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GIZZARD SHAD STOCK ESTIMATE FOR LAKE APOPKA, FLORIDA, 1995

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Executive Summary

Gizzard shad *Dorosoma cepedianum* have achieved a large biomass in Lake Apopka, Florida. Removal of a large portion of this biomass will remove significant amounts of phosphorus in this highly eutrophic lake and help create conditions more conducive for establishing desirable sportfish populations. Under the direction of the St. Johns River Water Management District, 281,198 kg of gizzard shad were commercially removed from Lake Apopka in 1995 by gill nets. Evaluation of this restoration method requires determining the proportion of the total gizzard shad population harvested. This report provides population estimates of gizzard shad prior to the harvest and evaluates methods used to produce the population estimates.

Population estimates were calculated by change-in-composition, depletion (Leslie estimate), and Baranov's catch equation methods. Input data for these calculations included harvest and fishing effort for the duration of the commercial fishery (16 January - 5 April 1995); age, length, weight, and gender of fish in experimental gill net (6.4-12.7 cm square mesh) samples collected before and after the commercial fishery and monthly during the commercial fishery; and length data from commercial gill net catches during August-November 1995. Age was determined by analysis of sagittal otoliths obtained from the sampled fish. Validation of otoliths for ageing gizzard shad was constrained by lack of otoliths collected throughout the year; however, marginal increment analysis of otoliths collected during January-June suggested otoliths provided accurate ages of gizzard shad in

Lake Apopka. We assumed the ages of gizzard shad assigned by otolith analysis were accurate and used these ages in population estimation calculations.

The change-in-composition method estimated the population of Lake Apopka gizzard shad was 1,618,354 fish (95% confidence limits [CL] = 1,441,597 and 1,795,111 fish) weighing 657,537 kg (95% CL = 585,721 and 729,354 kg). This estimate excludes the segment of the population too small to be effectively sampled by the experimental gill nets (<280 mm).

The depletion method estimated the population was 1,505,811 fish (95% CL = 903,490 and 18,390,461 fish) weighing 928,634 kg (95% CL = 557,182 and 11,341,397 kg). This estimate is for gizzard shad longer than 300 mm. Although similar to the change-in-composition estimate, the precision of the estimate was low. The variation in catch rates and relatively low harvest reduced the reliability of this estimate.

The catch equation method estimated the population was 3,877,582 fish (95% CL = 2,925,094 and 4,969,049 fish) weighing 2,195,874 kg (95% CL = 1,656,481 and 2,813,972 kg). This estimate is for fish longer than 280 mm and age 1 or older. Expanding the estimate to the entire population resulted in an estimated 12,041,034 fish weighing 2,911,809 kg. This estimate equates to a standing crop of 233 kg/hectare, which is lower than expected for hypertrophic Lake Apopka.

Population estimates from the change-in-composition method and the catch equation method both provided estimates with reasonable and relatively narrow confidence limits.

Although the catch equation method resulted in a population estimate more than twice the estimate obtained by the change-in-composition method, both estimates must be considered equally reliable based on similarly narrow confidence limits. Both methods are subject to errors in measurement of input parameters obtained at the beginning and end of the harvest period.

A total of 281,198 kg and an estimated 402,493 gizzard shad were harvested from Lake Apopka during January-April 1995. This harvest was 25% and 9% of the number of harvestable fish estimated by the change-in-composition and catch equation methods, respectively; and 43% and 11% of the weight of harvestable fish estimated by the change-in-composition and catch equation methods, respectively.

Future estimation of Lake Apopka gizzard shad should use the change-in-composition and catch equation methods. Both methods are subject to errors in measurement of input parameters obtained at the beginning and end of the harvest period. The reliability of future population estimates can be increased by greater harvest; complete subsampling of landings to measure length, weight, gender, and age of at least 300 fish during each month of the commercial fishery; and measuring length, weight, gender, and age of at least 300 fish from experimental gill net samples collected immediately before and after the commercial harvest program. Future interpretation of population estimates by these two methods should consider trends in population estimates and sensitivity analyses for variation in input parameters should be performed.

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Gizzard Shad Stock Estimate for Lake Apopka, Florida

Gizzard shad *Dorosoma cepedianum* have achieved a large biomass in Lake Apopka, Florida. Removal of a large portion of this biomass will remove significant amounts of phosphorus in this highly eutrophic lake and may provide a gizzard shad population more condicive for establishing desirable sportfish populations. Under the direction of the St. Johns River Water Management District, commercial fisherman fishing gill nets removed 281,193 kg of gizzard shad from Lake Apopka during January-April 1995. The purpose of this project is to provide an estimate of the stock of gizzard shad prior to the harvest and to evaluate methods used to provide the stock estimates.

Methods

Fish Sampling

Three samples of gizzard shad were collected with standard experimental gill nets by the Florida Game and Fresh Water Fish Commission (FGFWFC) and Mississippi State University 11-12 January 1995 prior to the commercial fishery. The experimental gill nets were 90-m long and consisted of six, 15-m long panels of mesh ranging in size from 6.4-cm to 12.7-cm square mesh. Gill nets were fished until a minimum of 100 fish was obtained for each of three replicate samples. Using the same experimental gill nets, samples of the gizzard shad were obtained by FGFWFC 27 February (four replicate samples), 27 March (four replicate samples) and 26 April (one replicate sample). A final sample of gizzard shad was collected 21-22 June (after the commercial fishery terminated) with standard experimental gill nets by FGFWFC. Gill nets were fished until approximately 100 fish were obtained for each of three replicate samples. Total length (TL, mm), weight (g), and gender were recorded and sagittal otoliths were removed from all fish in all samples. Otoliths were sent to Mississippi State University for age analysis.

The Lake Apopka gizzard shad commercial fishery began 16 January 1995 and continued until 5 April 1995. Gill nets used by commercial fishers had mesh size of 10.2-cm to 11.4-cm square mesh. Weights of landings were recorded daily for each fisher (Appendix 1).

Otolith Analysis

Gizzard shad were aged by analysis of sagittal otoliths. Except for otoliths of small (<250 mm TL) gizzard shad, opaque bands were not visible in whole view and sectioning otoliths was necessary to count opaque bands. Otoliths were prepared for analysis using methods similar to those evaluated by Benton et al. (1995). Whole otoliths were ground to make a thin dorso-ventral cross section that included the nucleus. Large otoliths (generally from fish larger than 300 mm TL) were held with a forceps to grind the anterior end of the otolith to near the nucleus. The partially ground otolith was mounted on a glass slide, ground face down, with thermoplastic cement. The posterior end was then ground leaving a thin (usually less than 0.5 mm), dorso-ventral section of the otolith containing the nucleus. Smaller otoliths were mounted vertically (anterior end up) on a glass slide with thermoplastic cement and the anterior end ground in a dorso-ventral plane to approximately the nucleus. The thermoplastic cement was heated to loosen the partially ground otolith, and the otolith recemented with the ground face on the slide. The posterior end was then ground as for larger otoliths. All otoliths were ground with a wet grinder until opaque bands were visible. Otoliths were then polished by wet-sanding with extra-fine, wet-dry sandpaper.

Sectioned and whole otoliths were viewed using compound and dissecting microscopes. Immersion oil was applied to the mounted otoliths to improve clarity. Opaque bands appeared as dark bands when viewed with transmitted light (cross sections viewed with a compound microscope) and as white bands when viewed with reflected light (whole otoliths and cross sections viewed with a dissecting microscope). Prior to assigning the number of opaque bands and presence of marginal opaque zones that would be used in data analysis, more than 100 otoliths were independently analyzed by two readers. Differences in interpretation were discussed and resolved, and criteria were developed for counting opaque bands, determining the presence of a marginal opaque zone, and measuring otolith radius and distance to recently formed opaque bands. Using these criteria, all otoliths were then analyzed by one reader. Otolith radius (distance from the center of the nucleus to the edge of the otolith, *OR*) and distance to the most recently formed opaque band (R_x) were measured in micrometer units.

Data Analyses

Although otoliths have been demonstrated to provide accurate ages for a variety of freshwater fishes, otoliths have not been validated (*sensu* Beamish and MacFarlane 1983) as accurate ageing structures for gizzard shad. Marginal increment analysis (Schramm and Doerzbacher 1983; Casselman 1987) was performed to provide presumptive validation of Lake

Apopka gizzard shad. Opaque bands (presumptive annuli) are initially formed at the surface of an otolith and would be visible in whole or cross-sectional views as an opaque zone at the otolith margin. An opaque band (annulus) is considered formed when a translucent or hyaline zone is visible distal to the opaque band. The hyaline zone distal to the most recently formed opaque band is called the marginal increment. In the case of a recently formed opaque band, the marginal increment would be narrow and a small proportion of the otolith radius. In the case of an opaque zone at the otolith margin, the marginal increment is zero. For relatively fast-growing and short-lived species such as gizzard shad, a marginal increment less than 5% of otolith radius may indicate the presence of a recently formed opaque band. If marginal increment analysis indicates that opaque bands are formed only once a year and during a relatively brief time period, the opaque bands can be considered valid annuli. The validation of Lake Apopka gizzard shad by marginal increment analysis was constrained by the absence of otoliths collected in July-December. All otoliths were inspected for the presence of opaque zones at the otolith margin and their presence noted. Marginal increments as a proportion of otolith radius (R_x/OR) was calculated for all fish.

Weight-length relationships were developed for gizzard shad collected with experimental gill nets in January. Assuming each opaque band was an annulus, mean length at each age was estimated from fish collected in the January sample. Differences between male and female fish in weight-length relationships and length at age were tested by analysis of covariance. All statistical analyses were performed using SAS (1990).

Population size was estimated by the change-in-composition (dichotomy) method, depletion (Leslie) method, and Baranov's catch equation method. Computations for all methods follow Ricker (1975).

Change-in-Composition Method

This method can be used to estimate population size if there are two types of fish in a population and the abundance of one type can be altered differentially from that of the other type. Growth rate of female gizzard shad in Lake Apopka was expected to be greater than growth rate of male gizzard shad (Benton et al. 1995). As a result of faster growth rate, the female fish would be more vulnerable to commercial harvest and, therefore, removed at a greater rate than would males.

Given that N is the number of gizzard shad, N_m is the number of male gizzard shad, and N_f is the number of female gizzard shad at $t=1$ (i.e., before the commercial fishery began), maximum likelihood estimators of N, N_m, and N_f are, after Chapman (1955):

$$N_m = \frac{p_1(C_m - p_2C)}{p_1 - p_2},$$

$$N = \frac{C_m - p_2C}{p_1 - p_2}, \text{ and}$$

$$N_f = N - N_m;$$

where:

$$p_1 = m_1/n_1,$$

$p_2 = m_2/n_2$,

n_1, n_2 are the size of samples taken at the beginning ($t=1$) and end ($t=2$) of the harvest period,

m_1, m_2 are the number of males in samples n_1, n_2,

f_1, f_2 are the number of females in samples n_1, n_2,

C_m = number of males caught during the harvest period (between $t=1$ and $t=2$),

C_f = number of females caught during the harvest period (between $t=1$ and $t=2$),

$C = C_m + C_f$.

Confidence limits for N are calculated from the variance of N by

$$Var(N) = \frac{N^2\,Var(p_1) + (N-C)^2\,Var(p_2)}{(p_1 - p_2)^2}$$

where:

$$Var(p_1) = \frac{p_1(1-p_1)(1-n_1/N_1)}{n_1 - 1}$$

$$Var(p_2) = \frac{p_2(1-p_2)(1-n_2/N_2)}{n_2 - 1}$$

N_1 = the estimated number of fish at time 1

N_2 = the estimated number of fish at time 2 = $N_1 + C$

(Everhart and Youngs, 1981).

The proportion of males (m_1, m_2) and proportion of females (f_1, f_2) at the beginning and end of the harvest period were obtained from the experimental gill net samples before and after the harvest period. The number of males caught during the harvest period (C_m) was obtained by summing the products of the proportion of males in each monthly sample of the landings multiplied by the estimated number of fish landed in that month for the three time periods. Similarly, summing the mean proportion of females in a sample times the estimated number of fish landed in the corresponding time period for the three time periods provided an estimate of C_f. The proportion of males and females for each sample was estimated from the experimental gill net samples obtained in February, March, and April. Length data for fish caught by commercial gill nets were available for commercial landings during August-November 1995. These data were analyzed to determine the minimum length at which gizzard shad were recruited to the commercial gill nets. Fish longer than this length caught with the experimental gill nets were assumed to be representative of fish caught in the commercial gill nets. Therefore, the proportions of males and females in the commercial landings during 16 January-27 February were the means of the number of males and females large enough to recruit to the commercial gill nets divided by the total number of fish large enough to recruit to the commercial gill nets in four replicate experimental gill net samples obtained 27 February. Similarly, the proportions of males and females in the commercial landings during 28 February-27 March were the means of the number of males and females large enough to recruit to the commercial gill nets divided by the total number of fish large enough to recruit to the commercial gill nets in four replicate experimental gill net samples obtained 27 March. The proportions of males and females in the 28 March-5 April commercial landings were the number of males and females large enough to recruit to the commercial gill nets divided by the total number of fish large enough to recruit to the commercial gill nets in the experimental gill net sample obtained 26 April (no replicates were available for the April sample). Weight of fish landed in each harvest period (16 January-27 February, 28 February-27 March, and 28 March-5 April) was converted to number of fish landed. The weights of fish large enough to recruit to the commercial gill nets in each experimental gill net sample (all replicate samples combined for each sample) were estimated from total lengths of individual fish in the experimental gill net sample by the weight-length relationship; for each fish, the weight was estimated from total length by gender and the weights of all fish in the sample were summed. This weight was divided into the total weight of the landings for the time period corresponding to the sample to estimate the number of fish landed during each time period. The 27 February sample was used for the 16 January - 27 February landings, the 27 March sample was used for the 28 February - 27 March landings, and the 26 April sample was used for the 28 March - 5 April landings.

The change-in-composition method estimated the number of gizzard shad in the population effectively sampled by the standard experimental gill nets. The numerical population estimate and 95% confidence limits were converted to weight by multiplying by average weight of fish in the January experimental gill net sample.

Depletion Method

This method estimates the size of the population from the equation that represents the relationship between catch/effort (C/f) and cumulative catch (K) (Ricker 1975):

$$C/f = a + q(K);$$

where:

a is the y-intercept of the regression equation, and

q is the slope of the regression equation.

The initial population (N_0) is estimated by substituting $C/f = 0$ into the equation and solving for K; at $C/f=0$, $K = a/q = N_0$.

The relationship between C/f and K was obtained by linear regression of the commercial gizzard shad landings. Catch rate (C/f) is expected to be highly variable due, possibly, to changes in efficiency of the gear with weather and changes in the behavior of the fish that would affect catchability. In an attempt to reduce some of this variation and provide a regression model that best fit the data, separate regressions were performed using average daily C/f, average weekly C/f, and average C/f for six equal time periods (approximately biweekly) during the period of commercial harvest (16 January - 5 April). In the above regressions, f was defined as (1) yards of net multiplied by hours fishing (SFU on the commercial landings report, Appendix I) and (2) yards of net. Therefore, a total of six regression equations were calculated.

Confidence limits for the depletion estimates were estimated by solving for N (using the upper and lower values from the quadratic equation as upper and lower confidence limits) in the formula provided by DeLury (1951):

$$N^2(q^2 - t_p^2 s_{yx}^2 c_{22}) - 2(q^2 N_0 - t_p^2 s_{yx}^2 c_{12})N + (q^2 N_0^2 - t_p^2 s_{yx}^2 c_{11}) = 0$$

where:

q = catchability coefficient, slope of regression,

N_o = estimated population at $t=0$,

s^2_{yx} = variance of the points of the regression line,

c_{11} = $\Sigma X^2/n\Sigma x^2$, where X is K and Σx^2 is sum of squares of K, ΣK^2-$(\Sigma K)^2/n$,

c_{12} = $\Sigma X/n\Sigma x^2$.

c_{22} = $1/\Sigma x^2$.

t_p = the t-statistic corresponding to a given probability P for n - 2 degrees of freedom,

n = the number of days of fishing

The depletion method estimates the initial population (before the commercial fishery began) in weight (calculations were made with pounds data). Estimated population and 95% confidence limit weights were converted to numbers of fish by dividing the mean weight of all fish in the January experimental gill sample that were considered recruited to the commercial gill nets into the estimated population and 95% confidence limit weights.

Baranov Catch Equation

Total instantaneous mortality (Z) is the sum of instantaneous fishing mortality (F) and instantaneous natural mortality (M) (Ricker 1975):

$$Z = F + M.$$

Z is the negative slope of the regression of $\ln(N)$ on age (catch curve). This estimation of Z assumes recruitment and mortality are constant for a time period at least equal to the life span of the fish. Because the catch curve is based on age measured in years, Z is an "annualized" rate; i.e., the reduction in the abundance of fish from age 2 to age 3 is assumed to occur in one year. There is no sport harvest of gizzard shad in Lake Apopka. Total mortality before the commercial fishery begins ($F = 0$) is natural mortality. Assuming natural mortality (M) remains constant, the difference between total mortality at the end of the commercial fishery (Z_2) minus total mortality at the beginning of the commercial fishery (Z_1) is fishing mortality:

$$Z_2 - Z_1 = F$$

From estimation of Z and F, population size (N) can be calculated by Baranov's catch equation (Ricker 1975):

$$C = \frac{FAN}{Z} = uN,$$

where:

C is total catch

$A = 1 - e^{-Z}$, actual total (annual) mortality

$u = \frac{FA}{Z}$, exploitation rate for a Type 2 fishery (fishing and natural mortality operate concurrently)

Z_1 was estimated from the age frequency of the 11-12 January experimental gill net catch. Z_2 was estimated from the age frequency of the 21-22 June experimental gill net catch.

No formula exists for the variance of N estimated by the catch equation. Confidence limits for catch equation estimation of N were developed from the pooled variance of Z_1 and Z_2. Confidence limits were calculated by substituting the upper and lower 95% confidence limits of Z (pooled variance of Z_1,Z_2 x $t_{df,\ 0.025}$) for Z and the corresponding values for A (calculated from the upper and lower confidence limits of Z) in the catch equation.

The catch equation method estimates the number of fish fully recruited to the experimental gill net. Estimated population size in numbers of fish was converted to weight by multiplying the estimated number of fish by the mean weight of fish fully recruited to the experimental gill net in January.

The catch curves were calculated for lengths and age classes fully recruited to the experimental gill nets fished in January and June. Fish longer than 280 mm and age 1 and older were considered recruited to the experimental gill nets (see Results). The total mortality estimate from the January catch curve (Z_1) was used (as in a cohort analysis) to estimate the number of younger fish. This estimation procedure required the assumption that mortality of younger fish (age-0 fish) was the same as the mortality of fish in the sample used to estimate Z (ages 1-5 fish). The number of age-1 fish was estimated from the population estimate times the proportion of age-1 fish in the population sample. Dividing the estimated number of age-1 fish by the annual survival rate (S, $S = e^{-Z}$) provided an estimate of the number of age-0 fish.

Results

Validation of otoliths as accurate ageing structures currently is being attempted by marginal increment analysis of gizzard shad from Aliceville Lake, Mississippi. Although validation has not been completed, results to date suggest otoliths provide valid ages for Lake Apopka gizzard shad. The age-length frequency indicated larger fish had more opaque bands (i.e., were aged as older fish, Figures 1 and 2). During January - June, most fish had a marginal increment greater than 5% of otolith radius (Table 1). The scarcity of small marginal increments suggests that opaque bands were not formed during January-June. Fish with a high percentage of small marginal increments were age 3 or older. This is attributable to slow growth in length (and in otolith radius) of older and larger fish (i.e., only a small increase in otolith radius since the formation of the last opaque band). The steady increase in length of most age groups also suggests that opaque bands had not formed between January and June (Table 2). New opaque bands at the margin of the otolith were not observed in any fish collected during January, February, March, or April but were present in 23-38% of fish with 0, 1, or 2 opaque bands on their otoliths in June. The presence of opaque zones at the otolith margin in June and the scarcity of small marginal increments during January-June suggests that opaque bands are just beginning to form in June. For the purpose of this report, the number of opaque bands on gizzard shad otoliths will be considered accurate ages of Lake Apopka gizzard shad.

Weight (*WT*) and total length (*TL*) were measured for 444 gizzard shad collected with experimental gill nets in January. Mean length of fish collected was 308.4 mm (SE = 3.25, range = 93-451 mm) and mean weight was 406.3 g (SE = 13.4, range = 56-1,300 g). The weight-length relation for Lake Apopka gizzard shad was:

all fish: $log_{10}(WT) = 0.9231 + 0.0051(TL)$

$N = 444,\ R^2 = 0.9644.$

The weight-length relations for Lake Apopka gizzard shad (Figure 3) differed ($P<0.001$) between male and female fish:

males: $log_{10}(WT) = -6.2141 + 3.5057(log_{10}TL)$

$N = 189,\ R^2 = 0.9832;$

mean TL = 295.1, SE = 4.01, range = 191-400 mm mean WT = 324.0, SE = 14.43, range = 60-848 mm

females: $log_{10}(WT) = 0.9584 + 0.0049(TL)$

N = 234, R^2 = 0.9663;

mean TL = 326.5, SE = 4.67, range = 93-451 mm

mean WT = 496.5, SE = 20.48, range = 68-1,300 mm

The N for the all-fish model exceeded the sum of N from the male and female models because gender was not determined for some fish. The model for males regressed $log_{10}(WT)$ on $log_{10}(TL)$, whereas the models for females and all fish regressed $log_{10}(WT)$ on TL. For all three models, the model selected was the model with higher R^2 and with better fit (based on visual inspection of plots) of predicted values (generated from the equation) and observed data.

Female gizzard shad growth rate was faster (P=0.009) than male gizzard shad (Table 2).

Change-in-Composition Population Estimate

The Lake Apopka gizzard shad population was 47.35% males in January (Table 3). Females were a larger percentage of the harvest than males. In June, the population was 50.44% males.

Sex ratio data for the commercial landings were obtained from experimental gill net catches by analyzing the catch with experimental gill nets of fish large enough to recruit to the commercial gill nets. Samples of fish from the commercial landings during August-November 1995 indicated gizzard shad were fully recruited to the commercial gill nets at 310 mm (Figure

4). However, length frequency distribution of gizzard shad caught with commercial gill nets in August 1995 indicated fish were fully recruited at 300 mm. The lower frequency of 300 mm length group fish for 1995 could have resulted from a weak 1994 year class (otolith analysis indicated age-1 gizzard shad averaged 318 mm) or rapid growth from 300 mm to greater lengths. We estimated the sex ratio of fish in the commercial landings from fish longer than 300 mm caught by the experimental gill nets. Mean percentages of male gizzard shad longer than 300 mm in experimental gill nets catches were 37% in February, 42% in March, and 29% in April (Table 3).

Mean weights of fish in the commercial gill net landings were also based on fish longer than 300 mm caught with experimental gill nets. Total landings during the three harvest periods ranged from 7,608-190,549 kg and 9,610-279,627 fish (Appendix 1, Table 3).

By calculation, the pre-commercial harvest population of gizzard shad was:

males (N_m) = 766,291 fish

females (N_f) = 852,063 fish

total estimated population (N) = 1,618,354 fish; lower and upper 95% confidence limits = 1,441,597 and 1,795,111 (Table 4).

(Note: calculations were based on greater precision than shown in Table 3.)

Average weight of fish sampled by the experimental gill nets in January was 406.3 g (N=444, standard error=13.4). Applying this weight to the population estimation resulted in an estimated population standing stock of 657,537 kg with 95% confidence limits of 585,721 kg and 729,354 kg.

<u>Depletion Estimate of Population Size</u>

Six depletion analyses were conducted. Regression analyses of average daily *C/f*, average weekly *C/f*, and average biweekly *C/f* on cumulative catch with *f* defined as yards of net multiplied by hours fished resulted in positive slopes (Equations 1-3, Figure 5) and precluded estimation of *N*.

Eq. 1. $C/f = 3.196 + 0.000007(K)$; $R2 = 0.0808$; slope significantly different (P=0.03) from 0

C/f is mean daily catch/(yards net x hours fished)

Eq. 2. $C/f = 1.142 + 0.0000002(K)$; $R2 = 0.0050$; slope not significantly different (P=0.81) from 0

C/f is mean weekly catch/(yards net x hours fished)

Eq. 3. $C/f = -0.020 + 0.000002(K)$; $R2 = 0.2554$; slope not significantly different (P=0.31) from 0

C/f is mean biweekly catch/(yards net x hours fished)

Regression analyses of average daily *C/f*, average weekly *C/f*, and average biweekly *C/f* on cumulative catch with *f* defined as yards of net resulted in negative slopes (Equations 4-6, Figure 6) and allowed estimation of *N*.

Eq. 4. $C/f = 257.958 - 0.000126(K)$; $R2 = 0.0702$; slope significantly different (P=0.04) from 0

C/f is mean daily catch/yards net

N = 2,047,287 pounds

Lower 95% confidence limit = 1,228,377 pounds

Upper 95% confidence limit = 25,003,501 pounds

Eq. 5. C/f = 254.965 - 0.000084(K); $R2$ = 0.0570; slope not significantly different (P=0.41) from 0

C/f is mean weekly catch/yards net

N = 3,032,693 pounds

Lower 95% confidence limit = 1,079,578 pounds

Upper 95% confidence limit = 1,279,951 pounds

Eq. 6. C/f = 237.154 - 0.000057(K); $R2$ = 0.0704; slope not significantly different (P=0.61) from 0

C/f is mean biweekly catch/yards net

N = 4,187,402 pounds

Lower 95% confidence limit = 496,911 pounds

Upper 95% confidence limit = 1,013,935 pounds

As is apparent in Figures 5 and 6 and indicated by the low variance accounted for (R^2), all relationships of C/f with cumulative catch were weak (there was a lot of scatter). Only Equation 4 had a negative slope that was significantly different from 0. Equation 4 also was the only equation that provided constants that resulted in calculation of 95% confidence limits that bounded N.

Fish longer than 300 mm TL were considered to be fully recruited to the commercial gill nets (Figure 4). Using the January experimental gill net data, mean weight of fish longer than 300 mm was 616.7 g (N = 244, SE = 2.11). Applying this weight to the population estimate from Equation 4 resulted in an estimated N of 1,505,811 fish with 95% confidence limits of 903,490 fish and 18,390,461 fish (Table 4).

Baranov Catch Equation Population Estimate

The catch curves for January and June experimental gill net catches both showed expected declines in catch frequency with age (Figures 1 and 2) and support the assumption of similar recruitment and mortality over time. By visual and statistical analysis (improvement in R^2) of January and June catch curves, gizzard shad were fully recruited to the experimental gill nets at TL $\geq$ 280 mm and age $\geq$ 1 (Figures 7 and 8). These are sizes and ages similar to those at which gizzard shad recruited to the commercial gill nets (Figures 5-7).

The catch curves (Equations 7 and 8) indicated Z_1 = 1.1106 and Z_2 = 1.2958.

Eq. 7. $ln(N) = 5.3861 - 1.1106(\text{age}), R^2 = 0.9566$

Eq. 8. $ln(N) = 5.6045 - 1.2958(\text{age}), R^2 = 0.9292$

By calculation, F = 0.1852, A = 0.7263, and u = 0.1038. Total catch during the harvest period was 402,493 fish (from change in composition calculations, Table 3); therefore, N = 3,877,582 fish. Pooled variance for Z_1 and Z_2 was 0.0678 and the 95% confidence limits for Z were 1.2958 $\pm$ 0.6694. Substituting these values for Z (0.6264 and 1.9652) and corresponding values of A (0.4655 and 0.8599) into the catch equation, the lower confidence limit for N was 2,925,094 fish and the upper 95% confidence limit for N was 4,969,049 fish.

Fish longer than 280 mm TL and age 1 or older were considered to be fully recruited to the experimental gill nets. Using the January experimental gill net data, mean weight of fish longer than 280 mm and age 1 or older was 566.3 g (N = 120, SE = 21.71). Applying this weight to the population estimation resulted in an estimated N of 2,195,874 kg with 95% confidence limits of 1,656,481 kg and 2,813,972 kg.

Age-1 fish were 69.17% of the January gill net sample used to estimate Z_I (i.e., fish longer than 280 mm and age 1 or older). Therefore, the population contained 2,689,041 age-1 fish. At Z_I = 1.1106, annual survival (S) is 0.3294. Assuming survival from age 0 to age 1 was the same as survival from age 1 to older ages, the population of age-0 fish was 8,163,452. Adding these fish to the population estimate of 3,877,582 resulted in a total gizzard shad population of 12,041,034 fish. This estimate does not include fish that were age 1 or older and less than 280 mm TL; only one age-1 or older fish in the January experimental gill net sample was less than 280 mm long. Estimation of the weight of the age-0 fish is limited because the average length of age-0 fish (Table 2) likely is biased by incomplete recruitment to the experimental gill net and the weight-length relationship may not estimate the weights of small fish as accurately as for large fish (i.e., small fish were not equally represented in the sample used to calculate the weight-length). However, to approximate the biomass of the age-0 fish, the average length of age-0 fish in January is assumed to be 200 mm; this estimate is 53 mm less than the average length of age-0 male fish and 63 mm less than the average length of age-0 female fish captured in the January experimental gill nets. By the weight-length relationship, a 200 mm fish weighs 87.7 g, and the age-0 population has a biomass of 715,935 kg. The biomass of the gizzard shad population including age-0 fish would be 2,911,809 kg (6,419,440 pounds).

Discussion

Validation of otoliths as an accurate structure for ageing gizzard shad awaits further analysis. At present, Mississippi State University is conducting a marginal increment analysis of gizzard shad otoliths collected throughout the year in Aliceville Lake, Mississippi. However, the marginal increment analysis of Lake Apopka gizzard shad collected during January-June does suggest that opaque bands are formed once a year. Length-at-age analyses corroborates this finding and indicates that ages determined from opaque bands on otoliths are reasonable. Rutherford et al. (1995), assuming otoliths provided accurate ages of gizzard shad, obtained reasonable changes in otolith growth increment of gizzard shad collected in the Mississippi River. Otoliths have been shown to provide valid ages for another clupeid, blueback herring *Alosa aestivalis* (Schramm et al. 1992).

Three depletion estimates were calculated and population estimates ranged from 2,047,287 pounds (1,505,811 fish) to 4,187,402 pounds (3,079,899 fish). The regression of average daily *C/f* on cumulative catch was the only regression with a slope significantly different from 0. Therefore the estimate of 1.5 million fish calculated from average daily *C/f* is considered the most reliable. This estimate also was the only population estimate calculated by the depletion method which was bounded by the calculated 95% confidence limits. However, all three regression equations that allowed calculation of population size (regressions using *C/f* with effort defined as yards of net) accounted for little variation in the data. Furthermore, the small slope values (-0.000057 to -0.000126) are conducive to errors in estimating population size and are the reason for the wide confidence interval and confidence limits that do not include the population estimate. The ineffectiveness of the depletion estimate likely results from the low harvest of gizzard shad from Lake Apopka. Given relatively low harvest rates, the depletion method is not considered a reliable method for estimating the gizzard shad population size in Lake Apopka.

The other two population estimates ranged from 1.6 million fish weighing 0.7 million kg (change-in-composition estimate) to 3.9 million fish weighing 2.2 million kg (catch equation estimate). Both estimates have narrow confidence limits and the confidence limits do not overlap. Both estimates are based on sufficient data to allow relatively precise estimation of the population size, and we consider them equally reliable estimates of the Lake Apopka gizzard shad population.

Surface area of Lake Apopka is 12,473 hectares (30,821 acres). The two population estimates equate to gizzard shad densities and standing stocks of 130 fish/hectare and 53 kg/hectare for the change-in-composition estimate and 311 fish/hectare and 176 kg/hectare for the catch equation estimate. Standing stock of gizzard shad was 10 kg/hectare in open water and 30 kg/hectare in a 47 hectare arm that included 31 hectares of open water in Douglas Reservoir, Tennessee (Haynes et al. 1967). Douglas Reservoir is a relatively deep and low trophic state reservoir. Standing stock of gizzard shad was 255 kg/hectare in an 85 hectare arm of Barkley Lake, Kentucky, and 263 kg/hectare in the open water portion of that arm

(Aggus et al. 1980). Lake Barkley is relatively shallow and moderately fertile. Lake Apopka is eutrophic (hypertophic) and is expected to support a higher biomass of gizzard shad. Based on comparison with the biomass in Lake Barkley, the population estimates provided by the change-in-composition and the catch equations both underestimate the population of gizzard shad in Lake Apopka; however, the estimate calculated by the catch equation method appears more reasonable.

The estimate provided by the catch equation did not include age-0 fish and fish less than 280 mm TL. Expanding the population estimate to include age-0 fish resulted in an estimated 12,041,034 fish and a weight of 2,911,809 kg. The biomass estimate equates to a biomass of 233 kg/hectare. In comparison to Lake Barkley, the estimate of approximately 12 million fish may still underestimate the gizzard shad population in Lake Apopka.

One possible reason for low estimates of the gizzard shad population by the change-in-composition and catch equation methods is the location of the samples used to calculate variables for population estimation. Both these methods relied on data from experimental gill nets fished in January and June. While these samples are considered representative of the gizzard shad population, all samples were collected in a relatively small portion of Lake Apopka. The commercial fishery, on the other hand, fished throughout the lake. Therefore, the experimental gill net samples may not reflect changes in the population lake-wide. Future sampling methodology should consider collection of representative samples with experimental gill nets throughout the lake before and after the commercial fishery.

The scope of work for this project specified estimation of the gizzard shad population by cohort analysis. Cohort analysis was used to estimate the population of age-0 fish from population estimates obtained by catch equation calculations; however, cohort analysis was not used to estimate the total population by estimating the number of fish in each age group (cohort). Catch curve analyses provided precise estimates of mortality that are considered reasonable and these mortality estimates were used to estimate population size. Given precise and reasonable estimates of mortality and age structure of the population, estimation of these same variables by successive iteration (cohort analysis) or approximation (e.g., Pope's method; Pope 1972) was considered unnecessary.

Acknowledgements

Brian Hochman and Chris Russell prepared and analyzed otoliths. Richard Davis, Todd Driscoll, and Brian Hochman collected gizzard shad from Aliceville Lake, Mississippi to validate otoliths for ageing gizzard shad. Dan Hayes and Steve Miranda reviewed the statistical analyses and population estimates and provided valuable insights.

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Table 1. Occurrence of opaque bands at the margin of the otolith (marginal band, MB) and percent of fish with relatively narrow marginal increments for gizzard shad collected in Lake Apopka, Florida, January-June 1996. Marginal increment is measured as the ratio of the distance to the distal opaque band (R_x) to the otolith radius (OR).

Number of opaque bands	N of fish	$R_x/OR \geq 0.90$ % of fish	$R_x/OR \geq 0.90$ % of fish	MB % of fish
		January		
0	152			0
1	84	1	0	0
2	30	21	7	0
3	4	75	50	0
4	3	100	67	0
5	1	100	100	0
		February		
0	30	0	0	0
1	156	2	1	0
2	92	16	0	0
3	27	56	0	0
4	2	100	0	0
5	3	100	33	0
		March		
0	72	0	0	0
1	106	6	1	0
2	47	21	0	0
3	13	92	0	0
4	4	100	0	0

Table 1. Continued

Number of opaque bands	*N* of fish	$R_x/OR \geq 0.90$ % of fish	$R_x/OR \geq 0.90$ % of fish	MB % of fish
April				
0	24	0	0	0
1	18	11	0	0
2	19	26	0	0
3	2	100	50	0
4	2	50	50	0
June				
0	89	0	0	33
1	69	9	0	38
2	31	25.8	0	23
3	3	67	0	0
4	2	100	0	0

Table 2. Mean total length of male and female gizzard shad, Lake Apopka, Florida, January and June 1995. Values in parentheses are sample size, standard error.

Gender	Number of opaque bands					
	0	1	2	3	4	5
January 1995						
Male	253 (66, 4.2)	318 (45, 2.7)	343 (13, 5.7)	365 (2, 6.5)	379 (2, 13.5)	
Female	263 (80, 3.0)	364 (39, 4.2)	382 (16, 8.9)	421 (2, 9.5)	410 (1,)	423 (1,)
June 1995						
Male	274 (51, 4.8)	337 (34, 5.3)	387 (12, 10.8)	407 (2, 3.5)	382 (2, 7.0)	
Female	284 (38, 6.1)	372 (35, 4.6)	431 (19, 2.9)	392 (1,)		

Table 3. Mean proportions of male and female gizzard shad in experimental gill net samples and total catch and estimated numbers of male and female fish harvested by commercial gill nets in Lake Apopka, Florida, January-June 1995. Catch statistics for experimental gill nets during February, March, and April are for fish longer than 300 mm. Values in parentheses are sample size, standard error.

Time period	Experimental gill net catch				Harvest			
	Males, %	Females, %	Weight, kg	Number	Weight, kg	Number, total	Number males	Number females
January	47.35 (3,0.02)	52.65 (3,0.02)		283				
February	36.55 (4, 0.15)	63.45 (4, 0.15)	191.48	281	190,549	279,627	102,200	177,427
March	42.36 (4, 0.15)	57.64 (4,0.15)	141.51	193	83,041	113,256	47,973	65,283
April	29.27 (1,)	70.73 (1,)	32.46	41	7,608	9,610	2,813	6,797
June	50.44 (3, 0.14)	49.56 (3, 0.14)		226				

Table 4. Number and weight of the gizzard shad population in Lake Apopka, Florida in January 1995 estimated by the change-in-composition (CIC) method, the depletion method, and the catch equation method.

	Method of estimation		
Estimate	CIC	Depletion	Catch equation
Number of fish	1,618,354	1,505,811	3,877,582
Lower 95% CL	1,441,597	903,490	2,925,094
Upper 95% CL	1,795,111	18,390,461	4,969,049
Weight of fish (kg)	657,537	928,634	2,195,874
Lower 95% CL	585,721	557,182	1,656,481
Upper 95% CL	729,354	11,341,397	2,813,972
Weight of fish (lbs)	1,449,621	2,047,287	4,841,073
Lower 95% CL	1,291,294	1,228,377	3,651,915
Upper 95% CL	1,607,949	25,003,501	6,203,746

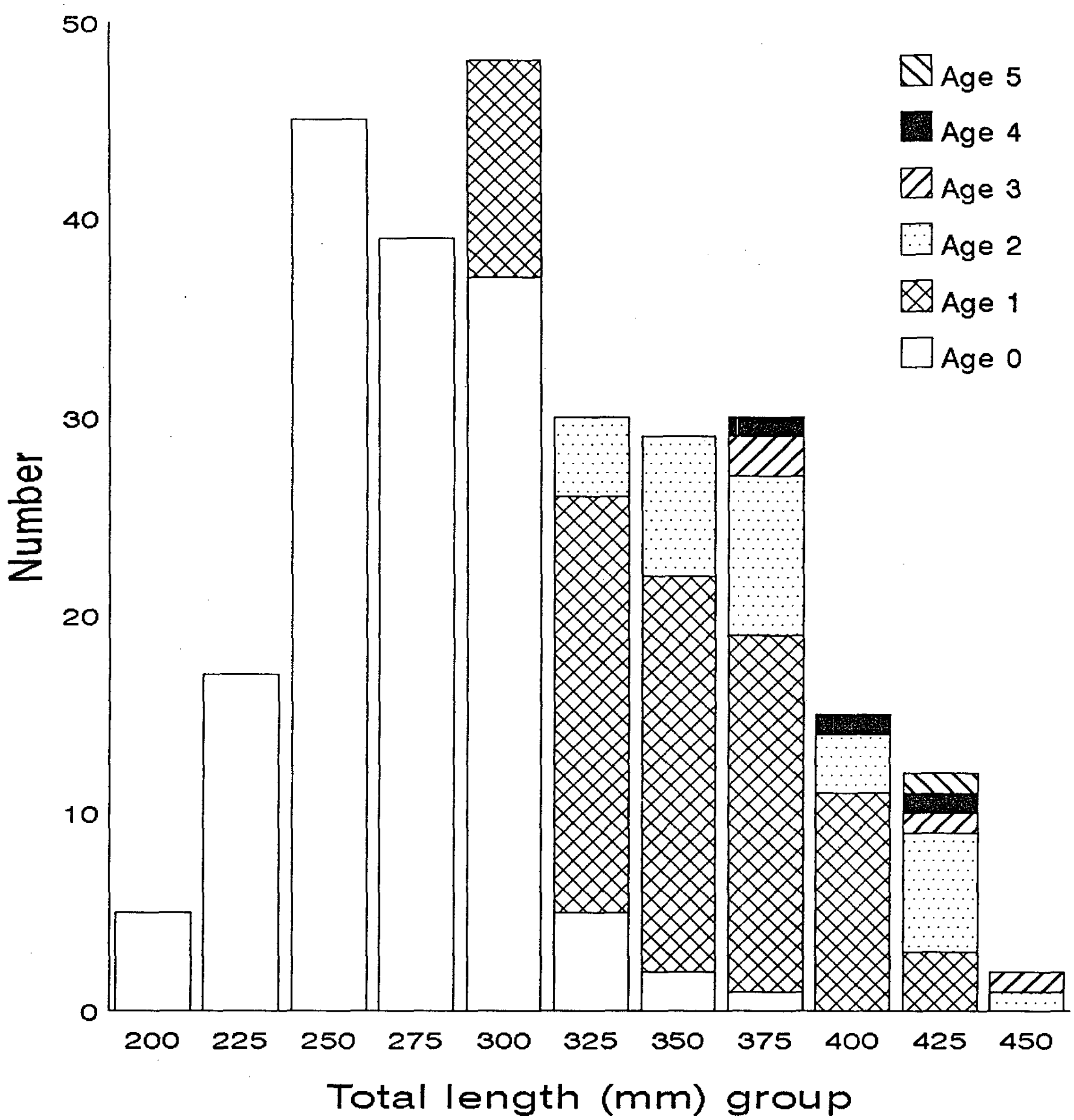

Figure 1. Frequencies of different ages and total lengths of gizzard shad in Lake Apopka, Florida, January 1995. Length group 200 includes all fish less than 225mm.

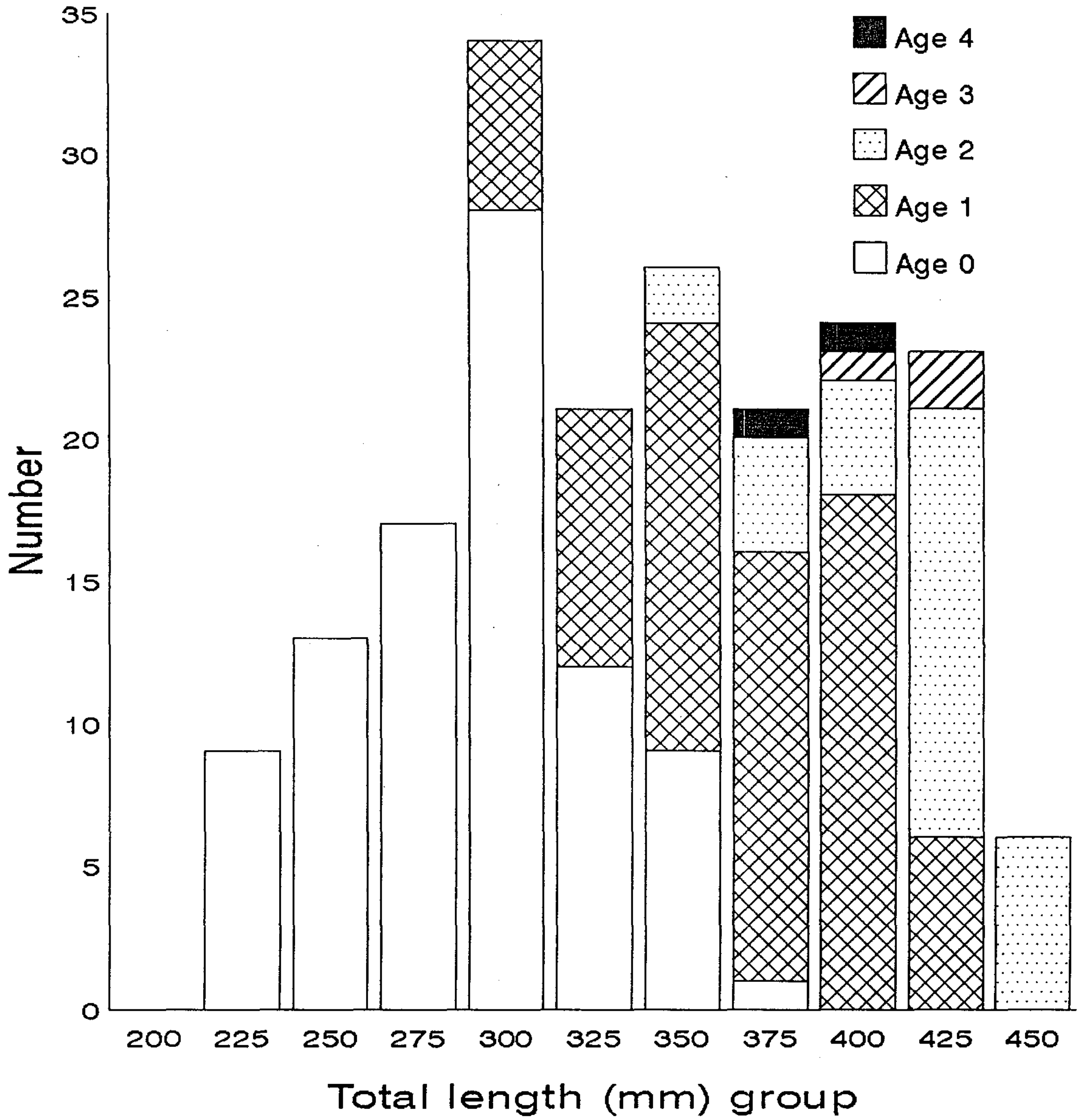

Figure 2. Frequencies of different ages and total lengths of gizzard shad, Lake Apopka, Florida, June 1995.

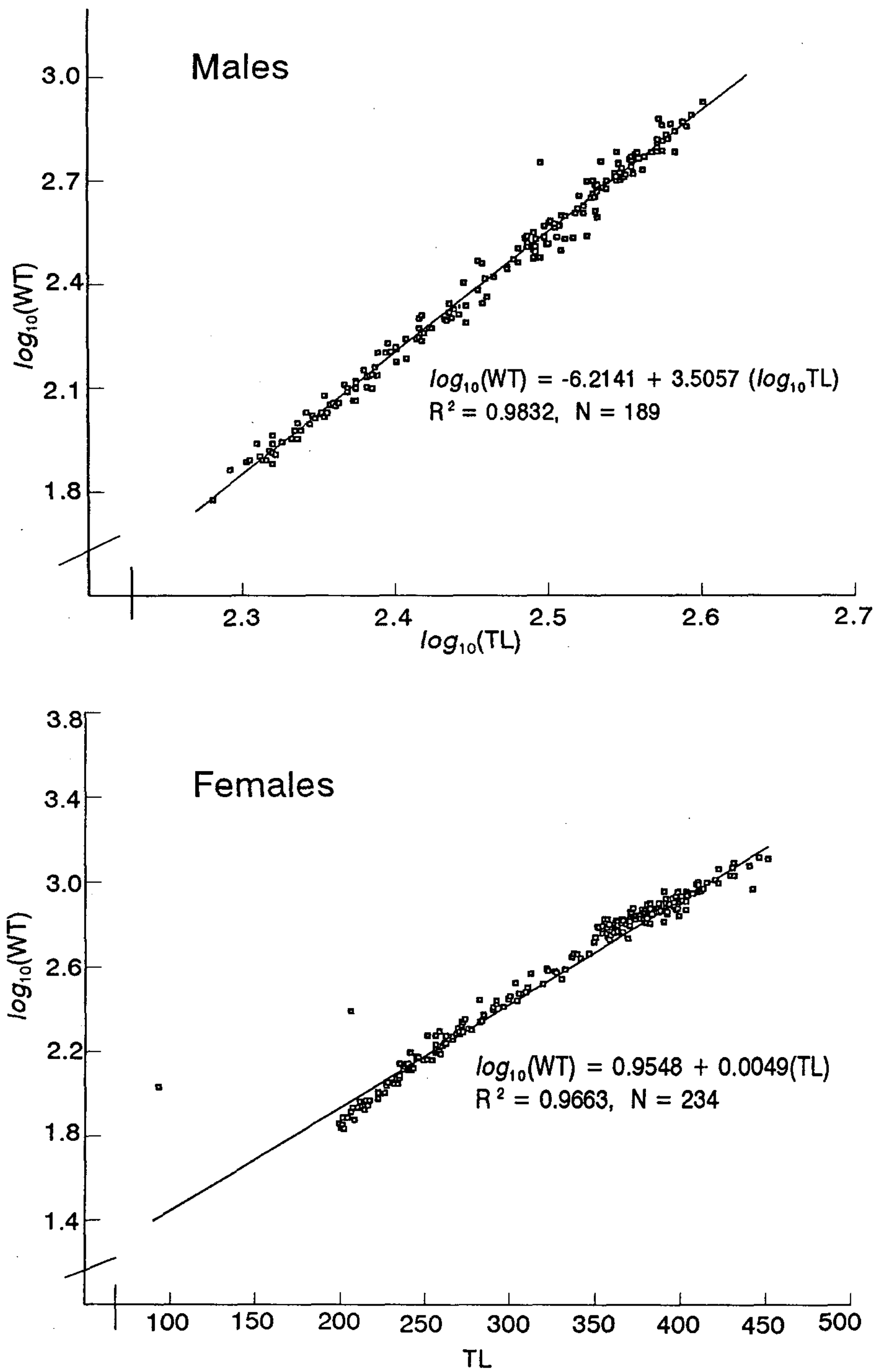

Figure 3. Relationships between weight (WT, gram) and total length (TL, mm) for male and female gizzard shad, Lake Apopka, Florida, January 1995.

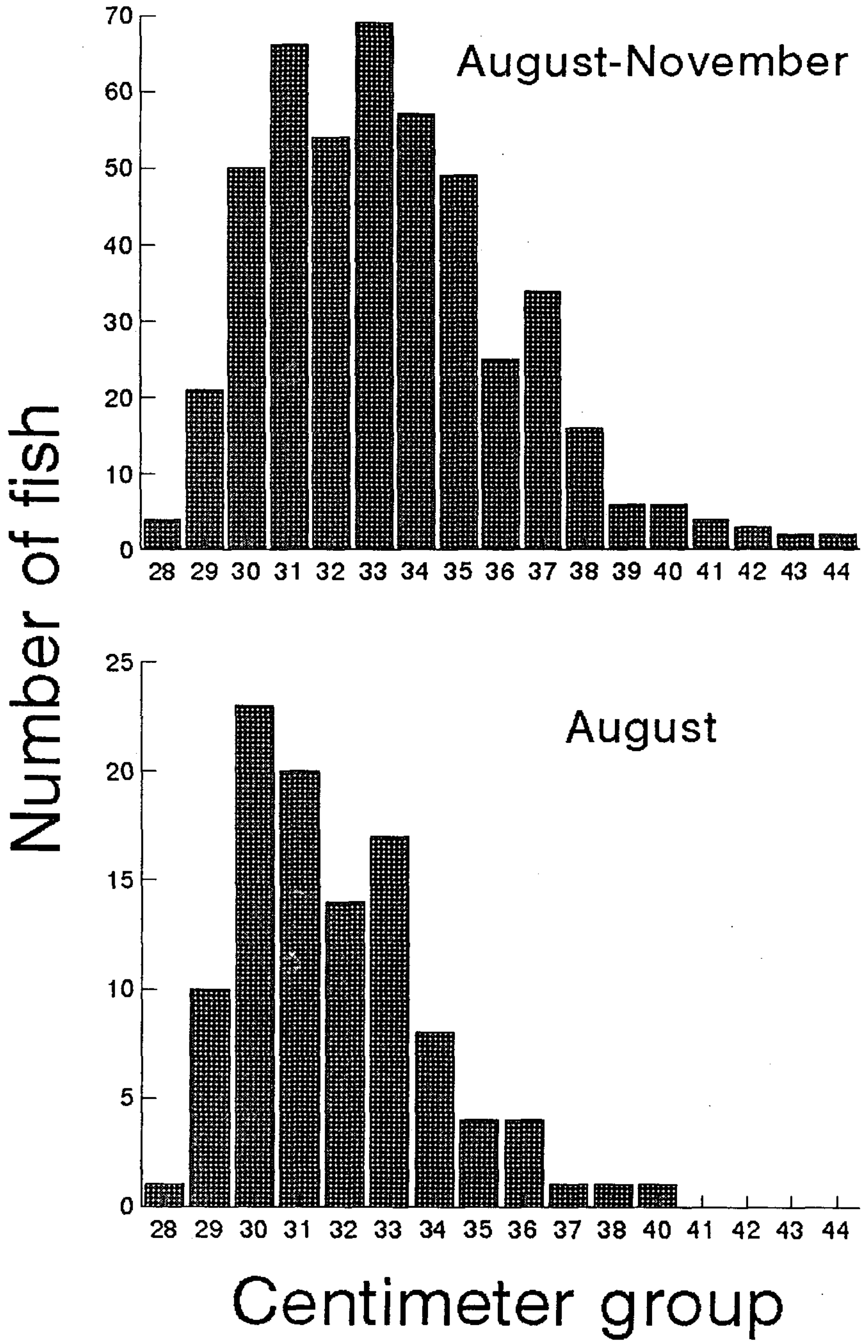

Figure 4. Frequencies of total lengths of gizzard shad caught with commercial gill nets during August-November 1995 and during August 1995.

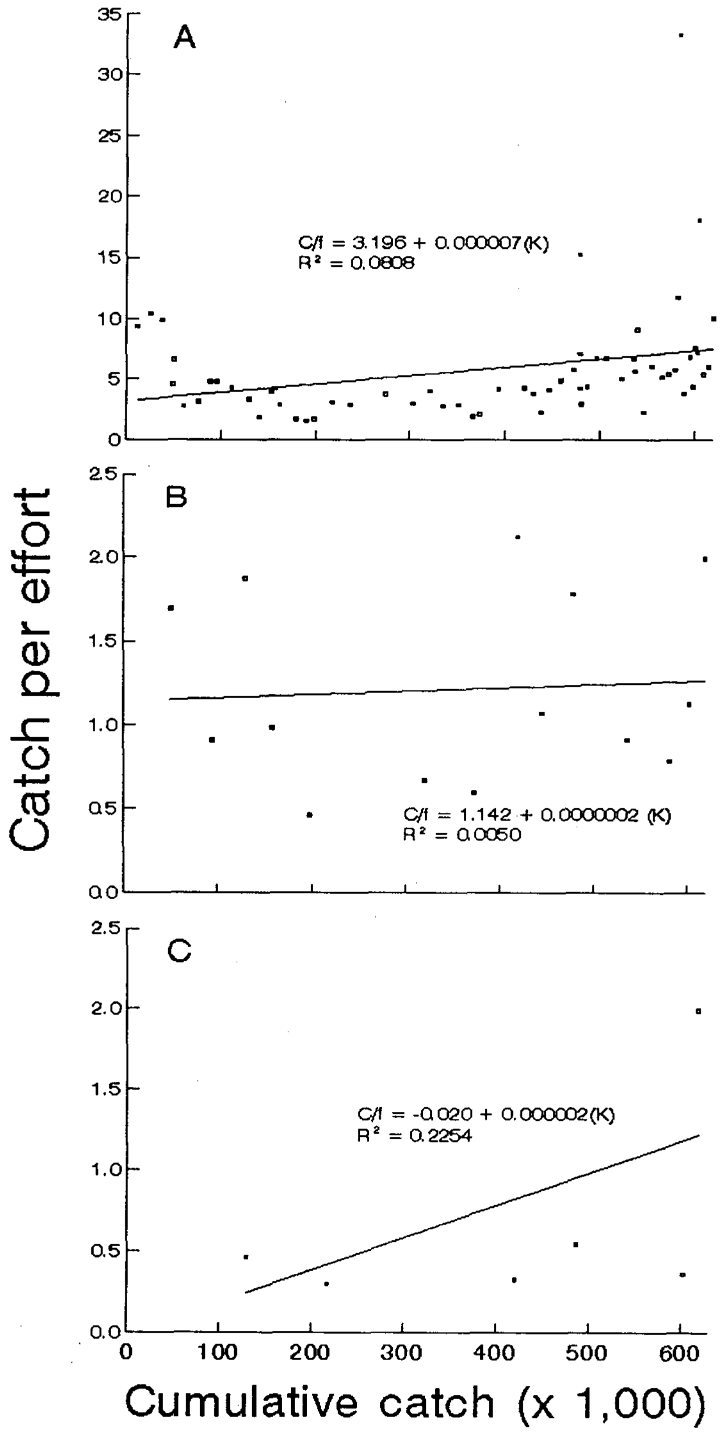

Figure 5. Relationships between catch per effort (*C/f*) and cumulative catch (pounds) for gizzard shad landed in Lake Apopka, Florida, January-April 1995. A. *C/f* is mean daily catch in pounds/(yards of net multiplied by hours fished). B. *C/f* is mean weekly catch in pounds/(yards of net multiplied by hours fished). C. *C/f* is mean biweekly catch in pounds/(yards of net multiplied by hours fished).

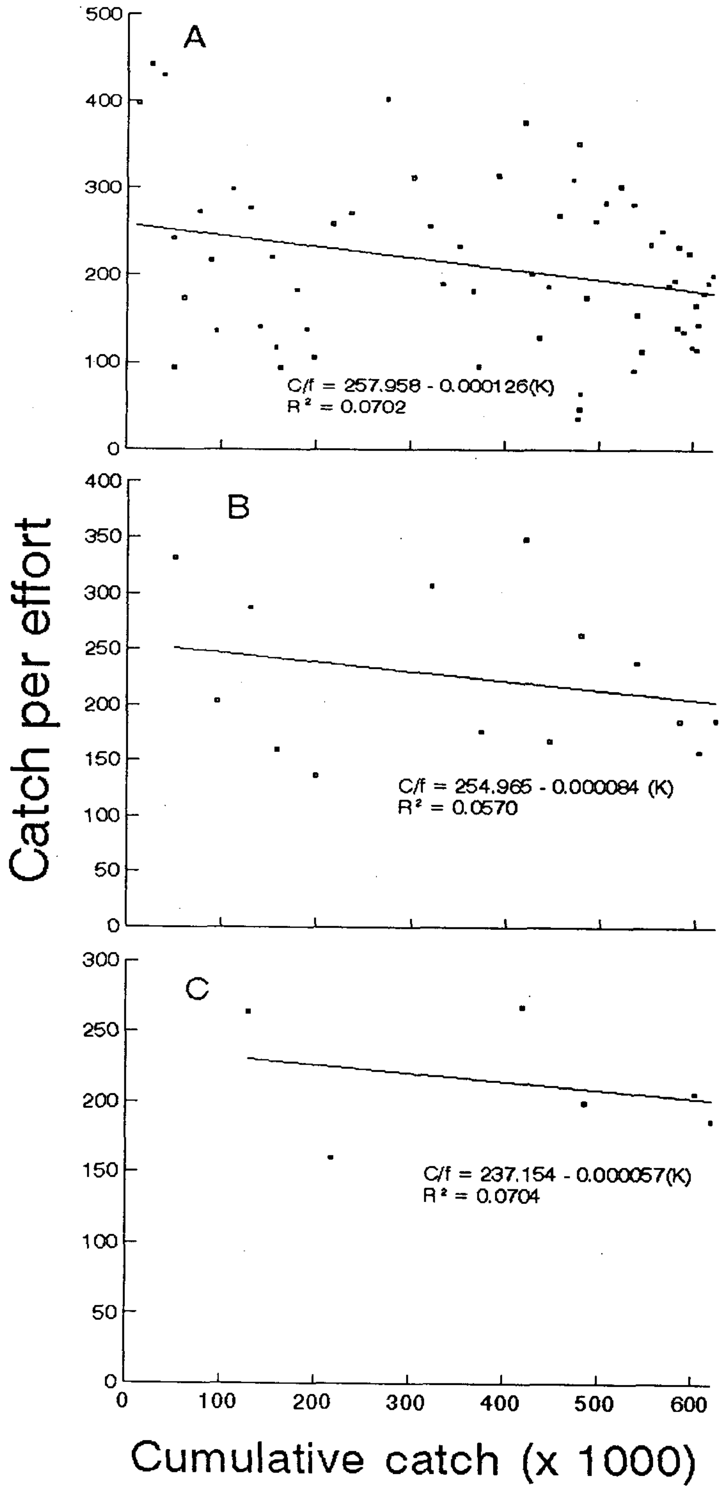

Figure 6. Relationships between catch per effort (*C/f*) and cumulative catch (pounds) for gizzard shad landed in Lake Apopka, Florida, January-April 1995. A. *C/f* is mean daily catch in pounds/yards of net. B. *C/f* is mean weekly catch in pounds/yards of net. C. *C/f* is mean biweekly catch in pounds/yards of net.

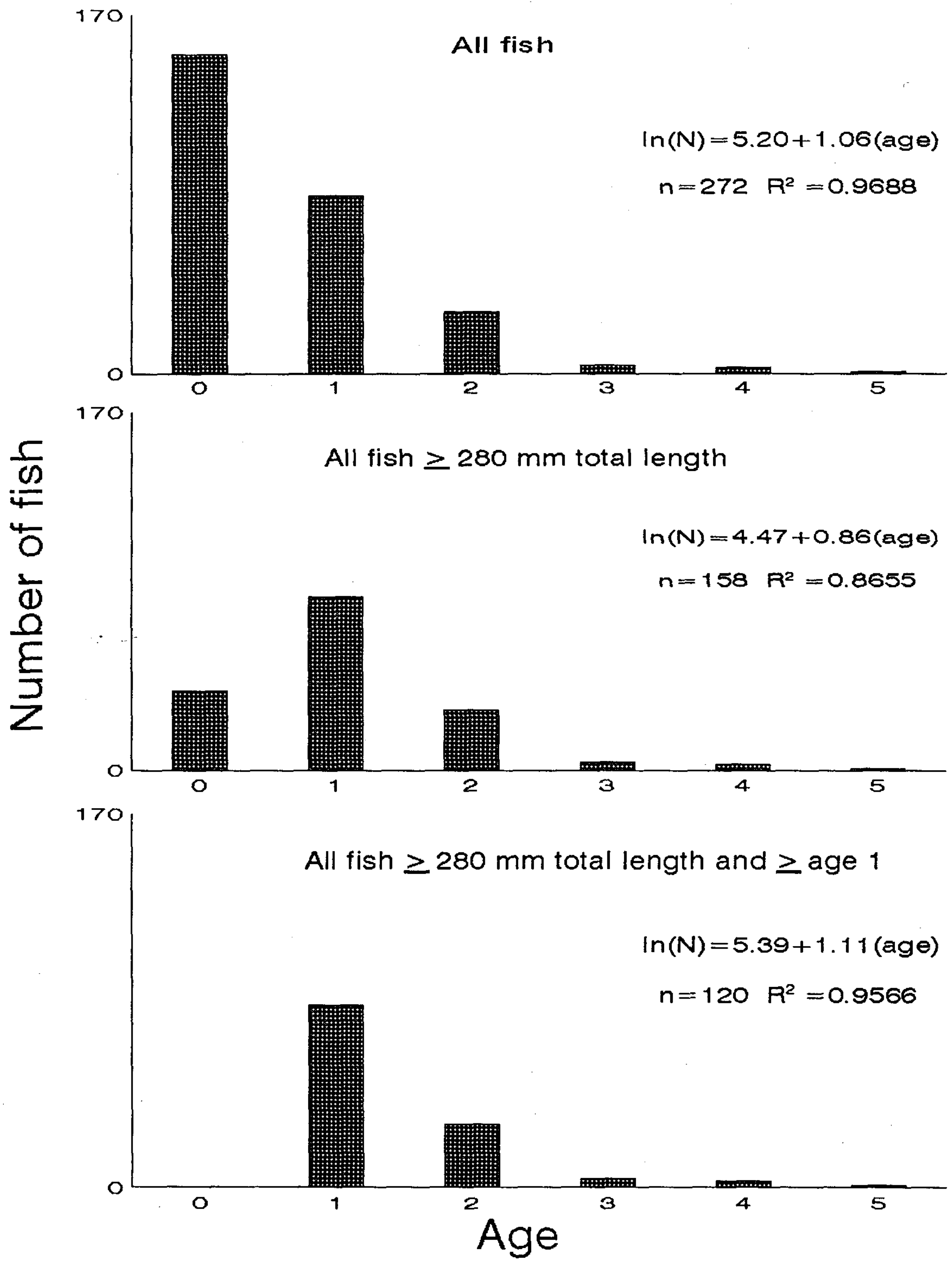

Figure 7. Frequencies of ages of gizzard shad captured with experimental gill nets in Lake Apopka, Florida, January 1995.

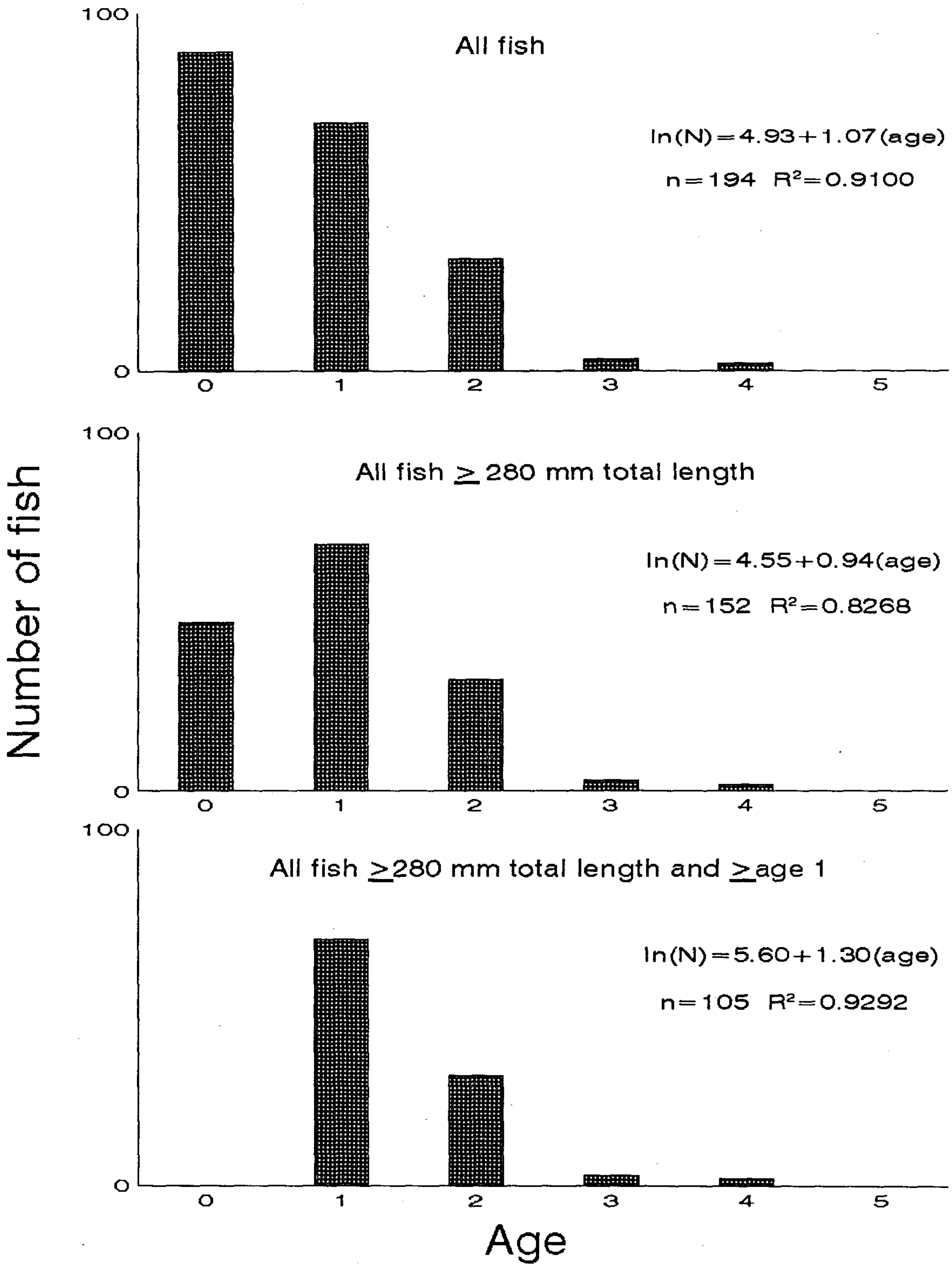

Figure 8. Frequencies of ages of gizzard shad captured with experimental gill nets in Lake Apopka, Florida, June 1995.

Appendix 1

LAKE APOPKA ROUGH-FISH REMOVAL								
Trip Ticket Data File								
(Notes: Hrs. effort is total time out)								
(Notes: Average catch influenced by weather conditions)								
		Net	Effort	Catch	SFU	CPUE Avg.	Effort	CPUE
Date	Name	100 yds.	Hours Out	Pounds	hrs*100 yds. net	Lbs./SFU	Boat Days	Boat Day
1/16/95	D. Brown	5.8	9.50	2,037	55.1	36.97	1	2,037.00
	S. Missildine	9.0	11.00	3,600	99.0	36.36	1	3,600.00
	L. Missildine	9.0	11.00	3,600	99.0	36.36	1	3,600.00
	J. Missildine	6.0	11.00	2,621	66.0	39.71	1	2,621.00
Totals				11,858	319.1	37.16	4	2,964.50
1/17/95	D. Brown	5.8	9.50	1,910	55.1	34.66	1	1,910.00
	S. Missildine	9.0	11.00	3,750	99.0	37.88	1	3,750.00
	L. Missildine	9.0	11.00	3,750	99.0	37.88	1	3,750.00
	J. Missildine	6.0	11.00	3,800	66.0	57.58	1	3,800.00
Total				13,210	319.1	41.40	4	3,302.50
1/18/95	D. Brown	5.4	9.50	2,204	51.3	42.96	1	2,204.00
	S. Missildine	9.0	11.00	3,216	99.0	32.48	1	3,216.00
	L. Missildine	9.0	11.00	3,216	99.0	32.48	1	3,216.00
	J. Missildine	6.0	12.00	4,035	72.0	56.04	1	4,035.00
Total				12,671	321.3	39.44	4	3,167.75
1/19/95	D. Brown	5.8	7.00	1,258	40.6	30.99	1	1,258.00
	S. Missildine	9.0	8.00	2,474	72.0	34.36	1	2,474.00
	L. Missildine	9.0	8.00	2,474	72.0	34.36	1	2,474.00
	J. Missildine	6.0	3.00	172	18.0	9.56	0.5	172.00
	J. Segers	6.0	5.00	551	30.0	18.37	0.5	551.00
	J. Raker	3.0	11.00	1,550	33.0	46.97	1	1,550.00
	J. Griffin	6.0	11.00	2,391	66.0	36.23	1	2,391.00
Total				10,870	331.6	32.78	6	1,811.67
1/20/95	J. Segers	6.0	5.50	969	33.0	29.36	0.5	969.00
	J. Raker	6.0	5.50	217	33.0	6.58	0.5	217.00
	J. Griffin	6.0	3.25	517	19.5	26.51	0.5	517.00
Total				1,703	85.5	19.92	1.5	1,135.33
1/23/95	D. Brown	6.0	4.50	430	27.0	15.93	0.5	430.00
	S. Missildine	9.0	7.00	980	63.0	15.56	1	980.00
	L. Missildine	9.0	7.00	980	63.0	15.56	1	980.00
	J. Missildine	9.0	11.00	3,529	99.0	35.65	1	3,529.00
	J. Segers	6.0	7.00	580	42.0	13.81	1	580.00
	J. Raker	6.0	11.00	1,509	66.0	22.86	1	1,509.00
	J. Griffin	6.0	10.50	1,338	63.0	21.24	1	1,338.00
	R. Corbin	6.0	5.00	567	30.0	18.90	0.5	567.00
Total				9,913	453.0	21.88	7	1,416.14
1/25/95	D. Brown	6.0	9.50	1,010	57.0	17.72	1	1,010.00
	S. Missildine	9.0	12.00	2,873	108.0	26.60	1	2,873.00
	L. Missildine	9.0	12.00	2,873	108.0	26.60	1	2,873.00
	J. Missildine	9.0	10.25	3,009	92.3	32.62	1	3,009.00
	J. Segers	6.0	11.00	1,170	66.0	17.73	1	1,170.00
	J. Raker	6.0	11.00	1,470	66.0	22.27	1	1,470.00
	J. Griffin	6.0	11.00	1,510	66.0	22.88	1	1,510.00
	R. Corbin	9.0	10.50	2,475	94.5	26.19	1	2,475.00
Total				16,390	657.8	24.92	8	2,048.75

1/26/95	D. Brown	6.0	9.00	1,183	54.0	21.91	1	1,183.00
	S. Missildine	9.0	6.00	1,970	54.0	36.48	1	1,970.00
	L. Missildine	9.0	6.00	1,970	54.0	36.48	1	1,970.00
	J. Missildine	9.0	4.00	1,667	36.0	46.31	0.5	1,667.00
	J. Raker	6.0	7.50	2,175	45.0	48.33	1	2,175.00
	J. Griffin	6.0	3.50	445	21.0	21.19	0.5	445.00
	R. Corbin	9.0	9.50	2,327	85.5	27.22	1	2,327.00
Total				11,737	349.50	33.58	6	1,956.17
1/27/95	D. Brown	6.0	6.50	887	39.0	22.74	1	887.00
	S. Missildine	9.0	4.00	1,018	36.0	28.28	0.5	1,018.00
	L. Missildine	9.0	4.00	1.018	36.0	28.28	0.5	1,018.00
	J. Missildine	9.0	4.00	1,014	36.0	28.17	0.5	1,014.00
	J. Raker	6.0	5.00	924	30.0	30.80	0.5	924.00
	R. Corbin	9.0	5.00	1,681	45.0	37.36	0.5	1,681.00
Totals				5525	222.0	24.89	3.5	1,578.58
1/30/95	D. Brown	6.0	10.50	1,785	63.0	28.33	1	1,785.00
	S. Missildine	9.0	11.00	3,300	99.0	33.33	1	3,300.00
	L. Missildine	9.0	11.00	3,300	99.0	33.33	1	3,300.00
	J. Missildine	9.0	11.00	4,298	99.0	43.41	1	4,298.00
	J. Griffin	6.0	11.00	1,378	66.0	20.88	1	1,378.00
	R. Corbin	8.0	8.25	1,703	66.0	25.80	1	1,703.00
	K. Jenkins	8.0	6.75	675	54.0	12.50	1	675.00
Total				16,439	546.0	30.11	7	2,348.43
1/31/95	D. Brown	6.0	8.50	762	51.0	14.94	1	762.00
	S. Missildine	9.0	11.00	2,981	99.0	30.11	1	2,981.00
	L. Missildine	9.0	11.00	2,981	99.0	30.11	1	2,981.00
	J. Missildine	9.0	10.25	2,682	92.3	29.07	1	2,682.00
	J. Raker	9.0	11.00	2,749	99.0	27.77	1	2,749.00
	J. Griffin	6.0	11.00	656	66.0	9.94	1	656.00
	R. Corbin	9.0	11.00	3,750	99.0	37.88	1	3,750.00
	K. Jenkins	9.0	10.00	1,758	90.0	19.53	1	1,758.00
Total				18,319	695.3	26.35	8	2,289.88
2/1/95	D. Brown	6.0	7.00	771	42.0	18.36	1	771.00
	S. Missildine	9.0	8.00	973	72.0	13.51	1	973.00
	L. Missildine	9.0	8.00	973	72.0	13.51	1	973.00
	J. Missildine	9.0	8.00	2,000	72.0	27.78	1	2,000.00
	J. Raker	9.0	11.00	1,737	99.0	17.55	1	1,737.00
	R. Segers	9.0	12.00	1,739	108.0	16.10	1	1,739.00
	J. Griffin	9.0	10.00	459	90.0	5.10	1	459.00
	R. Corbin	9.0	9.00	1,704	81.0	21.04	1	1,704.00
	K. Jenkins	9.0	5.00	682	45.0	15.16	0.5	682.00
Total				11,038	639.0	17.27	8.5	1,298.59
2/2/95	S. Missildine	9.0	9.00	2,833	81.0	34.98	1	2,833.00
	L. Missildine	9.0	9.00	2,833	81.0	34.98	1	2,833.00
	J. Missildine	9.0	7.00	905	63.0	14.37	1	905.00
	J. Raker	9.0	10.00	1,770	90.0	19.67	1	1,770.00
	R. Segers	9.0	11.00	1,517	99.0	15.32	1	1,517.00
	R. Corbin	9.0	10.25	1,977	92.3	21.43	1	1,977.00
Total				11,835	506.3	23.38	6	1,972.50

2/3/95	S. Missildine	9.0	5.00	1,363	45.0	30.29	0.5	1,363.00
	L. Missildine	9.0	5.00	1,363	45.0	30.29	0.5	1,363.00
	J. Raker	9.0	6.00	1,070	54.0	19.81	0.5	1,070.00
	R. Segers	9.0	6.00	985	54.0	18.24	0.5	985.00
	J. Griffin	9.0	6.00	515	54.0	9.54	0.5	515.00
Total				5,296	252.0	21.02	2.5	2,118.40
2/6/95	S. Missildine	9.0	6.00	1,043	54.0	19.31	0.5	1,043.00
	L. Missildine	9.0	6.00	1,043	54.0	19.31	0.5	1,043.00
	J. Raker	9.0	7.00	780	63.0	12.38	1	780.00
	J. Griffin	9.0	7.00	747	63.0	11.86	1	747.00
	S. Jeffcoat	9.0	7.00	645	63.0	10.24	1	645.00
Total				4,258	297.0	14.34	4	1,064.50
2/7/95	D. Brown	9.0	8.50	1,049	76.5	13.71	1	1,049.00
	S. Missildine	9.0	11.00	1,803	99.0	18.21	1	1,803.00
	L. Missildine	9.0	11.00	1,803	99.0	18.21	1	1,803.00
	J. Missildine	9.0	10.00	2,423	90.0	26.92	1	2,423.00
	J. Segers	9.0	12.00	1,649	108.0	15.27	1	1,649.00
	J. Raker	9.0	12.00	1,616	108.0	14.96	1	1,616.00
	J. Griffin	9.0	11.00	964	99.0	9.74	1	964.00
	R. Corbin	9.0	9.00	1,790	81.0	22.10	1	1,790.00
	K. Jenkins	9.0	12.00	2,437	108.0	22.56	1	2,437.00
	S. Jeffcoat	9.0	11.50	954	103.5	9.22	1	954.00
Total				16,488	972.0	16.96	10	1,648.80
2/9/95	S. Missildine	9.0	9.00	1,876	81.0	23.16	1	1,876.00
	L. Missildine	9.0	9.00	1,876	81.0	23.16	1	1,876.00
	J. Missildine	9.0	8.00	1,477	72.0	20.51	1	1,477.00
	J. Segars	9.0	7.00	876	63.0	13.90	1	876.00
	J. Raker	9.0	11.00	595	99.0	6.01	1	595.00
	J. Griffin	9.0	12.00	1,352	108.0	12.52	1	1,352.00
	R. Corbin	9.0	11.00	1,712	99.0	17.29	1	1,712.00
	K. Jenkins	9.0	12.00	884	108.0	8.19	1	884.00
	S. Jeffcoat	9.0	11.00	564	99.0	5.70	1	564.00
Total				11,212	810.0	13.84	9	1,245.78
2/10/95	D. Brown	9.0	5.00	411	45.0	9.13	0.5	411.00
	S. Missildine	9.0	5.00	709	45.0	15.76	0.5	709.00
	L. Missildine	9.0	5.00	709	45.0	15.76	0.5	709.00
	J. Missildine	9.0	5.00	491	45.0	10.91	0.5	491.00
	J. Raker	9.0	7.00	759	63.0	12.05	1	759.00
	J. Griffin	9.0	12.00	440	108.0	4.07	1	440.00
	R. Corbin	9.0	7.50	1,418	67.5	21.01	1	1,418.00
	K. Jenkins	9.0	12.00	2,655	108.0	24.58	1	2,655.00
	S. Jeffcoat	9.0	5.00	986	45.0	21.91	1	986.00
Total				8,578	571.5	15.01	7	1,225.43
2/13/95	D. Brown	9.0	11.00	2,868	99.0	28.97	1	2,868.00
	S. Missildine	9.0	11.00	3,282	99.0	33.15	1	3,282.00
	L. Missildine	9.0	11.00	3,282	99.0	33.15	1	3,282.00
	J. Missildine	9.0	11.00	2,814	99.0	28.42	1	2,814.00
	J. Griffin	9.0	11.00	481	99.0	4.86	1	481.00
	R. Corbin	9.0	6.00	467	54.0	8.65	0.5	467.00
	K. Jenkins	9.0	12.00	2,655	108.0	24.58	1	2,655.00
	S. Jeffcoat	9.0	11.00	2,829	99.0	28.58	1	2,829.00
Total				18,678	756.0	24.71	7.5	2,490.40

2/14/95	D. Brown	9.0	11.50	1,723	103.5	16.65	1	1,723.00
	S. Missildine	9.0	12.00	1,987	108.0	18.40	1	1,987.00
	L. Missildine	9.0	12.00	1,987	108.0	18.40	1	1,987.00
	J. Missildine	9.0	12.00	4,380	108.0	40.56	1	4,380.00
	J. Segars	9.0	11.50	1,203	103.5	11.62	1	1,203.00
	J. Griffin	9.0	12.00	3,850	108.0	35.65	1	3,850.00
	R. Corbin	9.0	12.00	3,305	108.0	30.60	1	3,305.00
	S. Jeffcoat	9.0	12.00	1,120	108.0	10.37	1	1,120.00
Total				19,555	855.0	22.87	8	2,444.38
2/15/95	D. Brown	9.0	7.00	4,639	63.0	73.63	1	4,639.00
	S. Missildine	9.0	12.00	4,792	108.0	44.37	1	4,792.00
	L. Missildine	9.0	12.00	4,792	108.0	44.37	1	4,792.00
	J. Missildine	9.0	11.00	2,004	99.0	20.24	1	2,004.00
	J. Raker	9.0	12.00	4,244	108.0	39.30	1	4,244.00
	J. Segars	9.0	12.00	5,290	108.0	48.98	1	5,290.00
	J. Griffin	9.0	12.00	3,212	108.0	29.74	1	3,212.00
	R. Corbin	9.0	11.00	2,739	99.0	27.67	1	2,739.00
	K. Jenkins	9.0	7.00	2,028	63.0	32.19	1	2,028.00
	S. Jeffcoat	12.0	12.00	3,798	144.0	26.38	1	3,798.00
Total				37,538	1,008.0	37.24	10	3,753.80
2/16/95	D. Brown	9.0	12.00	3,326	108.0	30.80	1	3,326.00
	S. Missildine	9.0	10.00	4,700	90.0	52.22	1	4,700.00
	L. Missildine	9.0	10.00	4,700	90.0	52.22	1	4,700.00
	J. Missildine	9.0	9.00	1,748	81.0	21.58	1	1,748.00
	J. Raker	9.0	11.00	1,684	99.0	17.01	1	1,684.00
	J. Segars	9.0	8.00	1,358	72.0	18.86	1	1,358.00
	J. Griffin	9.0	11.00	1,584	99.0	16.00	1	1,584.00
	R. Corbin	9.0	11.00	4,332	99.0	43.76	1	4,332.00
	K. Jenkins	9.0	12.00	2,594	108.0	24.02	1	2,594.00
	S. Jeffcoat	9.0	12.00	2,123	108.0	19.66	1	2,123.00
Total				28,149	954.0	29.51	10	2,814.90
2/17/95	D. Brown	9.0	8.00	1,356	72.0	18.83	1	1,356.00
	S. Missildine	9.0	6.00	3,881	54.0	71.87	0.5	3,881.00
	L. Missildine	9.0	6.00	3,881	54.0	71.87	0.5	3,881.00
	J. Raker	9.0	8.00	2,179	72.0	30.26	1	2,179.00
	J. Segars	9.0	10.00	2,960	90.0	32.89	1	2,960.00
	J. Griffin	9.0	10.00	1,186	90.0	13.18	1	1,186.00
	R. Corbin	9.0	6.00	843	54.0	15.61	0.5	843.00
	S. Jeffcoat	9.0	10.00	2,215	90.0	24.61	1	2,215.00
Total				18,501	576.0	32.12	6.5	2,846.31
2/20/95	D. Brown	9.0	9.00	1,710	81.0	21.11	1	1,710.00
	S. Missildine	9.0	9.00	2,257	81.0	27.86	1	2,257.00
	L. Missildine	9.0	9.00	2,257	81.0	27.86	1	2,257.00
	J. Missildine	9.0	9.00	2,219	81.0	27.40	1	2,219.00
	J. Raker	9.0	8.50	2,411	76.5	31.52	1	2,411.00
	R. Corbin	9.0	5.00	234	45.0	5.20	0.5	234.00
	S. Jeffcoat	9.0	8.00	200	72.0	2.78	1	200.00
	L. Langston	9.0	11.00	2,434	99.0	24.59	1	2,434.00
Total				13,722	355.5	38.60	7.5	1,829.60

2/22/95	D. Brown	9.0	11.00	2,109	99.0	21.30	1	2,109.00
	S. Missildine	9.0	9.00	1,661	81.0	20.51	1	1,661.00
	L. Missildine	9.0	9.00	1,661	81.0	20.51	1	1,661.00
	J. Missildine	9.0	11.00	3,748	99.0	37.86	1	3,748.00
	J. Raker	9.0	8.00	688	72.0	9.56	1	688.00
	J. Segers	9.0	11.00	1,747	99.0	17.65	1	1,747.00
	J. Griffin	9.0	12.00	2,010	108.0	18.61	1	2,010.00
	L. Langston	9.0	11.00	3,200	99.0	32.32	1	3,200.00
Total				16,824	738.0	22.80	8	2,103.00
2/23/95	D. Brown	9.0	10.00	883	90.0	9.81	1	883.00
	S. Missildine	9.0	10.00	1,481	90.0	16.46	1	1,481.00
	L. Missildine	9.0	10.00	1,481	90.0	16.46	1	1,481.00
	J. Missildine	9.0	11.00	2,043	99.0	20.64	1	2,043.00
	R. Corbin	9.0	11.00	1,746	99.0	17.64	1	1,746.00
	J. Segers	9.0	12.00	2,284	108.0	21.15	1	2,284.00
	J. Griffin	9.0	12.00	1,146	108.0	10.61	1	1,146.00
	S. Jeffcoat	9.0	11.00	993	99.0	10.03	1	993.00
	L. Langston	9.0	11.00	2,706	99.0	27.33	1	2,706.00
Total				14,763	792.0	18.64	9	1,640.33
2/24/95	S. Missildine	9.0	4.50	792	40.5	19.56	0.5	792.00
	L. Missildine	9.0	4.50	792	40.5	19.56	0.5	792.00
	J. Missildine	9.0	4.50	478	40.5	11.80	0.5	478.00
	R. Corbin	9.0	4.50	613	40.5	15.14	0.5	613.00
	J. Segers	9.0	5.00	1,261	45.0	28.02	0.5	1,261.00
	J. Griffin	9.0	10.00	1,111	90.0	12.34	1	1,111.00
	S. Jeffcoat	9.0	6.50	517	58.5	8.84	1	517.00
	L. Langston	9.0	6.00	1,335	54.0	24.72	0.5	1,335.00
Total				6,899	409.5	16.85	5	1,379.80
2/27/95	D. Brown	9.0	11.00	3,575	99.0	36.11	1	3,575.00
	S. Missildine	9.0	11.00	4,251	99.0	42.94	1	4,251.00
	L. Missildine	9.0	11.00	4,251	99.0	42.94	1	4,251.00
	J. Missildine	9.0	11.00	3,217	99.0	32.49	1	3,217.00
	J. Griffin	9.0	10.00	1,092	90.0	12.13	1	1,092.00
	S. Jeffcoat	9.0	11.00	478	99.0	4.83	1	478.00
	L. Langston	9.0	11.00	3,042	99.0	30.73	1	3,042.00
Total				19,906	684.0	29.10	7	2,843.71
2/28/95	D. Brown	9.0	11.00	3,425	99.0	34.60	1	3,425.00
	S. Missildine	9.0	11.00	4,448	99.0	44.93	1	4,448.00
	L. Missildine	9.0	11.00	4,448	99.0	44.93	1	4,448.00
	J. Missildine	9.0	12.00	3,294	108.0	30.50	1	3,294.00
	J. Griffin	9.0	10.00	2,659	90.0	29.54	1	2,659.00
	K. Jenkins	9.0	12.00	3,559	108.0	32.95	1	3,559.00
	S. Jeffcoat	9.0	11.00	1,979	99.0	19.99	1	1,979.00
	L. Langston	9.0	10.00	3,278	90.0	36.42	1	3,278.00
Total				27,090	792.0	34.20	8	3,386.25
3/1/95	S. Missildine	9.0	10.00	1,582	90.0	17.58	1	1,582.00
	L. Missildine	9.0	11.00	1,582	99.0	15.98	1	1,582.00
	K. Jenkins	9.0	11.00	1,392	99.0	14.06	1	1,392.00
	S. Jeffcoat	9.0	11.00	2,392	99.0	24.16	1	2,392.00
	L. Langston	9.0	10.50	2,153	94.5	22.78	1	2,153.00
Total				9,101	481.5	18.90	5	1,820.20

3/2/95	S. Missildine	9.0	8.00	1,112	72.0	15.44	1	1,112.00
	L. Missildine	9.0	8.00	1,112	72.0	15.44	1	1,112.00
	J. Missildine	9.0	6.00	260	54.0	4.81	0.5	260.00
	J. Segars	9.0	9.00	1,037	81.0	12.80	1	1,037.00
	J. Griffin	9.0	7.00	1,976	63.0	31.37	1	1,976.00
	S. Jeffcoat	9.0	11.00	927	99.0	9.36	1	927.00
	L. Langston	9.0	8.00	1,693	72.0	23.51	1	1,693.00
Total				8,117	513.0	15.82	6.5	1,248.77
3/3/95	J. Missildine	9.0	6.00	413	54.0	7.65	0.5	413.00
	J. Segars	9.0	11.00	1,305	99.0	13.18	1	1,305.00
	J. Griffin	9.0	11.00	1,352	99.0	13.66	1	1,352.00
	S. Jeffcoat	9.0	10.00	3,691	90.0	41.01	1	3,691.00
	L. Langston	9.0	8.00	1,693	72.0	23.51	1	1,693.00
Total				8,454	414.0	20.42	4.5	1,878.67
3/6/95	S. Missildine	9.0	11.00	3,482	99.0	35.17	1	3,482.00
	L. Missildine	9.0	11.00	3,482	99.0	35.17	1	3,482.00
	J. Griffin	9.0	11.00	421	99.0	4.25	1	421.00
	S. Jeffcoat	9.0	11.00	1,845	99.0	18.64	1	1,845.00
	L. Langston	9.0	11.00	2,900	99.0	29.29	1	2,900.00
Total				12,130	495.0	24.51	5	2,426.00
3/7/95	S. Missildine	9.0	11.00	4,139	99.0	41.81	1	4,139.00
	L. Missildine	9.0	11.00	4,139	99.0	41.81	1	4,139.00
	J. Griffin	9.0	10.00	1,188	90.0	13.20	1	1,188.00
	S. Jeffcoat	9.0	11.00	1,294	99.0	13.07	1	1,294.00
	L. Langston	9.0	11.00	3,231	99.0	32.64	1	3,231.00
Total				13,991	486.0	28.79	5	2,798.20
3/9/95	S. Jeffcoat	9.0	12.00	5,172	108.0	47.89	1	5,172.00
	L. Langston	9.0	11.00	1,156	99.0	11.68	1	1,156.00
Total				6,328	207.0	30.57	2	3,164.00
3/10/95	L. Langston	9.0	5.00	320	45.0	7.11	0.5	320.00
3/11/95	L. Langston	9.0	11.00	416	99.0	4.20	1	416.00
3/12/95	J. Missildine	9.0	11.00	744	99.0	7.52	1	744.00
	L. Langston	9.0	11.00	416	99.0	4.20	1	416.00
Total				1,160	198.0	5.86	2	580.00
3/13/95	D. Brown	9.0	8.50	262	76.5	3.42	1	262.00
	S. Missildine	9.0	8.50	480	76.5	6.27	1	480.00
	J. Missildine	9.0	11.50	3,415	103.5	33.00	1	3,415.00
	L. Langston	9.0	11.50	2,153	103.5	20.80	1	2,153.00
Total				6,310	283.5	22.26	4	1,577.50
3/14/95	S. Missildine	9.0	11.00	2,663	99.0	26.90	1	2,663.00
	J. Missildine	9.0	9.00	3,527	81.0	43.54	1	3,527.00
	J. Griffin	9.0	8.00	1,521	72.0	21.13	1	1,521.00
	L. Langston	9.0	11.00	1,764	99.0	17.82	1	1,764.00
Total				9,475	351.0	26.99	4	2,368.75
3/15/95	S. Missildine	9.0	11.00	3,530	99.0	35.66	1	3,530.00
	J. Missildine	9.0	9.00	2,659	81.0	32.83	1	2,659.00
	L. Langston	9.0	11.00	3,185	99.0	32.17	1	3,185.00

	S. Jeffcoat	9.0	11.00	832	99.0	8.40	1	832.00
Total				10,206	279.0	36.58	4	2,551.50
3/16/95	D. Brown	9.0	6.00	1,935	54.0	35.83	0.5	1,935.00
	S. Missildine	9.0	11.00	2,886	99.0	29.15	1	2,886.00
	L. Missildine	9.0	11.00	2,886	99.0	29.15	1	2,886.00
	J. Missildine	9.0	10.00	3,195	90.0	35.50	1	3,195.00
	L. Langston	9.0	11.00	3,323	99.0	33.57	1	3,323.00
	S. Jeffcoat	9.0	11.00	2,136	99.0	21.58	1	2,136.00
Total				16,361	387.0	42.28	5.5	2,974.73
3/17/95	D. Brown	9.0	9.00	1,883	81.0	23.25	1	1,883.00
	L. Missildine	9.0	8.00	1,905	72.0	26.46	1	1,905.00
	J. Missildine	9.0	5.00	1,112	45.0	24.71	0.5	1,112.00
	L. Langston	9.0	9.00	2,867	81.0	35.40	1	2,867.00
	S. Jeffcoat	9.0	11.00	4,909	99.0	49.59	1	4,909.00
Total				12,676	198.0	64.02	4.5	2,816.89
3/18/95	D. Brown	9.0	8.00	994	72.0	13.81	1	994.00
	J. Missildine	9.0	8.00	634	72.0	8.81	1	634.00
Total				1,628	270.0	6.03	2	814.00
3/19/95	D. Brown	9.0	9.00	1,945	81.0	24.01	1	1,945.00
	J. Missildine	9.0	8.00	839	72.0	11.65	1	839.00
Total				2,784	351.0	7.93	2	1,392.00
3/20/95	D. Brown	9.0	6.00	867	54.0	16.06	0.5	867.00
	S. Missildine	9.0	6.00	489	54.0	9.06	0.5	489.00
	L. Missildine	9.0	6.00	489	54.0	9.06	0.5	489.00
	J. Missildine	9.0	10.00	2,189	90.0	24.32	1	2,189.00
	L. Langston	9.0	11.00	1,654	99.0	16.71	1	1,654.00
	S. Jeffcoat	9.0	11.00	433	99.0	4.37	1	433.00
Total				6,121	297.0	20.61	4.5	1,360.22
3/21/95	J. Missildine	9.0	11.00	2,216	99.0	22.38	1	2,216.00
	J. Griffin	9.0	6.00	782	54.0	14.48	0.5	782.00
	L. Langston	9.0	11.00	2,448	99.0	24.73	1	2,448.00
	S. Jeffcoat	9.0	11.00	3,058	99.0	30.89	1	3,058.00
Total				8,504	252.0	33.75	3.5	2,429.71
3/22/95	D. Brown	9.0	11.00	2,778	99.0	28.06	1	2,778.00
	J. Missildine	9.0	11.00	2,173	99.0	21.95	1	2,173.00
	J. Griffin	9.0	5.00	562	45.0	12.49	0.5	562.00
	L. Langston	9.0	11.00	3,284	99.0	33.17	1	3,284.00
	S. Jeffcoat	9.0	11.00	2,495	99.0	25.20	1	2,495.00
Total				11,292	144.0	78.42	4.5	2,509.33
3/23/95	J. Missildine	9.0	8.00	1,969	72.0	27.35	1	1,969.00
	J. Griffin	9.0	8.00	1,000	72.0	13.89	1	1,000.00
	L. Langston	9.0	11.00	2,928	99.0	29.58	1	2,928.00
	S. Jeffcoat	9.0	8.00	898	72.0	12.47	1	898.00
Total				6,795	243.0	27.96	4	1,698.75
3/24/95	D. Brown	9.0	11.00	2,821	99.0	28.49	1	2,821.00
	J. Griffin	9.0	8.00	1,003	72.0	13.93	1	1,003.00
	L. Langston	9.0	5.00	1,463	45.0	32.51	0.5	1,463.00
	S. Jeffcoat	9.0	10.00	1,728	90.0	19.20	1	1,728.00
Total				7,015	216.0	32.48	3.5	2,004.29

3/25/95	D. Brown	9.0	5.00	433		45.0	9.62	0.5	433.00
	L. Langston	9.0	7.00	2,101		63.0	33.35	1	2,101.00
Total				2,534		351.0	7.22	1.5	1,689.33
3/26/95	L. Langston	9.0	7.00	2,101		63.0	33.35	1	2,101.00
3/27/95	D. Brown	9.0	8.00	275		72.0	3.82	1	275.00
	J. Missildine	9.0	8.00	873		72.0	12.13	1	873.00
	L. Langston	9.0	11.50	3,123		103.5	30.17	1	3,123.00
	S. Jeffcoat	9.0	8.00	606		72.0	8.42	1	606.00
Total				4,877		247.5	19.71	4	1,219.25
3/28/95	D. Brown	9.0	11.00	1,289		99.0	13.02	1	1,289.00
	J. Missildine	9.0	11.00	2,215		99.0	22.37	1	2,215.00
	L. Langston	9.0	11.00	2,607		99.0	26.33	1	2,607.00
Total				6,111		297.0	20.58	3	2,037.00
3/29/95	D. Brown	9.0	8.00	1,078		72.0	14.97	1	1,078.00
	J. Missildine	9.0	8.00	435		72.0	6.04	1	435.00
	L. Langston	9.0	11.00	1,678		99.0	16.95	1	1,678.00
Total				3,191		243.0	13.13	3	1,063.67
3/30/95	J. Missildine	9.0	11.00	886		99.0	8.95	1	435.00
	L. Langston	9.0	11.00	2,114		99.0	21.35	1	2,114.00
Total				3,000		198.0	15.15	2	1,500.00
3/31/95	J. Missildine	9.0	8.00	864		72.0	12.00	1	864.00
	L. Langston	9.0	8.00	1,209		72.0	16.79	1	1,209.00
Total				2,073		144.0	14.40	2	1,036.50
4/2/95	J. Missildine	9.0	8.00	1,301		72.0	18.07	1	1,301.00
4/3/95	D. Brown	9.0	8.00	1,104		72.0	15.33	1	1,104.00
	J. Missildine	9.0	12.75	2,191		114.8	19.09	1	2,191.00
	L. Langston	9.0	12.75	1,579		114.8	13.76	1	1,579.00
Total				4,874		301.5	16.17	3	1,624.67
4/4/95	D. Brown	9.0	8.00	482		72.0	6.69	1	482.00
	J. Missildine	9.0	12.00	2,191		108.0	20.29	1	1,630.00
	L. Langston	9.0	12.00	2,513		108.0	23.27	1	2,513.00
Total				5,186		288.0	18.01	3	1,728.67
4/5/95	D. Brown	9.0	9.00	950		81.0	11.73	1	950.00
	J. Missildine	9.0	9.00	1,948		81.0	24.05	1	1,948.00
	L. Langston	9.0	2.00	2,513		18.0	139.61	0.5	298.00
Total				5,411		180.0	30.06	2.5	2,164.40