounted on a 1- × 2-m frame. The net was fitted with a General Oceanics model 2030 digital flowmeter for calculation of water volumes sampled. Each station was sampled at night with a tow of approximately 5 minutes at a speed of 1.0 m/second, sampling a volume of roughly 400 $m^3$. Fish were preserved in denatured alcohol immediately following capture. In the laboratory, all shad were counted and, when available, total lengths (mm) of a subsample of at least 200 fish from each station were measured. Shad >20 mm were identified to species by anal fin ray counts, smaller shad were identified simply as *Dorosoma.*

Sampling for shad in 1991 and 1992 was confined to 2 embayments on the east side of the lake. Three replicate night samples were collected in each bay by the same methods described above. The southern-most embayment (64 ha) was also sampled during the period of 1988–1990, facilitating comparisons of samples from bay and main lake areas. Shad densities are reported as averages for the 9 main lake stations, and densities in the southern embayment are reported separately for comparison of 1991 and 1992 data.

Crappie were sampled in all years with overnight trap net sets during October and November. Trap nets were composed of 2 0.9-m × 1.8-m steel frames and 4 0.9-m diameter hoops with a single 15.2-m × 0.9-m lead. Netting was 1.25-cm bar mesh throughout. Effort for the period 1986 through 1992 ranged from 36 to 78 net nights, and averaged 53 net nights each year. All crappie collected were separated by species and total lengths (mm) measured. Samples were broken down into 10-mm size classes and when available, 10 fish of each species in each size class were weighed. Otoliths were removed from 4 fish in each species size class for determination of age at capture. The whole otolith technique of Maceina and Betsill (1987) was employed for aging. Relative weights ($W_r$) were calculated using the equations of Neumann and Murphy (1991). For the purposes of this study, relative weights are reported as means for stock, quality, preferred, and memorable size classes for each species (Gabelhouse 1984).

Comparisons of crappie relative weights among pairs of years were made using orthogonal comparisons (Snedecor and Cochran 1980). Statistical significance was declared at the level of $P < 0.05$. Length and weight relationships of black crappie populations in the different years were also compared using analysis of covariance of log-transformed data.

## Results

Trends in total larval and juvenile shad densities were similar in the 2 years before the winterkill of threadfin shad (Fig. 1). Peak density (±1 SE) of *Dorosoma* larvae was 2.5/$m^3$ (±0.5) in 1988 and 1.9 (±0.6) in 1989. In 1990, when only gizzard shad were present, peak larval density was as high or higher than observed in years with both species (2.7±1.1). A relatively weak spawn of gizzard shad

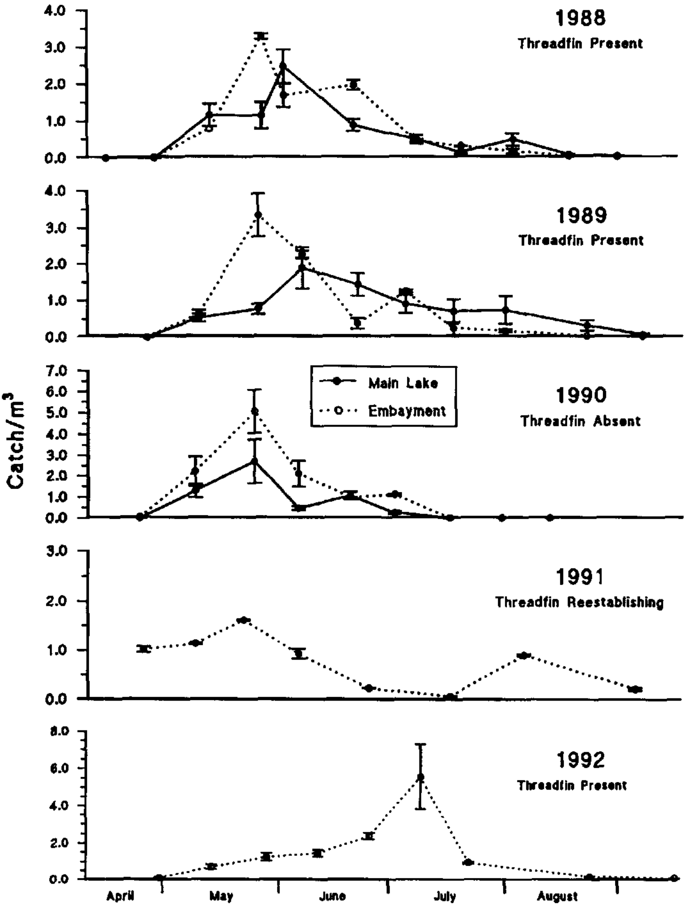

Figure 1. Catches of larval and juvenile shad (±1 SE) in the main lake and in an embayment of B. Everett Jordan Lake, 1988–1992.

(1.6±.01) in May 1991 was followed by a smaller threadfin shad spawn in August (0.9±.02). A protracted threadfin shad spawn in 1992 resulted in a late peak in July of 5.6 fish per m$^3$ (±1.7).

Due to increasing gear avoidance as shad grow beyond 40 mm, combined with the tendency for gizzard shad to move into littoral areas as juveniles, accurate quantitative assessment of shad species composition was not possible, but combined representation of the 2 species in pelagic and littoral (electrofishing) samples indicated that threadfin dominated the shad community in 1989 and 1992, while both species were well-represented in 1988 and 1991. Gizzard shad were the only species captured in any samples in 1990.

Routine sampling with gill nets (quarterly), trap nets (monthly), and shoreline electrofishing (tri-weekly) throughout the period of the study indicated that the

**Table 1.** Population characteristics of black crappie in B. Everett Jordan Lake, 1986–1992.

| Year | Black crappie as a percentage of all crappie | Size at age 2 Mean (range) (TL, mm) | Size at age 3 Mean (range) (TL, mm) | Size at age 4 Mean (range) (TL, mm) | $PSD_{23}$ |
|---|---|---|---|---|---|
| 1986 | 82 | 190 (160–285) | 214 (173–258) | 258 (178–323) | 3 |
| 1987 | 68 | 213 (147–295) | 226 (168–325) | 227 (167–284) | 10 |
| 1988 | 87 | 191 (167–224) | 246 (179–342) | 254 (201–318) | 7 |
| 1989 | 83 | 209 (168–304) | 244 (208–277) | 279 (228–337) | 22 |
| 1990 | 85 | 230 (155–305) | 221 (177–271) | 240 (180–289) | 21 |
| 1991 | 82 | 188 (142–258) | 226 (197–262) | 261 (244–293) | 20 |
| 1992 | 84 | 197 (168–222) | 255 (218–301) | 269 (218–317) | 30 |

impact of the 1989 freeze was primarily reflected in the loss of threadfin shad. No other notable shifts in the adult fish community were observed in catches of any gear (Jackson et al. 1991).

Black crappie were the dominant species of crappie throughout the study (Table 1). Catch rates for white crappie, particularly in the later years of the study, were too low for meaningful analysis, so responses to the winterkill of threadfin shad were interpreted through analyses of black crappie population parameters.

The black crappie population in Jordan Lake showed general improvements during the years after threadfin shad became established. Size at age, proportional stock density ($PSD_{23}$), and $W_r$ all tended to increase from 1986 through the years prior to the threadfin shad winterkill in December 1989, particularly for larger fish (Tables 1, 2). No consistent trends in black crappie catch rates were observed through the study period: high catch rates before 1989 probably reflected a strong 1985 year class (Table 3).

Responses of black crappie to the threadfin shad winterkill were immediately reflected in 1990 population data. Mean $W_r$'s were significantly lower in 1990 than 1989 for all size classes ($P \leq 0.001$) (Table 2). Size at age for Age 3 and 4 fish declined from 1989 to 1990; size at Age 2 increased in 1990, but declined in 1991 to a smaller size than observed in 1989 (Table 1). Responses of the black crappie popu-

**Table 2.** Relative weights (±1 SE) and sample sizes (*N*) of black crappie captured by fall trap netting in B. Everett Jordan Lake, 1986–1992.

| Year | Stock (130–199 mm) | Quality (200–249 mm) | Preferred (250–299 mm) | Memorable (≥ 300 mm) |
|---|---|---|---|---|
| 1986 | 74.0 ±0.9 (78) | 72.2 ±2.3 (16) | 81.5 ±4.3 (8) | 79.4 ±4.7 (7) |
| 1987 | 88.1 ±0.7 (95) | 86.0 ±0.8 (69) | 88.0 ±1.4 (31) | 97.5 ±2.5 (2) |
| 1988 | 86.5 ±1.0 (81) | 84.4 ±1.2 (53) | 89.1 ±1.6 (26) | 92.3 ±5.2 (4) |
| 1989 | 92.1 ±1.0 (70) | 90.2 ±1.0 (68) | 93.0 ±2.0 (33) | 97.9 ±2.2 (14) |
| 1990 | 86.7 ±1.1 (67) | 81.7 ±0.8 (66) | 83.9 ±1.2 (35) | 79.7 ±0.7 (3) |
| 1991 | 83.3 ±1.3 (34) | 86.3 ±1.8 (33) | 90.2 ±1.6 (12) | 99.2 ±3.6 (4) |
| 1992 | 87.9 ±0.9 (60) | 88.3 ±1.2 (41) | 93.1 ±2.2 (28) | 102.5 ±2.6 (4) |

**Table 3.** Catch rates (fish/net night) of black crappie captured by fall trap netting in B. Everett Jordan Lake, 1986–1992.

| Year | Stock (130–199 mm) | Quality (200–249 mm) | Preferred (250–299 mm) | Memorable ($\geq$ 300 mm) |
|---|---|---|---|---|
| 1986 | 14.6 | 0.9 | 0.3 | 0.1 |
| 1987 | 12.5 | 5.6 | 0.6 | <0.1 |
| 1988 | 16.4 | 4.7 | 0.6 | 0.1 |
| 1989 | 2.0 | 3.1 | 0.5 | 0.2 |
| 1990 | 2.6 | 3.7 | 0.8 | 0.1 |
| 1991 | 2.1 | 1.9 | 0.3 | 0.1 |
| 1992 | 2.4 | 2.3 | 0.9 | 0.1 |

lation to the reoccurrence of threadfin shad were as rapid as those to the winterkill. $PSD_{23}$ rose to the highest level of the study by 1992 (Table 1). $W_r$'s increased in 1991 for all but stock-sized fish, and by 1992 had reached levels near or above those observed prior to the winterkill for all size classes (Table 2). $W_r$'s were higher in 1991 than 1990 for all but the stock size class (quality $P = 0.008$, preferred $P = 0.062$, memorable $P = 0.002$), and higher than 1990 for all size classes by 1992 (stock $P = 0.427$, quality $P < 0.001$, preferred $P < 0.001$, memorable $P = 0.001$). Comparisons of 1989 and 1992 $W_r$'s confirmed that conditions of the larger size classes of crappie had returned to levels that were not significantly different from those observed prior to the winterkill (quality $P = 0.229$, preferred $P = 0.965$, memorable $P = 0.276$).

Declines in weight of black crappie >200 mm were further confirmed by analysis of covariance of $\log_{10}$ transformed length and weight data for the years 1989, 1990 and 1992. The slopes of the length-weight regressions did not differ among years ($P > 0.258$). However, elevations did differ among the 3 years. Weights at length for black crappie between 200 mm and 320 mm were 11%–12% lower in 1990 than in 1989 ($P < 0.001$) and 12%–15% lower than in 1992 ($P < 0.001$). Weights in 1989 were from 0%–4% lower than 1992, and the difference in elevations for the 1989 and 1992 regressions were marginally significant ($P = 0.04$). The trends in length-weight relationships among the 3 years agree with those indicated by $W_r$ values. In the absence of threadfin shad, larger black crappie exhibited more than a 10% reduction in weight at all sizes relative to years with threadfin shad.

## Discussion

The observed responses of crappie populations to the complete winterkill of threadfin shad in 1989 clearly demonstrate the importance of this forage species to crappie in Jordan Lake. Declines in all measures of population condition were observed during 1990, despite the presence of a year class of gizzard shad which resulted in shad densities comparable to years when both shad species were present. The improvements in growth and condition which followed the reestablishment of threadfin shad in the lake provide further evidence that they provide valuable forage for piscivorous crappie.

Changes in crappie population parameters probably are not attributable to differences in crappie densities among years. In the years before and after the winterkill, black crappie densities were 5.8 and 7.2/net night, respectively (Table 3). The density of the 3 larger size classes was only 1.2/net night higher in the year when conditions declined. Crappie density in 1992, when improvements in population condition were observed, was 5.7/net night. Fluctuations in catch rates in the years surrounding the winterkill were therefore <2 fish/net night, and are not likely to explain the observed shifts in population parameters. Furthermore, growth and condition were better in 1988 than 1990, despite catch rates that were close to 3 times higher. Condition of black crappie, therefore, did not vary consistently with catch rates during the study, and observed responses to the removal of threadfin shad are not likely to have been attributable to density-dependent factors acting within the crappie population.

The stronger response of crappie in the quality, preferred, and memorable size classes reflects the importance of piscivory to larger crappie. Keast (1968) concluded that piscivory becomes important to continued growth of crappie as they reach sizes >160 mm. Our data confirm that larger black crappie are more dependent on the availability of fish forage. $W_r$'s of crappie >190 mm were impacted to a greater extent by the winterkill of threadfin shad than were those of smaller fish, indicating the increased importance of piscivory to fish at those sizes (Fig. 2). Responses of stock size crappie to the winterkill may be an indication that smaller crappie benefit from but are not dependent upon the availability fish forage.

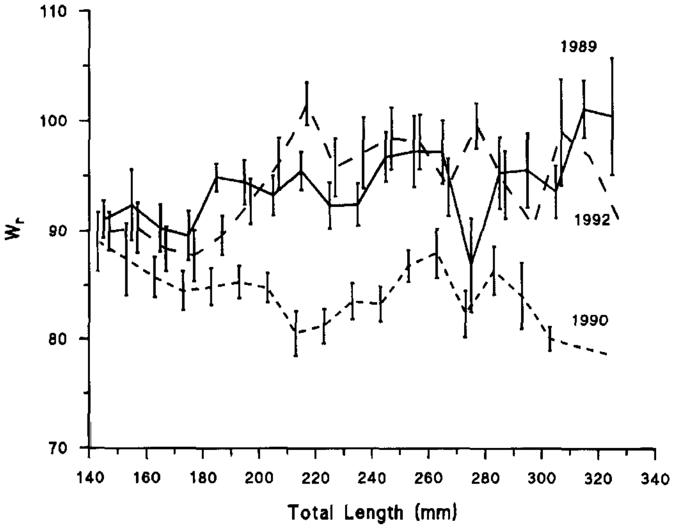

**Figure 2.** Relative weights of black crappie by 10-mm size classes (±1 SE) in B. Everett Jordan Lake, 1989, 1990, and 1992.

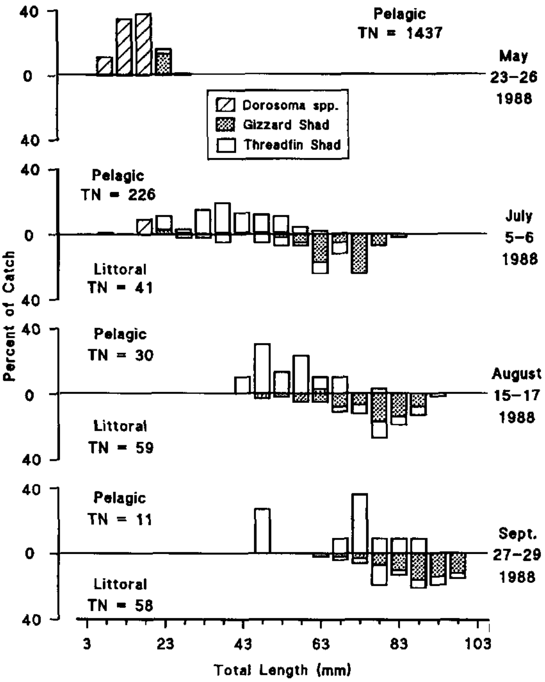

**Figure 3.** Species composition of shad catches in pelagic (neuston net) and littoral (electrofishing) samples in an embayment of B. Everett Jordan Lake, 1988.

The differential importance of threadfin shad and gizzard shad as forage for crappie is most likely due to differences in the distribution of juveniles of the 2 species. Growth rates of gizzard shad in Jordan Lake are slow, and fall sizes of juveniles rarely exceed 100 mm, only slightly larger than sizes obtained by threadfin shad (Jackson et al. 1991). Therefore, both species remain vulnerable to predation by larger crappie throughout their first growing season (Jenkins and Morais 1976), and size differences are not likely to explain differences in importance as forage. The failure of gizzard shad to support the growth and condition of crappie is most likely linked to the inshore movement of gizzard shad juveniles. Comparisons of pelagic and littoral samples in an embayment of the lake establish that threadfin shad are more likely to remain in open-water habitats while gizzard shad become more littorally oriented (Fig. 3). Todd and Willis (1985) noted a similar tendency for juvenile gizzard shad to move into inshore areas early in their first growing season in a Kansas reservoir. Gizzard shad exhibited the same inshore movement in 1990, when no threadfin shad were present. This segregation of habitat use by juveniles of the 2 species of shad explains the observed differences in their value as forage for crappie.

The importance of threadfin shad to adult crappie in Jordan Lake is clearly demonstrated by responses to the winterkill in 1989. However, the rapid recolonization of the lake by threadfin shad did not allow assessment of other system responses to their absence. While threadfin shad obviously benefit adult crappie, possible direct and indirect impacts on younger crappie and on other components of the system require further investigation if the role of threadfin shad in reservoir systems is to be fully understood.

## Literature Cited

DeVries, D. R. and R. A. Stein. 1990. Manipulating shad to enhance sport fisheries in North America: an assessment. North Am. J. Fish. Manage. 10:209–223.

Gabelhouse, D. W., Jr. 1984. A length-categorization system to assess fish stocks. North Am. J. Fish. Manage. 4:273–285.

Jackson, J. R., J. A. Rice, R. L. Noble, and S. C. Mozley. 1991. Mechanisms of reservoir fish community dynamics. Final Rep., Fed. Aid in Fish Restoration Proj. F-30-1, N.C. Wildl. Resour. Comm., Raleigh. 104pp.

Jenkins, R. M. and D. I. Morais. 1976. Prey-predator relations in the predator-stocking-evaluation reservoirs. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies. 30:141–157.

Keast, A. 1968. Feeding biology of the black crappie, *Pomoxis nigromaculatus*. J. Fish. Res. Board Can. 25:285–297.

Kohler, C. C., J. J. Ney, and W. E. Kelso. 1986. Filling the void: development of a pelagic fishery and its consequences in a Virginia mainstream reservoir. Pages 166–177 *in* G. E. Hall and M. J. Van Den Avyle, eds. Reservoir fisheries management: strategies for the 80's. Am. Fish. Soc., Bethesda, Md.

Maceina, M. J. and R. K. Betsill. 1987. Verification and use of whole otoliths to age white crappie. Pages 267–278 *in* R. C. Summerfelt and G. E. Hall, eds. Age and growth of fish. Iowa State Univ. Press, Ames.

Mosher, T. D. 1984. Responses of white crappie and black crappie to threadfin shad introductions in a lake containing gizzard shad. North Am. J. Fish. Manage. 4:365–370.

Neumann, R. M. and B. R. Murphy. 1991. Evaluation of the relative weight ($W_r$) index for assessment of white crappie and black crappie populations. North Am. J. Fish. Manage. 11:543–555.

Ney, J. J. 1981. Evolution of forage-fish management in lakes and reservoirs. Trans. Am. Fish. Soc. 110:725–728.

Noble, R. L. 1981. Management of forage fishes in impoundments of the southern United States. Trans. Am. Fish. Soc. 110:738–750.

Range, J. D. 1973. Growth of five species of game fishes before and after introduction of threadfin shad into Dale Hollow Reservoir. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 26:510–518.

Snedecor, G. W. and W. G. Cochran. 1980. Statistical methods, 7th ed. Iowa State Univ. Press, Ames. 507pp.

Todd, B. L. and D. W. Willis. 1985. Food habits of juvenile gizzard shad in open-water and near-shore habitats of Melvern Reservoir, Kansas. Prairie Nat. 17:127–132.