Growth and Reproduction of Blueback Herring in a North Texas Reservoir

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Abstract: The growth and reproductive cycle of a landlocked population of blueback herring (*Alosa aestivalis*) were evaluated in Lake Theo, a North Texas reservoir. Scales were collected and length, weight, and gonad characteristics were recorded for individual herring. Herring reproduced each year of the study. Average size of Age I herring ranged from approximately 70 to 170 mm total length (TL). Average size of Age II herring was approximately 200 mm TL and maximum size was 237 mm TL. Scale annuli formation in immature fish began in April; spawning marks occurred on scales in late summer. Herring matured at Age I or II and lived 2–3 years. Size at sexual maturity was 175–200 mm TL. Fecundity ranged from approximately 30,000 to 60,000 eggs (> 0.2 mm diameter) for females 190 to 216 mm TL. Gonadosomatic indices suggested protracted spawning from April through July with a peak in May and June. Spawning temperatures ranged from 21° to 25°C; spawning ceased above 27°C.

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Blueback herring (*Alosa aestivalis*) and alewife (*A. pseudoharengus*) are anadromous clupeids indigenous to the Atlantic coast (Carlander 1953). When landlocked in fresh water, alewives are reported to grow slower and reach a smaller maximum size than anadromous stocks (Smith 1970). Landlocked populations of alewives were limited to the northeastern United States (Gross 1959, Rothschild 1963, Norden 1967, Smith 1970), but their landlocked growth characteristics and cold tolerance has encouraged their introduction into more southern reservoirs as prey for large piscivores (Boaze and Lackey 1974, Lewis 1981, Moore et al. 1985, Strange et al. 1985). Landlocked populations of blueback herring have been documented in Connecticut, North Carolina, and South Carolina (Brooks and Dodson 1965, Prince and Barwick 1981).

Various aspects of the life history of landlocked alewives have been documented (Gross 1959; Rothschild 1963; Norden 1967; Boaze and Lackey 1974; Kohler and Ney 1980, 1981; Lewis 1981; Nigro and Ney 1982; Moore et al. 1985; Strange et al. 1985); however, little is understood about the life history of landlocked blueback herring. The Texas Parks and Wildlife Department considered the possible utilization of blueback herring as a prey species in Texas reservoirs where winterkill of threadfin shad (*Dorosoma petenense*) occur. A prerequisite to this consideration requires a better understanding of the landlocked life history of blueback herring. Therefore, blueback herring were experimentally introduced in Lake Theo, a North Texas reservoir, to investigate the growth and reproductive cycle of this relatively new landlocked fish.

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Methods

Site Description

Lake Theo is a 30-ha reservoir impounded in 1959, located 5 km north of Quitaque in Briscoe County, Texas. It is adjacent to Palo Duro Canyon on Holmes Creek, a tributary of Prairie Dog Town Fork of the Red River. The topography of the area is very rugged; steep characteristics of the lake basin restrict the amount of littoral habitat. The open water area contains a few ridges sloping to the creek channel; maximum depth is about 12 m.

Small sunfishes *Lepomis* spp., black crappie *Pomoxis nigromaculatus* and white crappie *P. annularis* constitute the bulk of the prey for largemouth bass *Micropterus salmoides* in Lake Theo (Kraai 1979). No clupeids were present in the reservoir prior to the blueback herring introduction.

Blueback Herring Introduction

Adult herring were collected during their spawning run from Cooper River, South Carolina, and flown to Lake Theo using handling procedures described by Guest and Prentice (1982). One hundred and forty adults (270–300 mm total length, TL) were stocked (4.7/ha) in Lake Theo in March 1982.

Sampling Frequency

Sampling was conducted quarterly from summer (Jun–Aug) 1982 through winter (Dec–Feb) 1983–1984. When it became apparent that quarterly sampling was inadequate to monitor herring growth and reproduction, supplemental sampling began in April 1984 and continued monthly through April 1986.

Age and Growth

A sample of at least 20 blueback herring was collected between approximately 1800 and 2300 hours each trip by electrofishing supplemented with gill nets when electrofishing was ineffective. The fish were placed in 10% formalin (except those used for fecundity estimates which were held on ice) for later processing.

Total length (mm), weight (g), and sex were recorded for each herring. Scales were removed according to procedures described by Marcy (1969), cleaned in 2% potassium hydroxide, dried, placed between glass slides, and read using a microfilm reader (19x).

Total lengths at time of annulus formation were determined by the Fraser-Lee method of back-calculating fish lengths (Ricker 1971). Intercepts for back-calculations were estimated separately for each year class using lengths and scale radii from fish of that year class collected throughout the study. Marcy (1969) assumed 1 January as the annulus formation date for anadromous herring, and this convention was followed in aging herring in the present study. Year class determination was based on modes from length distributions until July 1985 when considerable overlap in size distributions of fish began occurring. Criteria used to separate individual fish into the appropriate year class during this size overlap period (Jul 85–Apr 86) were presence of spawning marks as described by Cating (1953) and/or false annuli on scales, and gonadal development.

Reproductive Cycle

Gonads were removed and weighed to the nearest 0.1 g. Gonadosomatic indices (GSI) were calculated using body weight of the preserved fish before gonad removal. Fecundity estimates were made from fresh ovaries collected during the spawning season. These ovaries were preserved in Gilson's fluid to harden the eggs and break down the ovarian tissue (Ricker 1971). The disassociated ovary contents were then suspended in a known volume of concentrated sodium chloride solution and 3 1-ml subsamples were taken with a Henson-Stempel pipette. Eggs per subsample were measured and counted, and the mean number was multiplied by the total volume of the sample to determine fecundity. Since no mature females were collected with easily extrudable eggs, fecundity estimates were made only on those ovaries containing a majority of eggs with diameters > 0.5 mm. Eggs < 0.2 mm were not counted because they were difficult to positively identify as eggs. Fecundity estimate was expressed as the total number of eggs per female.

Statistical Analyses

Least-squares regression and analysis of covariance were used to calculate the weight-length relations for blueback herring and to compare the regressions between sexes, respectively. Relationships between fecundity and ovary weight also were described by least-squares regression. All analyses were performed with SAS (SAS 1982). Statistical significance was tested at the 5% level ($P = 0.05$).

Results and Discussion

Age and Growth

First year growth varied with each year class and ranged from approximately 70 to 170 mm TL (Fig. 1). Back-calculated lengths at first annulus formation for

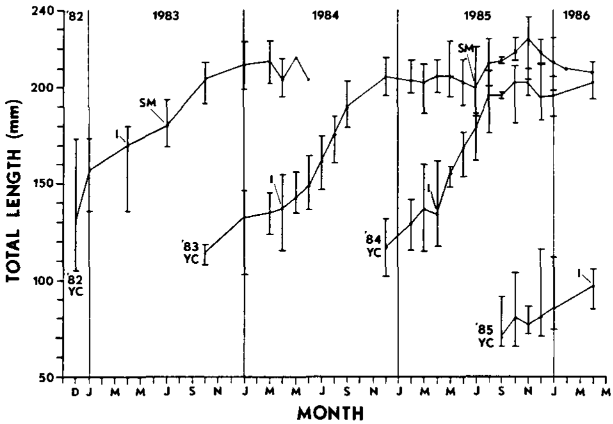

Figure 1. Mean lengths (with ranges) of 4 year classes (YC) of blueback herring (N = 601) sampled from Lake Theo, Briscoe County, Texas, from December 1982 through April 1986. Fish were assigned to the appropriate year class through interpretation of length-frequency distributions, scale analyses, and gonadal development. Symbols denote month when first annuli (I) and spawning marks (SM) were first observed on scales.

immature fish of the 1982–1985 year classes were 159 ± 12, 133 ± 13, 117 ± 19, and 79 ± 6 mm TL, respectively. Length of young-of-year (Y-O-Y) blueback herring in Lake Marion, South Carolina, just prior to migration from the lake to marine areas in late November, was approximately 70 mm TL (Bulak and Christie 1980). Prince and Barwick (1981) reported Y-O-Y herring ranged from 25 to 100 mm TL in August cove rotenone samples from 2 landlocked South Carolina reservoirs. The 1982 year class grew the fastest and 1983 and 1984 year classes were similar but somewhat slower; the 1985 year class grew the slowest. The fast growth of the 1982 year class probably can be expected when introducing a clupeid into a reservoir with no other clupeid present, at least until their population reaches carrying capacity (Boaze and Lackey 1974). Slow growth of the 1985 year class would be considered an attribute in regards to prey potential; however, this slow growth may have been attributed to a decline in zooplankton abundance. Guest (1986) suggested herring predation contributed to the zooplankton decline in Lake Theo and that prey availability, population density, and competition would probably affect growth of landlocked blueback herring populations.

Blueback herring were approximately 200 mm TL at Age II and growth had slowed appreciably (Fig. 1). The maximum length attained by blueback herring in Lake Theo was 237 mm TL (Nov 85; Age II). This maximum length was smaller than that of herring (approximately 300 mm TL) collected from the 2 reservoirs studied by Prince and Barwick (1981).

When aging blueback herring, the first annulus was easily recognized on scales collected in April (Fig. 1) and were found on all scales collected in May. However, the 1982 year class (which exhibited the fastest first-year growth) was the exception.

Only 14% of these fish collected in April 1983 had formed a year mark (annulus). Sixty percent of this year class had formed a mark by July, but of these, 55% appeared to be spawning marks rather than annuli formed by immature fish. A plausible explanation for fish collected in April and July with no year mark is that they grew steadily during the period of normal annulus formation, reached sexual maturity, spawned, and represented fish collected in subsequent samples with spawning marks. Back-calculated lengths at spawning mark formation for the 1982 year class was 175 ± 2 mm TL (mean back-calculated length at first annulus formation was 159 ± 12 mm TL), suggesting that the fast growing fish spawned at Age I+.

Second annuli were observed only on scales of the 1983 year class and began appearing as spawning marks on scales in July 1985 (Fig. 1). Second annuli did not appear on scales during the winter or early spring when first annuli were formed, probably because Age II fish did not grow during the spring. Annulus and spawning mark formation occur simultaneously in the spring in anadromous populations of blueback herring (Beal 1968, Street and Adams 1969, Kornegay 1978).

Sexes of blueback herring from Lake Theo were not easily distinguishable by examination of gonads until fish were approximately 100 mm TL. Females were usually longer than males of the same age in any given sample (Table 1). There was no significant difference ($P = 0.31$; $F = 1.04$; df $= 1{,}460$) among adjusted mean weights between sexes so these data were combined to calculate the overall weight-length relation:

$$\log W = -5.34 + 3.12 \log L \; ; r^2 = 0.97; N = 601.$$

Adult anadromous blueback herring are usually collected during their spawning migrations up rivers; females are typically longer than males of the same age, and weight-length relationships between sexes are different (Beal 1968).

Blueback herring in Lake Theo achieved a maximum age of 2–3 years (Fig. 1) which is much less than that reported for anadromous populations. According to other investigations, anadromous herring live 7 to 9 years (Beal 1968, Marcy 1969, Kornegay 1978).

Reproductive Cycle

Young-of-year herring were first collected in December 1982 (Fig. 1). In subsequent years, Y-O-Y herring were first collected in fall or winter. Successful reproduction and recruitment of blueback herring occurred each year of the study. As previously noted, no other clupeids were present in Lake Theo. C. R. Guier (N.C. Wildl. Resour. Comm., Raleigh, pers. commun.) stated that it was difficult to establish blueback herring in North Carolina reservoirs and herring recruitment became limited in 2 South Carolina reservoirs when the density of threadfin shad increased (Bulak and Christie 1980).

Based on GSI values, some of the 1982 year class reached sexual maturity at Age I+ (Fig. 2) when they averaged 175 mm TL (Fig. 1) as scale analyses suggested. Females of the 1983 and 1984 year classes did not mature until Age II+

Table 1. Mean total lengths (with SE) for male and female blueback herring by age, year class, and month of collection, Lake Theo, Briscoe County, Texas. Sample size is in parentheses.

Age group	Month	1982 year class Male	1982 year class Female	1983 year class Male	1983 year class Female	1984 year class Male	1984 year class Female	1985 year class Male	1985 year class Female
I	3			134 ± 4 (5)	137 ± 3 (3)				
	4	174 ± 1 (10)	170 ± 4 (7)	151 ± 4 (2)	141 ± 3 (8)	132 ± 3 (8)	137 ± 3 (12)	99 ± 2 (3)	99 ± 2 (8)
	5			144 ± 3 (7)	147 ± 2 (10)	149 ± 6 (4)	160 ± 3 (6)		
	6			149 ± 2 (11)	152 ± 4 (8)	169 ± 6 (6)	168 ± 6 (6)		
	7	175 ± 1 (15)	187 ± 2 (9)	159 ± 3 (7)	167 ± 4 (5)	179 ± 4 (5)	182 ± 2 (4)		
	8			174 ± 2 (12)	179 ± 2 (8)	187 ± 5 (3)	199 ± 1 (11)		
	9			185 ± 2 (9)	194 ± 2 (9)	195 (1)	197 (1)		
	10	201 ± 2 (12)	211 ± 1 (7)			181 (1)	209 ± 1 (4)		
	11					202 ± 3 (3)	204 ± 2 (5)		
	12					191 ± 2 (7)	205 ± 4 (3)		
II	1	204 ± 1 (9)	217 ± 1 (14)			194 ± 3 (6)	200 ± 3 (3)		
	2					201 ± 2 (5)	208 ± 3 (5)		
	3	201 (1)	220 ± 5 (2)	198 ± 2 (6)	207 ± 1 (7)				
	4	196 ± 1 (3)	216 ± 1 (2)	201 ± 1 (10)	212 ± 1 (10)	199 ± 3 (3)	211 ± 3 (2)		
	5			199 ± 1 (9)	214 ± 3 (7)				
	6			200 ± 2 (10)	206 ± 3 (10)				
	7			196 ± 4 (6)	201 ± 4 (12)				
	8			209 ± 3 (4)	218 ± 5 (3)				
	9			212 (1)	215 (1)				
	10			215 ± 1 (2)	221 ± 3 (3)				
	11			212 ± 5 (3)	230 ± 2 (8)				
	12			217 ± 5 (2)	219 ± 3 (3)				
III	1			198 (1)	214 ± 4 (4)				

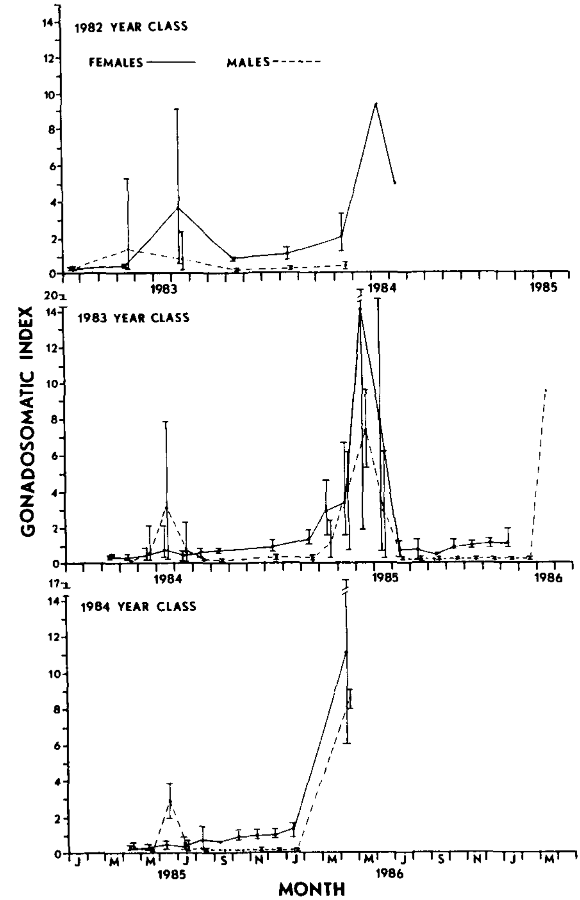

Figure 2. Mean gonadosomatic indices (with ranges) by year class for male and female blueback herring, Lake Theo, Briscoe County, Texas, 1983–1986.

when they were approximately 200 mm TL. Males of both year classes showed signs of maturation at Age I+, but higher GSI values were noted for Age II+ males. The 1982 year class grew more rapidly early in life than the other year classes and matured earlier. Length attained prior to the spawning season could determine age at maturity.

Fecundity of female blueback herring (Age II; 190–216 mm TL; $N = 10$) ranged from 30,933 to 61,333 eggs. The equation explaining the egg-ovary weight relationship was:

$$\text{egg number} = 26{,}441 + 2{,}804\,(\text{ovary weight; g});\ r^2 = 0.69.$$

Age and size at maturity of Lake Theo herring differed from that reported for anadromous populations. Anadromous blueback herring first mature at Age III to

IV and at lengths of approximately 240 to 250 mm TL (Marcy 1969, Street and Adams 1969, Scherer 1972). Fecundity estimates for anadromous blueback herring varied widely, ranging from 45,00 to 400,000 eggs (Street 1969, Loesch and Lund 1977). If the lower fecundity range cited is associated with the smallest mature herring, then fecundity estimates from the landlocked population of herring in Lake Theo are similar.

Based on GSI values, blueback herring spawned in Lake Theo from April through July (Fig. 2). In 1985 spawning occurred in May–June. Mean water temperatures (1-m depth) were 21° and 25°C, respectively, during sampling in these months. Temperatures in July and August were 27°C and GSI values indicated an end to spawning activity. For anadromous blueback herring, spawning begins at 14°C, optimum temperatures are between 21° and 24°C and spawning ceases above 27°C (Loesch and Lund 1977).

The findings of this study, although specific to Lake Theo, contribute to the utility of further introductions of blueback herring in southern reservoirs. Spawning and recruitment requirements were met in Lake Theo. What effect competition with other clupeids has on successful blueback herring recruitment was not evaluated; however, alewives have been shown to be compatible with gizzard shad due to spatial segregation (Tisa et al. 1985). Blueback herring's potential early age at maturity offsets their relatively short life span. Growth and maximum size attained by blueback herring will probably be influenced by competition and prey availability more than any other factor. If reduced zooplankton density is a requirement for optimal slow growth of blueback herring, effects on the recruitment of other fish species warrants concern.

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