# RELATIONSHIP OF THREADFIN SHAD DENSITY AND SIZE STRUCTURE TO IMPINGEMENT AT A STEAM-ELECTRIC PLANT

THOMAS A. McDONOUGH, Division of Water Resources, Tennessee Valley Authority, Norris, TN 37828

PETER A. HACKNEY, Division of Water Resources, Tennessee Valley Authority, Norris, TN 37828

*Abstract:* Threadfin shad (*Dorosoma petenense*) impingement at the Tennessee Valley Authority's Cumberland Steam-Electric Plant followed a seasonal pattern related to the abundance and length distribution of young-of-year fish. Electrofishing samples taken near the plant showed a similar pattern. The number of impinged fish (larger than 50 mm) decreased rapidly with increasing length due to reduction in abundance by natural mortality. Impingement mortality was found to be length dependent. Most individuals. less than 50 mm in length passed through the screens, while increasingly larger individuals were more likely to become impinged. Impinged fish less than 100 mm total length tended to be more plump than fish collected in rotenone samples, while impinged fish larger than 100 mm tended to be in poorer condition.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 33:639-647

Threadfin shad play an important role as a prey species in the ecology of lakes and reservoirs in the southern United States. Prior to 1950, the range of this species was restricted to the Gulf of Mexico drainages, extending as far north as Oklahoma and Tennessee (Carlander 1969). Introduction into other areas to serve as prey for piscivores has resulted in a substantial range extension (Minkley and Krumholz 1960). Threadfin shad populations are now established in reservoirs as far north as West Virginia and west to California and Hawaii (Griffith 1978).

Impingement of fish on cooling water intake screens of steam-electric generating plants has received greatly increased attention because of the enactment of the 1972 Amendments to the Federal Water Pollution Control Act Section 316 (b). The majority of fish impinged in the Southeast are threadfin shad (Griffith 1978). This species is intolerant of cold temperatures (Strawn 1965) and, at most Tennessee Valley Authority steam-electric plants, the greatest numbers are impinged during the coldest part of the year (Griffith and Tomljanovich 1975). At the Cumberland Stream-Electric Plant, however, highest threadfin shad impingement occurred in late summer and early fall (Griffith and Tomljanovich 1975). A previous study (McDonough and Hackeny 1978) suggested that this pattern was due to seasonal changes in abundance and length of fish in the reservoir and pointed to the need for analysis of these factors. The current study was designed to address these ideas in greater detail.

## MATERIALS AND METHODS

The Cumberland Steam-Electric Plant is located on the south bank of Barkley Reservoir, a 23,440 ha (at full pool) mainstream impoundment on the Cumberland River in northwest Tennessee. The plant is a two-unit coal-fired installation with open cycle cooling. Cooling water for both units is provided through a 133 m long intake channel located perpendicular to the shoreline. Maximum total condenser and auxiliary flow is 120 $m^3$ per sec. A skimmer wall, located at the entrance of the channel, extends 14 m down from the surface to prevent entry of floating debris. Eight condenser cooling pumps withdraw water through 16 intake chambers. Trash racks are located at the mouth of each intake chamber to screen large debris. Behind each trash rack is a vertical traveling screen having 9.5 mm square openings. The physical characteristics of Barkley Reservoir and Cumberland Steam-Electric Plant are described more fully elsewhere (Tennessee Valley Authority 1977a).

Intake screens were examined weekly beginning 7 August, 1974. All screens in operation were cleared of fish which had accumulated during the previous 24 hours. Usually 2 adjacent screens were washed together. Impinged fish were flushed into a sluice pipe leading to a catch basin. Numbers and total weight were recorded by species and 25 mm length groups.

Comparisons were made of the seasonal change in numbers, size distribution, and length-weight relationship of impinged threadfin shad versus individuals collected by electrofishing, rotenone, and larval fish gear in the vicinity of Cumberland Steam-Electric Plant. The sampling methodology has been described by the Tennessee Valley Authority (1977b). Fish densities were transformed using $\log_{10}$ (density + 1) in order to normalize frequency distributions, stabilize variances, and avoid the log transformation problem of zeros in the data.

## RESULTS AND DISCUSSION

Impingement of threadfin shad followed similar patterns in both 1975 and 1976 at the Cumberland Plant (Fig. 1). In spring and early summer, few fish were impinged. Numbers rose rapidly in July as young-of-year fish became large enough to be inpinged. Numbers then tended to decrease through the fall, probably due to natural mortality of larger fish and increased swimming ability. Impingement increased again in early winter, as water temperatures fell, and then it decreased through the rest of the winter.

Samples taken in the discharge basin of the plant using electrofishing gear followed a similar seasonal pattern revealing that the numbers impinged were related to threadfin shad abundance (or availability for impingement) in the vicinity of the plant. Regression analysis indicated that this relationship was highly significant ($H_o$: $\beta = 0$; $P < .001$), although the correlation coefficient was low ($R^2 = 0.229$).

Fig. 2 is a three-dimensional plot showing the change in length distribution of impinged threadfin shad from May 1975 to April 1976. Numbers per screen were expressed as logarithms to permit greater detail for all sizes. Young-of-year threadfin were first impinged in July as the largest individuals in the year class attained lengths of 50 to 75 mm. Growth resulted in a gradual increase in length distribution through summer and fall. By November, most fish impinged were longer than 75 mm. However, in January, most of the impinged threadfin shad were again less than 75 mm long. A similar seasonal pattern was observed in the size distribution of the 1976 year class. The reasons for this are imperfectly understood. It is possible that there were 2 major spawning periods. A plot of 1976 larval cluepid density by 5 mm groups (Fig. 3) does not totally support this hypothesis. There appears to have been a single peak in the density of larval clupeids of 5 mm or less, followed by an extended period of decreasing density for this group. However, the larger size groups (6 to 10 mm and 11 to 15 mm) do show 2 peaks. It is possible that individuals spawned early grow rapidly and suppress growth and survival of individuals spawned later in the season. Late spawned individuals may grow slowly as a result of food competition and low water temperatures and thus would not reach impingeable size until January.

A plot of the logarithm of the mean number of fish impinged versus fish length (Fig. 4) revealed that impingement decreased with increasing length for fish larger than 50 mm. This is to be expected since as length increases, numbers decrease due to natural mortality.

Impingement mortality was found to be length dependent. Fish smaller than 50 mm passed readily through the screens, the probability of becoming impinged, rather than entrained, increasing with size (Fig. 4). As a result, impingement samples were selective for longer young-of-year fish. Length frequencies of impinged threadfin shad were compared with those for individuals collected during the same week in cove rotenone

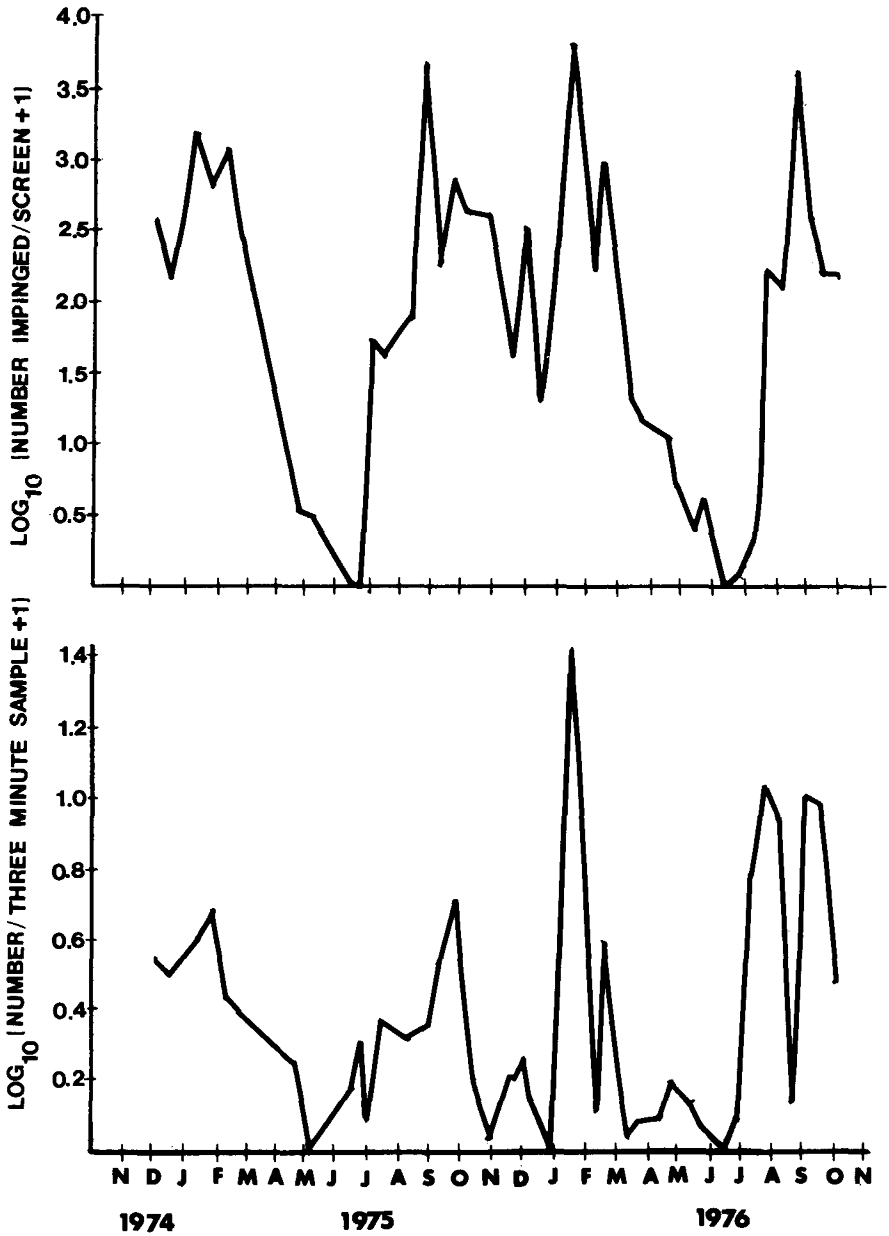


Fig. 1. Number impinged (upper figure) and electrofishing catch per unit effort data (lower figure) for threadfin shad, Barkley Reservoir.

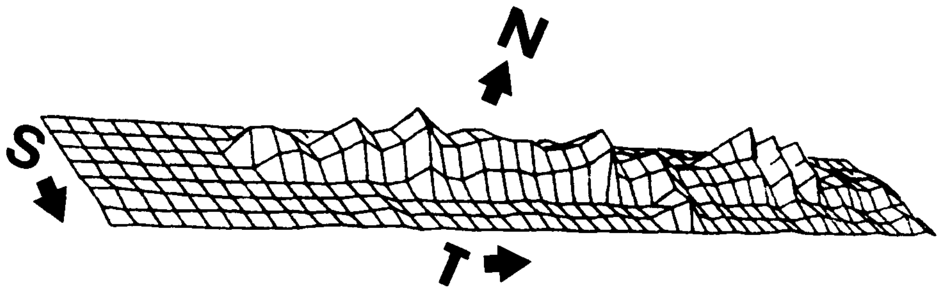


Fig. 2. Three dimensional graph of the logarithm of threadfin shad numbers impinged through time (May 1975 through April 1976) by 25 mm groups. N = Logarithm of numbers impinged per screen, T= Time in weeks, S = Size in mm.

samples (Fig. 5) taken at irregular intervals between 30 June and 2 September 1976. Both sampling techniques showed an increase in length distribution through the season. In late June, when the first cove samples were taken, young of year in the 26 to 50 mm length group comprised over 75% of the threadfin shad collected; however, none were impinged on the screens. Young of year were apparently small enough to pass through the screens and therefore would have been entrained rather than impinged. In subsequent periods, impingement samples were selective for larger sizes, since the smaller individuals were evidently entrained rather than impinged.

The relationship between the logarithm of weight versus length was plotted for impinged threadfin shad and also for fish collected in rotenone samples (Fig. 6). These differences were significant for fish in the 101 to 125 mm and 151 to 175 mm size classes ($H_o$:$X_1 = X_2$; $P < 0.05$). The average weights of impinged fish greater than 100 mm were lower than those for fish of similar length collected using rotenone. This suggests that the weaker fish, which may be diseased and already dead or dying, quite likely were selectively impinged. Healthy fish of these lengths were probably able to swim against the current velocities encountered in the intake channel.

Smaller impinged threadfin shad (less than 100 mm length) were in better condition than those in rotenone samples. These differences were significant for each size class ($H_o$: $X_1 = X_2$; $P < 0.05$). The heavier, fuller bodied fish at these lengths appeared to be selectively impinged because of a greater probability of retention by the screens. However, this is not necessarily selective mortality since thinner individuals probably were entrained rather than impinged; i.e., all were probably killed. There is some possibility, however, that a portion of the entrained individuals survived plant passage.

## CONCLUSIONS

Numerous studies have examined factors thought to cause fish impingement at power plant intake screens. Most of these studies have stressed the relationship between physical factors and impingement (Grimes 1975, Mathur et al. 1977) while population density and size distribution have been ignored.

This study has shown that spawning dates, rate of growth, abundance in the vicinity of the plant, and natural mortality all have a bearing on the numbers impinged. Like most conventional fishing gear, steam-electric plants selectively exploit fish of certain sizes. Knowledge of these relationships will be required to estimate both impingement and its impact on fish populations.

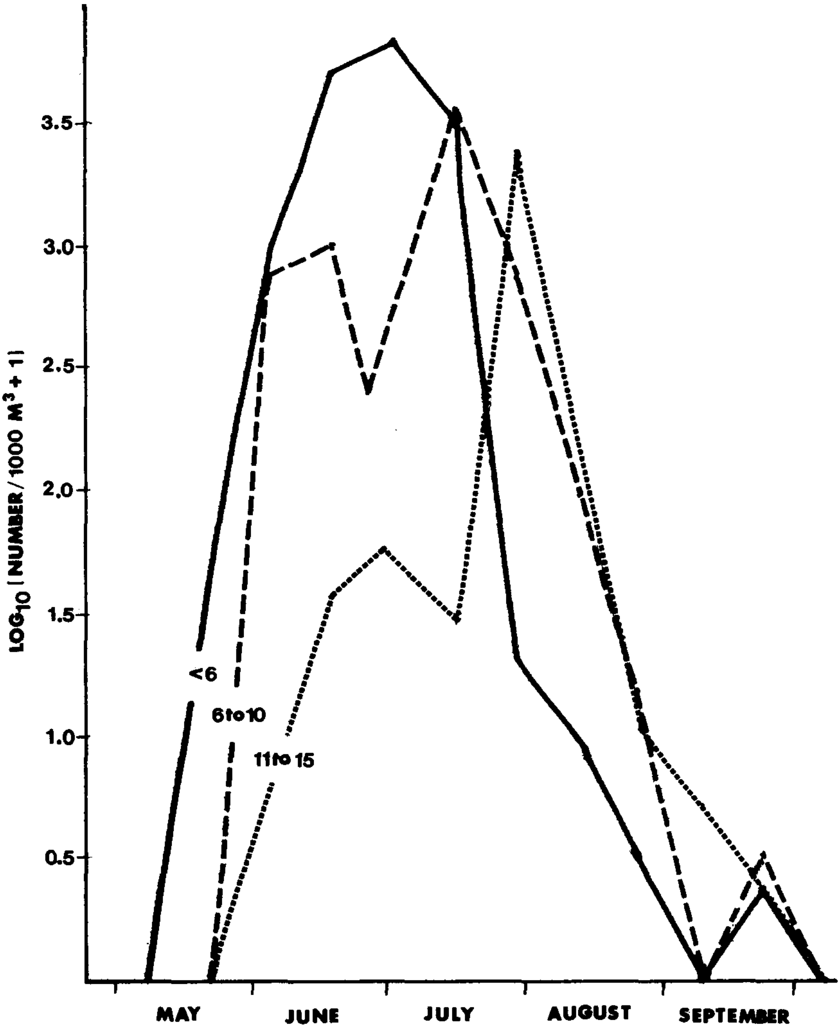


Fig. 3. Density of larval Clupeidae taken in night samples through time near Cumberland Steam Electric Plant by 5 mm length groups (May 7, 1976, to October 2, 1976).

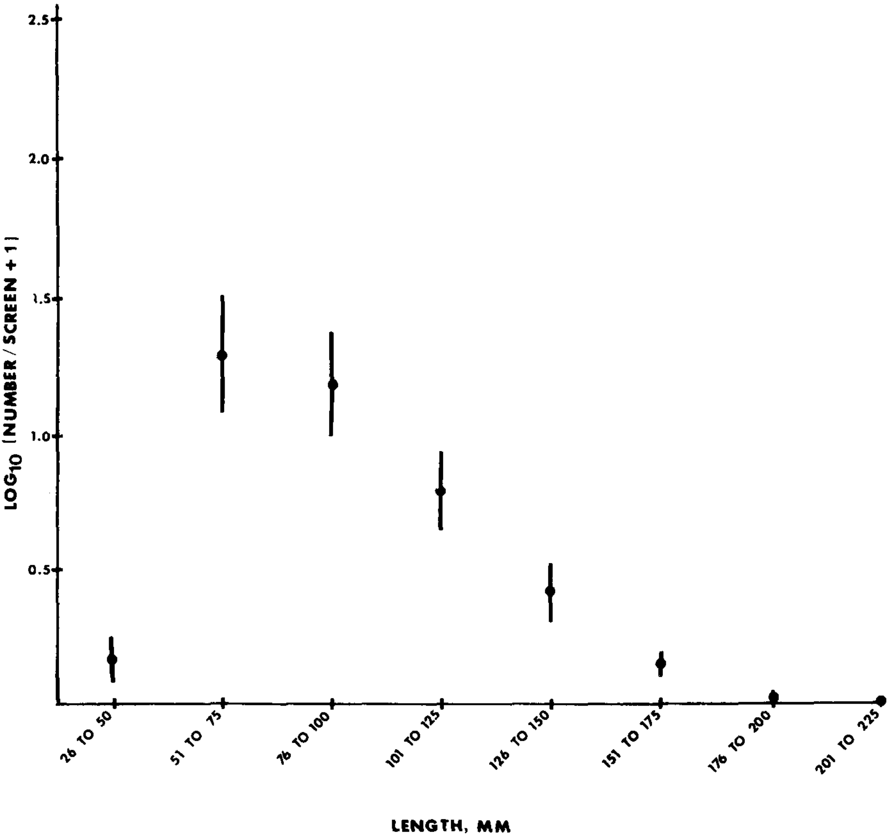


Fig. 4. Logarithm of the mean number of threadfin shad (plus or minus two standard errors) impinged by 25 mm length groups.

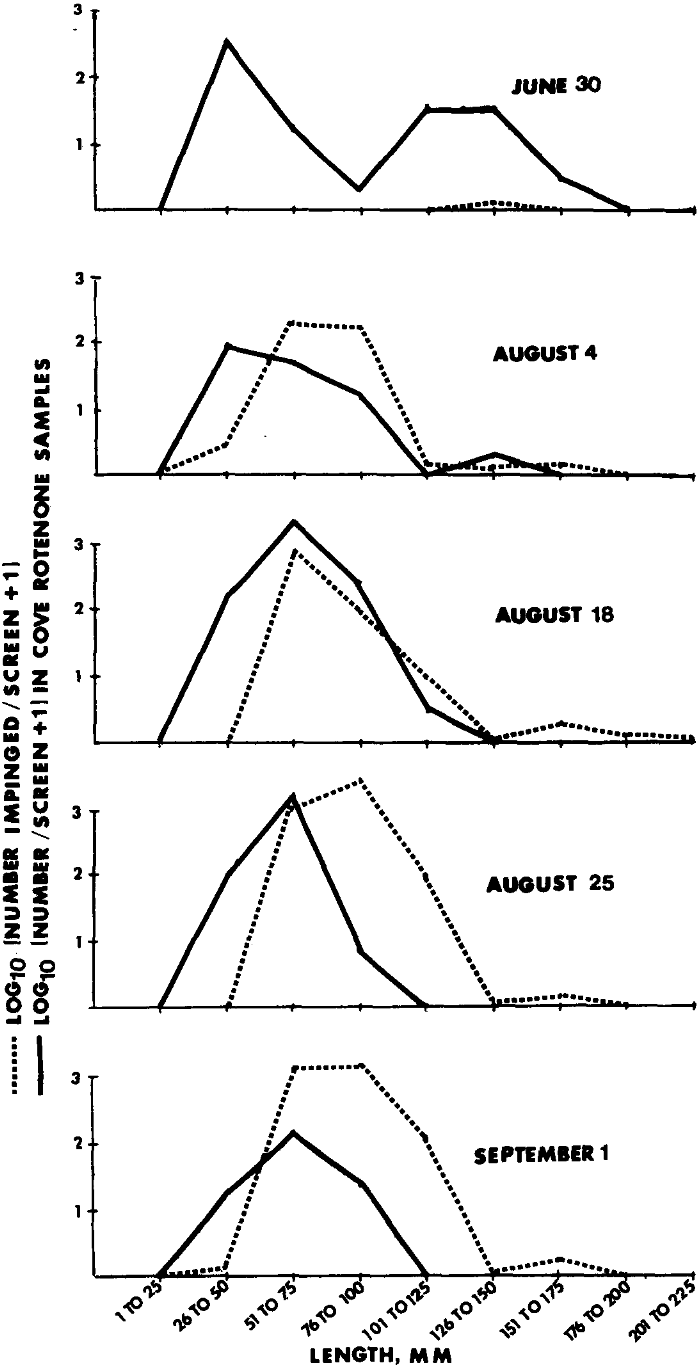


Fig. 5. Comparison of the length frequencies for impinged threafin shad versus those of individuals collected during the same week in cove rotenone samples (June 30, 1976, to September 3, 1976).

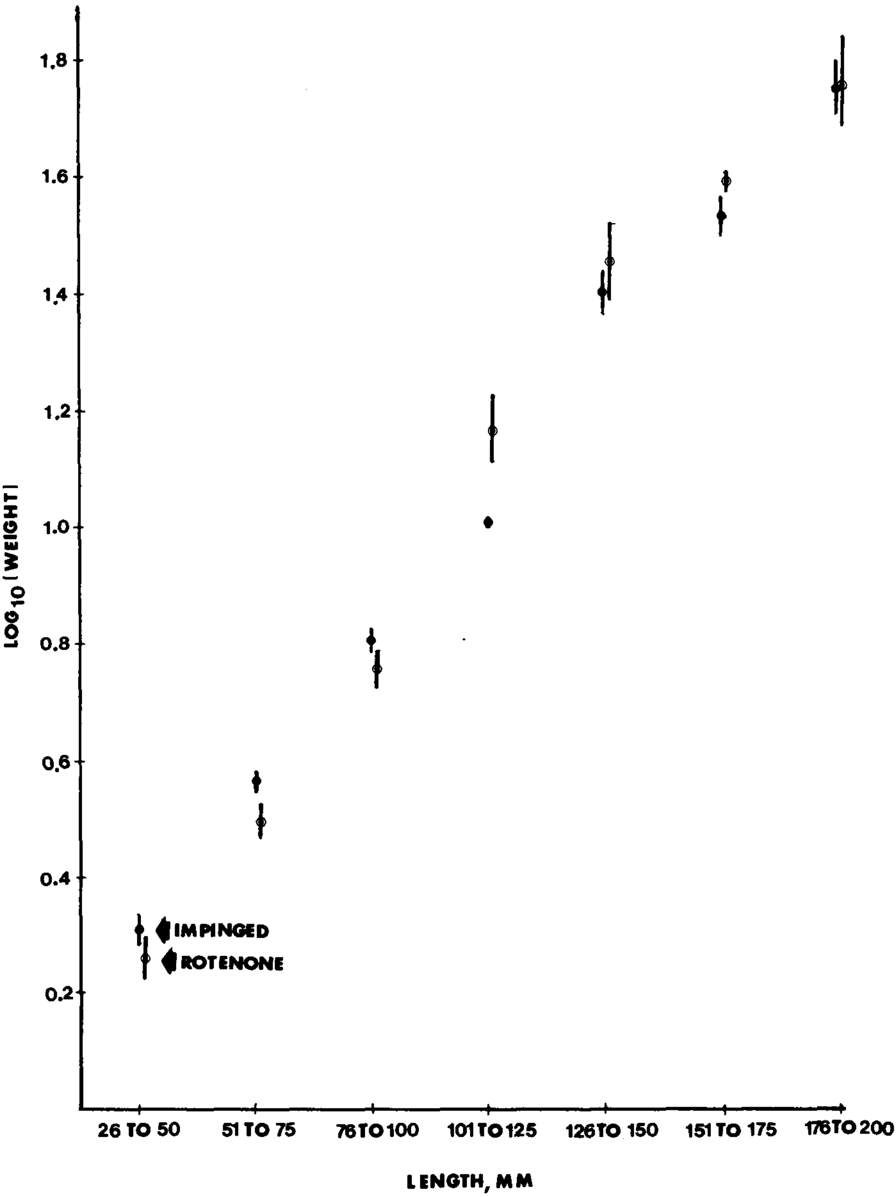


Fig. 6. The relationship between the logarithm of weight (plus or minus two standard errors) and length for threadfin shad impinged in July and August versus those for fish collected in summer cove rotenone samples.

## LITERATURE CITED

Carlander, K.D. 1969. Handbook of freshwater fisheries biology. Iowa State University Press, Ames, Iowa. 752 pp.

Griffith, J.S. 1978. Effects of low temperature on the survival and behavior of threadfin shad, *Dorosoma petenense*. Trans. Amer. Fisheries Soc. 107:63-70.

______________ and D.A. Tomljanovich. 1975. Susceptibility of threadfin shad to impingement. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 17;290-293.

Grimes, C.B. 1975. Entrapment of fish on intake water screen at a steam-electric station. Chesapeake Sci. 14:172-177.

McDonough, T.A., P.A. Hackney. 1978. An analysis of factors affecting impingement of fish at Cumberland Steam Plant. Proc. Int. Symp. Env. Effects Hydraulic Eng. Works. Knoxville, Tennessee. In press.

Minkley, W.L., and L.A. Krumholz. 1960. Natural hybridization between the clupeid genera *Dorosoma* and *Signalosa*, with a report on the distribution of *S. petenense*. Zoologica 44:171-180.

Mathur, D., P.G. Heisey, and N.C. Magnusson. 1977. Impingement of fishes at Peach Bottom Atomic Power Station, Pennsylvania. Trans. Amer. Fisheries Soc. 106:258-267.

Strawn, K. 1965. Resistance of threadfin shad to low temperatures. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 17:290-293.

Tennessee Valley Authority. 1977a. 316 (a) and (b) Demonstration - Cumberland Steam Plant. Vol. 5: Effects of the Cumberland Steam Plant cooling water intake on the fish populations of Barkley Reservoir. Tennessee Valley Authority. Norris, TN 84 pp.

Tennessee Valley Authority. 1977b. 316 (a) and (b) Demonstration - Cumberland Steam Plant. Vol. 4: Effects of thermal discharges from Cumberland Steam Plant on the fish populations of Barkley Reservoir. Tennessee Valley Authority. Norris, TN 234 pp.