# POPULATION DYNAMICS OF BLUE TILAPIA IN TRINIDAD LAKE, TEXAS

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*Abstract*: Scales from blue tilapia (*Tilapia aurea*) captured in gillnets indicated that annulus formation occurred primarily in March and April in 1973 and 1974, but in April and May 1975. Average back-calculated total lengths of males were 197 and 258 mm at Age I and II and for females 183 and 248 mm. Total population of blue tilapia in December 1974 was estimated as 4,856,963. Of this total 3,120,810 were Age 0 and 1,591,823 were Age I. Biomass of the tilapia population was estimated to be 799,978 kg or 2,640 kg/ha. Survival of blue tilapia from Age I to II was calculated to be 7%. From these estimates the potential yield of harvestable blue tilapia would be 1,629,501 fish weighing 521,153 kg.

Proc. Annual Conf. S.E. Assoc. Fish & Wildlife Agencies 31:412-417

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Heated discharges from power plants make it possible for sub-tropical fishes to survive where survival would otherwise be limited by low water temperatures during winter. The blue tilapia, which was originally introduced into the United States for vegetation control, fish culture, and recreation, has become widely established because of such conditions. Rapid growth and expansion of blue tilapia populations have been documented in Florida lakes. Blue tilapia invaded Lake Parker in 1966. Horel (1969) sampling the lake in 1968-1969 found that tilapia comprised about 5 percent, by weight, of the fish population. Further sampling in 1972, 6 yrs after tilapia became established, indicated the cichlid dominated the fish population comprising 68 percent, by weight, of the samples (Babcock and Chapman 1973).

Few data exist on population dynamics of blue tilapia in waters of the United States. The biology of the blue tilapia was described by McBay (1961). Limited data on growth in a heated reservoir were presented by Gleastine (1974), and on growth in ponds under culture conditions by Swingle (1960).

The blue tilapia was inadvertently introduced into Trinidad Lake, Texas, in the late 1960's (Noble et al. 1975) and rapidly became established. The purpose of this study was to determine the population size, growth rates, condition, and mortality rates, and from these parameters to determine potential yield to sport and commercial harvest.

This study was supported by a grant from the Texas Power and Light Company to the Department of Wildlife and Fisheries Sciences and the Texas Agricultural Experiment Station of Texas A&M University (Project S-1896). We wish to thank the many students, especially J. Pennington, T. O'Keefe and M. Van Den Avyle, who assisted in collecting data.

## MATERIALS AND METHODS

### *Study Area*

Trinidad Lake is a 303 ha cooling reservoir for the Texas Power and Light Company Steam Electric Generating Station. The main body of the reservoir contains 237 ha with an average depth of approximately 2.5 m. The intake canal is approximately 6 ha in area with an average depth of 4 m, while the discharge canal averages only about 1 m in depth and is approximately 60 ha in area. The lake is eutrophic and maintains a phytoplankton bloom throughout the year. Gleastine (1974) reported that nutrient levels were high in the lake (0.5 mg/l phosphate); pH was high, usually above 9.0; alkalinity averaged about 200 ppm and dissolved oxygen was near saturation from surface to bottom throughout most of the lake.

### *Population Sampling*

Experimental multifilament gillnets were set once each month at 10 sites for 2 consecutive 1 day intervals starting in January 1973, and continuing through December 1975. Five of the nets were 45.7 m long and 2.4 m deep with equal panels of 25, 38, 51, 63, 77 and 89 mm square mesh; 5 nets were 36.6 m long with equal panels of 63, 77, 89

and 102 mm square mesh. All catches were returned to the laboratory for measurement of total length and weight. Sex and maturity were also determined. Scales of a representative subsample of tilapia were taken from the left side below the lateral line at the tip of the pectoral fin.

*Age, Growth, and Condition*

Scale impressions made in clear cellulose acetate were examined using a Bausch and Lomb Tri-Simplex Micro-projector at 23X magnification. Scale length in millimeters along the dorso-ventral axis from the center of the focus to the margin of the scale and to each annulus was recorded from magnified images. The Lee method (Lagler 1956) was used in back-calculation of length at each annulus using an intercept value of 52 mm for males and 44 mm for females, calculated from body-scale relationships (Germany 1977). Length-weight relationships were determined separately for male and female tilapia caught in gillnets over the 3 yr period. Differences in length-weight relationships of the sexes were tested by analysis of covariance.

*Population Estimate*

Population estimates for tilapia were made by using the Petersen mark and recapture method (Ricker 1975). Confidence intervals for population estimates were determined by the normal approximation to the Poisson (Davis 1964).

Tilapia were captured by seining, cast netting and hook-and-line during the marking period which extended from 19 October 1974 to 17 November 1974. During this period 30,104 tilapia were marked by clipping the right pelvic fin. The recapture period began on 18 January 1975 and concluded on 5 March 1975. During this period 99,930 tilapia were collected by seining and examined. To insure against checking any fish for marks more than once during the recapture period, an accessory upper caudal clip was given to all tilapia examined and returned to the lake. Total lengths of fish from an approximate 10 percent subsample were recorded during the marking and recapture periods. Ages were assigned to the length-frequency distributions from scale-aged fish caught in gillnets during November and December 1974.

## RESULTS AND DISCUSSION

*Gillnet Catches*

Catches of blue tilapia in gillnets followed definite trends within and among years (Table 1). Catches were always low during winter months when tilapia moved out of the main body of the reservoir into the warmer waters of the discharge canal. Catch generally increased in March and April when the fish returned to the lake. First-year growth of tilapia was usually rapid and Age 0 fish grew to sizes large enough to be caught in

Table 1. Monthly total catches of blue tilapia in gillnets set for 2 consecutive 1-day periods at 10 sites in Trinidad Lake, Texas.

| | *Number of Fish Caught* | | |
|---|---|---|---|
| *Month* | *1973* | *1974* | *1975* |
| January | 0 | 4 | 1 |
| February | 6 | 0 | 0 |
| March | 84 | 49 | 2 |
| April | 96 | 56 | 19 |
| May | 67 | 57 | 37 |
| June | 120 | 85 | 39 |
| July | 63 | 18 | 62 |
| August | 29 | 91 | 22 |
| September | 50 | 35 | 44 |
| October | 129 | 141 | 58 |
| November | 222 | 48 | 78 |
| December | 57 | 2 | 0 |
| Total | 923 | 586 | 362 |

gillnets in September in each of the 3 years of the study. In 1973 and 1974 Age 0 tilapia made up a large portion of tilapia captured from September through December. In 1975 only three Age 0 tilapia were captured during these months.

Over the 3 yr period, a marked decline in gillnet catches occurred (Table 1). The low catch in 1975 was in part because of slow growth of young tilapia. Seine samples taken during each summer indicated that tilapia reproduction in 1975 was intermediate between that in 1973 and 1974 (Noble 1976). Gillnet catches prior to September, however, were markedly lower in 1975, indicating that population level of adults had also declined. These trends in annual catches may indicate that the population had surpassed carrying capacity during the earlier years of population explosion, and had begun to approach a lower standing crop, possibly accompanied by stunting of young tilapia.

*Age, Growth and Condition*

Scales from 913 tilapia collected in monthly gillnet sets were examined during this study. Of these fish 566 were males and 347 females. Males ranged in total length from 133 to 317 mm and Age 0 to III. Females were 132 to 304 mm total length and Age 0 to II.

Annulus formation in 1973 and 1974 occurred primarily in March and April. In 1975 annulus formation occurred in April and May. Close correspondence of ages determined by the scale method to length-frequency distributions for the blue tilapia caught in gillnets indicated that the scale method of age determination is valid for the tilapia in Trinidad Lake. Most of the tilapia captured during the study were either Age I or II. Only 3 Age III tilapia were gillnetted during the entire 3 years of this study.

Average back-calculated total lengths of males were always significantly larger than for females at each annulus (Tables 2 and 3). Average total lengths of males at annuli I to III, were 197, 258 and 299 mm respectively; total lengths of females at annuli I and II were 183 and 248 mm, respectively. These lengths were consistently less than those found by Gleastine (1974) for tilapia in Trinidad Lake in 1971-72. His data indicated that males reached 242, 318, and 346 mm at Age I, II, and III, respectively, whereas females reached 223 and 307 mm at Ages I and II.

Table 2. Average back-calculated total lengths and growth increments (mm) for male blue tilapia.

| *Year Class* | *I* | | | *II* | | | *III* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Length* | *Increment* | (*n*) | *Length* | *Increment* | (*n*) | *Length* | *Increment* | (*n*) |
| 1974 | 205 | 205 | (80) | -- | -- | -- | -- | -- | -- |
| 1973 | 193 | 193 | (197) | 253 | 50 | (68) | -- | -- | -- |
| 1972 | 187 | 187 | (175) | 257 | 52 | (39) | 308 | 37 | (2) |
| 1971 | 217 | 217 | (89) | 263 | 46 | (76) | 282 | 36 | (1) |
| Mean | 197 | 197 | | 258 | 49 | | 299 | 37 | |

Table 3. Average back-calculated total lengths and growth increments (mm) for female blue tilapia.

| *Year Class* | *I* | | | *II* | | | *III* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Length* | *Increment* | (*n*) | *Length* | *Increment* | (*n*) | *Length* | *Increment* | (*n*) |
| 1974 | 199 | 199 | (71) | -- | -- | -- | -- | -- | -- |
| 1973 | 179 | 179 | (90) | 252 | 46 | (10) | -- | -- | -- |
| 1972 | 187 | 187 | (116) | 251 | 53 | (10) | -- | -- | -- |
| 1971 | 201 | 201 | (32) | 246 | 46 | (32) | -- | -- | -- |
| Mean | 183 | 183 | | 248 | 48 | | -- | -- | -- |

Growth increments calculated for both sexes suggest that growth of males exceeded that of females only during their first year. Average growth increments in their first year of growth for males and females were 197 and 183 mm, respectively. In their second year of growth, increments were 49 and 48 mm for males and females, respectively. Average growth for males in their third year of growth was 37 mm, however, this estimate was based on a paucity of Age III tilapia.

Overall length-weight relationships of blue tilapia were determined for males and females collected in gillnets over the 3 yr period. The resulting equations were as follows:

$$\text{Males:} \quad \log W = -4.8614 + 3.0501 \log L$$
$$\text{Females:} \quad \log W = -4.9887 + 3.1061 \log L$$

Analysis of covariance indicated no significant differences between slopes of the lines ($F = 3.04$; 1,909 df). Slopes of the 2 regressions of nearly 3.0 indicated little change in plumpness with length for either of the sexes. The test of adjusted means detected no significant difference ($F = 3.14$; 1,910 df) in elevation of regression lines, indicating no overall difference in condition between sexes.

*Population and Biomass Estimates*

Assignment of ages to fish in the mark-recapture experiment indicated that fish were Age 0, I and II at the time of marking, and that Age 0 tilapia separated into 2 size groups on the basis of length-frequency, one less than 160 mm total length and the other greater than 160 mm. Therefore, Age 0 tilapia were sub-divided into these 2 groups for a more accurate estimate of the biomass of Age 0 fish.

Population estimated for Age 0 tilapia less than 160 mm was 1,378,517 and for those greater than 160 mm, 1,742,293, resulting in a total of 3,120,810 Age 0 tilapia. Age I and II tilapia estimates were 1,591,823 and 144,330, respectively. Combining these age groups produced a total estimate of 4,856,963 tilapia for December 1974 (Table 4).

Table 4. Petersen population estimate and biomass estimates of tilapia in Trinidad Lake for December 1974, with 95% confidence limits.

| *Age* | *TL (mm)* | *Marked* | *Captured* | *Recaptured* | $\hat{A}$ $\hat{N}$ *(CI)* | *W* (g) | *Total W (kg)* | *kg/ha* |
|---|---|---|---|---|---|---|---|---|
| 0 | 50-159 | 5,022 | 31,018 | 113 | 1,378,517 (1,145,385-1,657,153) | 14.44 | 19,905.8 | 65.69 |
| 0 | 160-219 | 8,415 | 40,374 | 195 | 1,742,293 (1,516,729-2,010,339) | 129.90 | 226,323.9 | 746.94 |
| I | 200-299 | 15,392 | 27,406 | 265 | 1,591,823 (1,410,813-1,795,035) | 305.63 | 486,507.8 | 1,605.64 |
| II | 270 | 1,275 | 1,132 | 10 | 144,330 (78,355-266,292) | 465.88 | 67,240.7 | 221.92 |
| Total | | 30,104 | 99,930 | 583 | 4,856,963 | | 799,978.2 | 2,640.19 |

No weights of tilapia were taken at the time of marking, so the biomass estimate was based on weights of tilapia of various lengths taken from gillnet samples during the time of the marking period. For tilapia between 50-160 mm, total weights of 320 tilapia were averaged to be 14.4 g, yielding a total weight of 19,905.8 kg and 65.7 kg/ha for this size group. Age 0 tilapia between 160-219 mm averaged 129.9 g from a sample of 40. This produced an estimate of 226,323.9 kg and 746.9 kg/ha for the larger Age 0 fish. Age I tilapia between 200-299 mm averaged 305.6 g from a sample of 116; with the population estimate of 1,591,823 a biomass estimate was obtained of 486,507.8 kg with 1,605.6 kg/ha. Age II tilapia which were greater than 270 mm averaged 465.9 g from a sample of 17, producing 67, 240.7 kg and 221.9 kg/ha. This yielded a total of 799,978.2 kg and 2,640.2 kg/ha (Table 4).

*Annual Survival*

The ratio of estimated numbers of the 1972 and 1973 year classes from the population estimate in 1974 produced a survival estimate of 9 percent from Age I to Age II (Table 5). Equal recruitment of year classes must be assumed for this estimate to be valid (Ricker 1975). To test whether uniform recruitment had occurred, the gillnet catches of Age I tilapia in 1973 and 1974 were compared. A ratio of 378/501 was found, which indicates that recruitment was variable and an overestimation of survival of about 25

Table 5. Estimates of survival from Age I to Age II tilapia based on population estimate data and gill net c/f data.

| *Year of Capture* | *Year Class* | $\hat{N}$ | $\hat{s}$ | *Gillnet Catch* | $\hat{s}$ |
|---|---|---|---|---|---|
| 1973 | 1972 | | | 501 | |
| | | | | | 0.15 |
| 1974 | 1972 | 144,330 | | 74 | |
| | | | 0.09 | | |
| 1974 | 1973 | 1,591,832 | | 378 | |
| | | | | | 0.25 |
| 1975 | 1973 | | | 95 | |

percent occurred. The survival of 9 percent from the population estimate was therefore adjusted by 25 percent and produced an estimated annual survival estimate of 7 percent from Age I to Age II.

Estimates of survival from Age I to Age II based on gillnet catches in sequential years were computed for comparison with that based on the population estimate. These estimates do not require equal recruitment, but are based on the assumption of equal vulnerability of age classes to gillnets. The estimate for the 1972 year class was 15 percent, and for the 1973 year class, 25 percent (Table 5). The high values for these estimates indicates that increased vulnerability of older fish to the nets probably occurred.

An estimate of Age 0 tilapia surviving to Age I was also calculated using the ratio of population sizes of the 1973 and 1974 year classes from the population estimates in 1974. This produced a survival estimate of 51 percent, which is subject to error because of the possibility of annual variations in recruitment.

Survival of tilapia in temperate waters is determined by the lower temperatures of these waters. Tilapia are semi-tropical fish and need temperatures above 10 C for survival. McBay (1961) found that 2.5 cm to 15.2 cm blue tilapia did not tolerate temperature as low as 9 C. The 22.9 cm to 27.9 cm fish were affected less by the colder water and tolerated temperatures as low as 3.5 C for short periods of time. Sarig (1970) stated that blue tilapia would die at temperatures of 8.0 to 8.5 C. Avault et al. (1968) found blue tilapia unable to survive temperatures below 12 C. Some overwinter mortality of blue tilapia in Trinidad Lake was observed each year when water temperature in the discharge canal reached 10 C. During an extended period of cold weather in December 1975 and January 1976 water temperatures ranged from 6 to 9 C and a massive tilapia die-off occurred. Subsequent sampling by seining, gillnetting, and electrofishing in 1976 and 1977 failed to produce a single survivor or progeny of the tilapia population.

*Yield*

The data provided by this study, plus some available from the literature, were integrated to provide an estimate of the annual yield which could have been available from the Trinidad Lake tilapia population. Tilapia in Trinidad Lake attain a weight of 182 g (marketable size) at approximately 220 mm total length, therefore all tilapia above this length could be available for the market. Data from the population and biomass estimates indicate 1,629,501 tilapia weighing 521,153 kg would be of marketable size. Most of them could readily be harvested by a system of weirs as fish enter the discharge canal each winter.

Maturity data for female tilapia captured in gillnets in 1974 and 1975 (Table 6) indicated that Age 0 females did not mature until October of each year during this study. By then water temperature had cooled below that necessary for reproduction, therefore it appeared no Age 0 female tilapia spawned and the total spawning population would be Age I or older. However, the remaining adult stock of 1,965,532 tilapia between 170 and 219 mm should, with multiple spawning (Dadzie 1970) produce adequate numbers of young to sustain the population. In addition, growth rates of young tilapia would likely increase if adults were being harvested, resulting in higher survival of young and earlier maturity of females.

Table 6. Maturity of female blue tilapia captured in 1974-75.

| *TL (mm)* | *Immature* | *Mature* | *% Mature* |
|---|---|---|---|
| 130-139 | 4 | 0 | 0 |
| 140-149 | 1 | 0 | 0 |
| 150-159 | 1 | 0 | 0 |
| 160-169 | 0 | 0 | 0 |
| 170-179 | 1 | 5 | 83 |
| 180-189 | 4 | 11 | 79 |
| 190-199 | 5 | 17 | 77 |
| 200-209 | 5 | 11 | 69 |
| 210-219 | 4 | 13 | 76 |
| 220-229 | 1 | 4 | 80 |
| 230-239 | 0 | 2 | 100 |
| 240-249 | 1 | 13 | 93 |
| 250-259 | 0 | 17 | 100 |
| 260-269 | 0 | 32 | 100 |
| 270-279 | 0 | 14 | 100 |
| 280-289 | 0 | 6 | 100 |
| 290-299 | 0 | 1 | 100 |
| 300-309 | 0 | 2 | 100 |
| Total | 27 | 148 | 85 |
| 170-219 | 19 | 57 | 75 |

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