GROWTH, SURVIVAL AND DISTRIBUTION OF STRIPED BASS STOCKED INTO WATTS BAR RESERVOIR, TENNESSEE

M.J. VAN DEN AVYLE, Tennessee Cooperative Fishery Research Unit, Tennessee Technological Univ., Cookeville, TN 38501

B.J. HIGGINBOTHAM, Tennessee Cooperative Fishery Research Unit, Tennessee Technological Univ., Cookeville, TN 38501[a]

Abstract: Striped bass (Morone saxatilis) were collected from Watts Bar Reservoir, Tennessee, in 1977 and 1978 to assess relationships between growth rates, survival, stocking density, and distribution patterns of stocked fingerlings. Survival and average sizes attained at ages 1 and 2 were inversely related to stocking density and directly related to size at stocking. Average lengths of age 3 and older fish were not related to stocking size, and the principal advantage of stocking large fingerlings was improved survival. Fingerlings stocked during June and July 1978 dispersed rapidly but tended to remain within the general area into which they had been introduced. During October and November 1978, electrofishing catch data indicated a preference for sandy shoreline habitats. Site-specific factors, such as the presence of preferred habitats, should be considered to enhance striped bass survival following stocking.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 33: 361-370

Freshwater introductions of the striped bass have been popular because this species grows rapidly, attains a large size, and utilizes abundant shad (*Dorosoma* spp.) populations common in many impoundments. Establishment of self-sustaining populations, however, has been rare, and striped bass are maintained in the majority of reservoirs by annual stockings of fry and/or fingerlings. Growth rates, food habits, maturation, and other aspects of adult life history have been reported for many populations, but habitat requirements, distribution, and effects of stocking density on growth and survival of juvenile striped bass are poorly understood. An improved understanding of early life history is needed to better define the times, sites, sizes, and densities at which striped bass should be stocked into impoundments.

The objectives of this study were to monitor growth, dispersal, and habitat preferences of fingerling striped bass that were stocked into Watts Bar Reservoir, Tennessee. Relationships among growth rates, survival, numbers stocked and the size at stocking were evaluated for 7 year classes and the effects of stocking density on relative abundance of young-of-the-year striped bass were studied at 7 sites in 1978.

This study was funded through the Tennesee Wildlife Resources Agency and the Tennessee Cooperative Fishery Research Unit by the Commercial Fisheries Research and Development Act, U.S. Department of Commerce, NOAA, Project 2-295-R. Cooperators of the Tennessee Cooperative Fishery Research Unit include the U.S. Fish and Wildlife Service, Tennessee Technological University and the Tennessee Wildlife Resources Agency.

METHODS AND MATERIALS

Watts Bar Dam was constructed in 1942 at Tennessee River Mile 530 in Tennessee (Fig. 1). Principal uses of the reservoir include flood control, power generation, navigation and recreation. At full pool elevation (225.8m MSL), the reservoir has a surface area of 15,628 ha, is 116.5 km long and average depth is 8.9 m (Moss 1967). Upstream boundaries are Melton Hill Dam on the Clinch River and Ft. Loudoun Dam

[a]Present address: Tennessee Wildlife Resources Agency, Crossville, TN 38555.

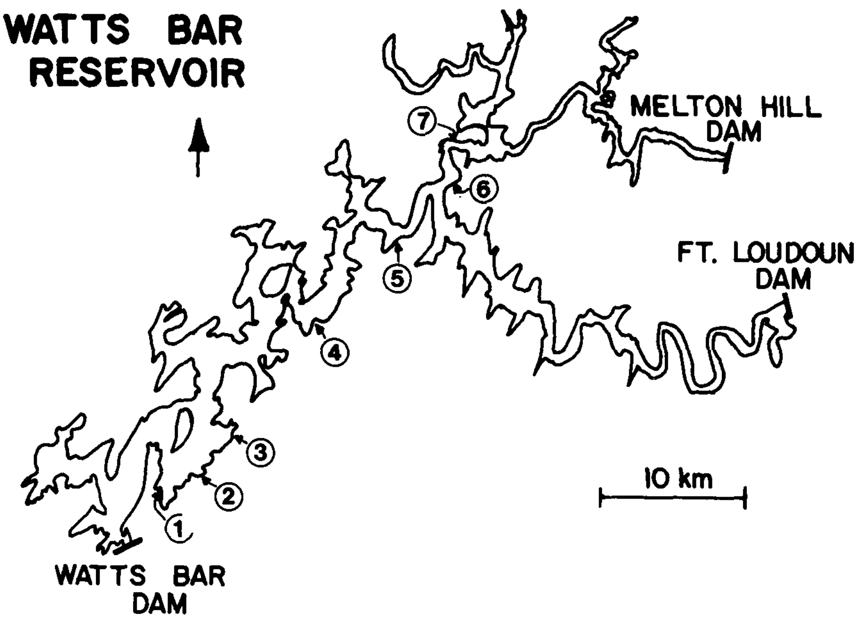

Fig. 1. Map of Watts Bar Reservoir Tennessee, showing seven sites where striped bass were stocked in 1978.

on the Tennessee River. Hydropower generation and flood releases create current throughout the reservoir and the hydraulic retention period varies from 10 to 14 days (Churchill 1967).

The upstream arms of the reservoir are river-like and bottom substrates are primarily clay or rock. Substrates adjacent to shorelines in the main body of the reservoir are clay, sand or a mixture of rock and gravel. Rip-rap has been placed near commercial operations in several areas of the reservoir. Striped bass eggs and fry were first introduced into Watts Bar Reservoir by the Tennessee Game and Fish Commission (presently Wildlife Resources Agency) in 1964. Fingerlings have been stocked annually since 1971 at densities ranging from 0.5 to 13.8 fish per ha (Table 1).

Many fish species serve as potential competitors, predators and/or prey for the introduced striped bass. Sport fishes include largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieui*), white bass (*M. chrysops*), yellow bass (*M. mississippiensis*), white crappie (*Pomoxis annularis*), black crappie (*P. nigromaculatus*), walleye (*Stizostedion vitreum*), sauger (*S. canadense*) and sunfishes (*Lepomis* spp.). Major prey species are gizzard shad (*Dorosoma cepedianum*) and threadfin shad (*D. petenense*). Rough fishes include buffalofishes (*Ictiobus* spp.), carp (*Cyprinus carpio*), freshwater drum (*Aplodinotus grunniens*) and catfishes (*Ictaluridae*) (Heitman and Van Den Avyle 1978).

Striped bass were collected from Watts Bar Reservoir and its tailwater region from September 1977 through December 1978. Adults were collected by electrofishing in the tailwaters of Melton Hill, Ft. Loudoun and Watts Bar Dams and by gill netting along the main channel of the reservoir. Some adult specimens were provided by personnel of the Tennessee Wildlife Resources Agency and the Tennessee Valley Authority.

Habitat preferences and dispersal of fingerlings stocked during June and July 1978 were evaluated by using catch per effort data from shorline electrofishing at night.

TABLE 1. Numbers and sizes of striped bass stocked in Watts Bar Reservoir, 1964-1978.

Year	Total Number Stocked	Number per Ha[1]	Size
1964	2,240,000	143.3	eggs and fry
1971	65,000	4.2	75-200 mm
1972	7,100	0.5	85-225 mm
1973	112,850	7.2	33-100 mm
1974	106,300	6.8	13 mm
1975	174,850	11.2	13-25 mm
1976	146,000	9.3	25-75 mm
1977	197,530	12.6	110-880 per kg[2]
1978	215,198	13.8	20-45 mm

[1]At full pool elevation, surface area is 15,628 ha.

[2]expressed as the number of fingerlings per Kg, lengths not available.

Shorelines near the 7 stocking sites were classified as sand, clay or rock and gravel and 100-m transects were established in each substrate type that was present. Transects were also classified into inner, intermediate and outer regions according to straight-line distance from the stocking sites (0-0.5 km, 0.6-1.0 km or approximately 2.5 km, respectively). Only stocking site 1 possessed all substrates in 3 regions and these 9 transects were sampled twice per month from July through November 1978. The other 6 sites possessed only the inner and intermediate regions and several did not include all substrate types. These sites had 4 to 6 transects that were sampled once per month.

Total lengths (mm), weights (g) and scale samples were obtained from all fish collected. Scale impressions were made on cellulose-acetate strips; age was determined and scales were measured at 27X magnification; and the length at each annulus was calculated using the Lee method (Lagler 1956). Preliminary analyses indicated that growth rates were similar between sexes and between fish collected from the reservoir and tailwater areas (Higginbotham 1979) and all data were pooled in subsequent analyses. The average back-calculated lengths at age 1 and 2 were compared to the numbers stocked for 7 year classes using linear regression techniques.

The effect of stocking density on survival was evaluated by computing relative annual mortality rates (RM) for the 1971-1975 year classes, where

$$RM = -[\ln(Nc/Ns)]/\Delta t,$$

Nc = the number of fish collected from a particular year class,

Ns = the number stocked for the same year class and

Δt = the average time elapsed, in years, between stocking and capture for the Nc fish. This relative rate is similar to an estimate of annual instantaneous mortality and differs from it only because the number caught (Nc) rather than the number of survivors is used in the computation. Relative mortality rates for all year classes would be similar if survival was equal among all ages and year classes. The 1976 and 1977 year classes were not included in this analysis because most age 1 and older fish were collected from tailwater regions where mature fish had congregated on spawning migrations. Since striped bass generally do not mature until age 3 or 4, we believe that catches of age 1 and 2 fish were not reflective of their abundance throughout the reservoir.

RESULTS

Between September 1977 and November 1978, 662 striped bass were collected from Watts Bar Reservoir and its tailwater region. The oldest specimens were from the 1971 year class (n=2) and 275 were from the 1978 year class.

Most adult fish were collected below Watts Bar Dam, but data from all sampling locations were pooled for the age-and-growth analyses because striped bass apparently were not restricted to the reservoir in which they were stocked. Seven striped bass from year classes that had been stocked in Watts Bar Reservoir, but not in the downstream reservoir (Chickamauga), were collected below Watts Bar Dam. Although some natural reproduction has been detected in both reservoirs, we believe that the 7 fish captured below Watts Bar Dam had passed downstream through the navigation locks. In 5 years of larval fish sampling (1975-1979), the Tennessee Valley Authority collected striped bass larvae only in 1978, when 3 specimens were obtained from Watts Bar Reservoir and 1 larva was collected 8 km below Watts Bar Dam in Chickamauga Reservoir (J. Tuberville, TVA, personal communication). Bishop (1968) reported that a striped bass stocked in Watts Bar Reservoir in 1964 was collected 3 years later below Wheeler Dam. This fish had moved 526 km downstream and passed around or through 5 dams.

The length attained after 1 growing season ranged from 170 mm for the 1976 year class to 230 mm for the 1972 year class and averaged 182 mm (Table 2). Lengths at annulus 1 were negatively correlated ($r = -0.80$, $p \leq 0.05$) with the numbers stocked for the 1971-1977 year classes (Fig. 2). Samples were not available to back-calculate lengths at age 1 for the 1978 year class, however, a small average length during November 1978 (117 mm, n=41) corresponded to a high number stocked (215,198).

Since low stocking rates were usually accompanied by large stocking sizes (Table 1), length at annulus 1 may have been related to size at stocking rather than an outcome of some density-dependent mechanism. Lengths at age 1 were not regressed on stocking size because length data were not available for all years and only size ranges rather than averages were usually available for analysis. Lengths at age 2 also declined with increased stocking density (Fig. 2), but the correlation coefficient was not significant ($r = -0.73$, $p > 0.05$). Beyond age 2, back-calculated lengths at specific annuli were similar among year classes, indicating that stocking of larger fish did not produce any long-term size advantage (Table 2).

Relative mortality rates of the 1971-1975 year classes (Table 3) increased with stocking density, indicating that survival was enhanced by stocking fewer, larger fingerlings (Fig. 3). The correlation coefficient between relative mortality and stocking density, $r = 0.874$, was slightly less than the value required (0.878) for the relationship to be significant at $p \leq 0.05$.

Mean numbers of age 0 striped bass collected per transect at the 7 stocking locations in 1978 were positively correlated with stocking rates (Fig. 4). Realtive catch rates (mean number caught per transect divided by the number stocked), however, were highly variable and indicated that some factor(s) other than stocking density also contributed to the differences in catch rates between locations. Relative rates were not significantly correlated with stocking density, but sites with low adjusted catches tended to be those that received less than 30,000 fish (Fig. 5). The sizes of fish stocked at each location were nearly identical.

Dispersal of fish from the stocking sites was rapid. Average catch rates per transect (all sites and substrates combined) from the intermediate and outer regions were always higher than catches from the inner region (Fig. 6). Since the July samples were collected within 2 weeks of stocking, it was apparent that the fingerlings did not show a strong tendency to remain in the immediate vicinities of the stocking sites.

TABLE 2. Average total lengths (mm) at annuli for striped bass in Watts Bar Reservoir, Tennessee.

Year Class	Year Collected	Number Collected	1	2	3	4	5	6	7
1977	1978	61	192						
1976	1977	73	176						
	1978	27	154	368					
	All	100	170	368					
1975	1977	11	184	349					
	1978	18	167	361	547				
	All	29	174	356	547				
1974	1977	1	222	383	577				
	1978	16	193	358	551	694			
	All	17	195	360	552	694			
1973	1977	5	203	319	509	673			
	1978	22	195	351	528	692	792		
	All	27	197	345	525	688	792		
1972	1977	5	244	397	553	671	775		
	1978	1	160	395	543	667	753	827	
	All	6	230	396	551	670	771	827	
1971	1977	0							
	1978	2	198	407	559	697	840	933	992
	All	2	198	407	559	697	840	933	992
Weighted average length (mm)			182	361	541	688	793	906	992
Weighted average annual increment (mm)			182	179	181	150	105	88	59

Catch rates increased over time within all sampling regions (Fig. 6). The fish apparently were not highly vulnerable to electrofishing soon after stocking and because the patterns of increasing catch were similar between regions, it is probable that the monthly trend was reflective of movement into shallow water rather than a change in distribution patterns along the shoreline.

Catch rates in specific substrates (all locations and regions combined) were similar within the July and August sampling periods (Fig. 7). After August, rates were highest from either clay or sand substrates. The high average catches from sand substrates during October and November were primarily due to the samples collected from the 3 transects at site 1. These were located in the only sandy areas within 2.5 km of the stocking site, which indicated a strong preference for sand substrates during October and November. The young-of-the-year averaged 103 mm and 117 mm total length, respectively, during these months.

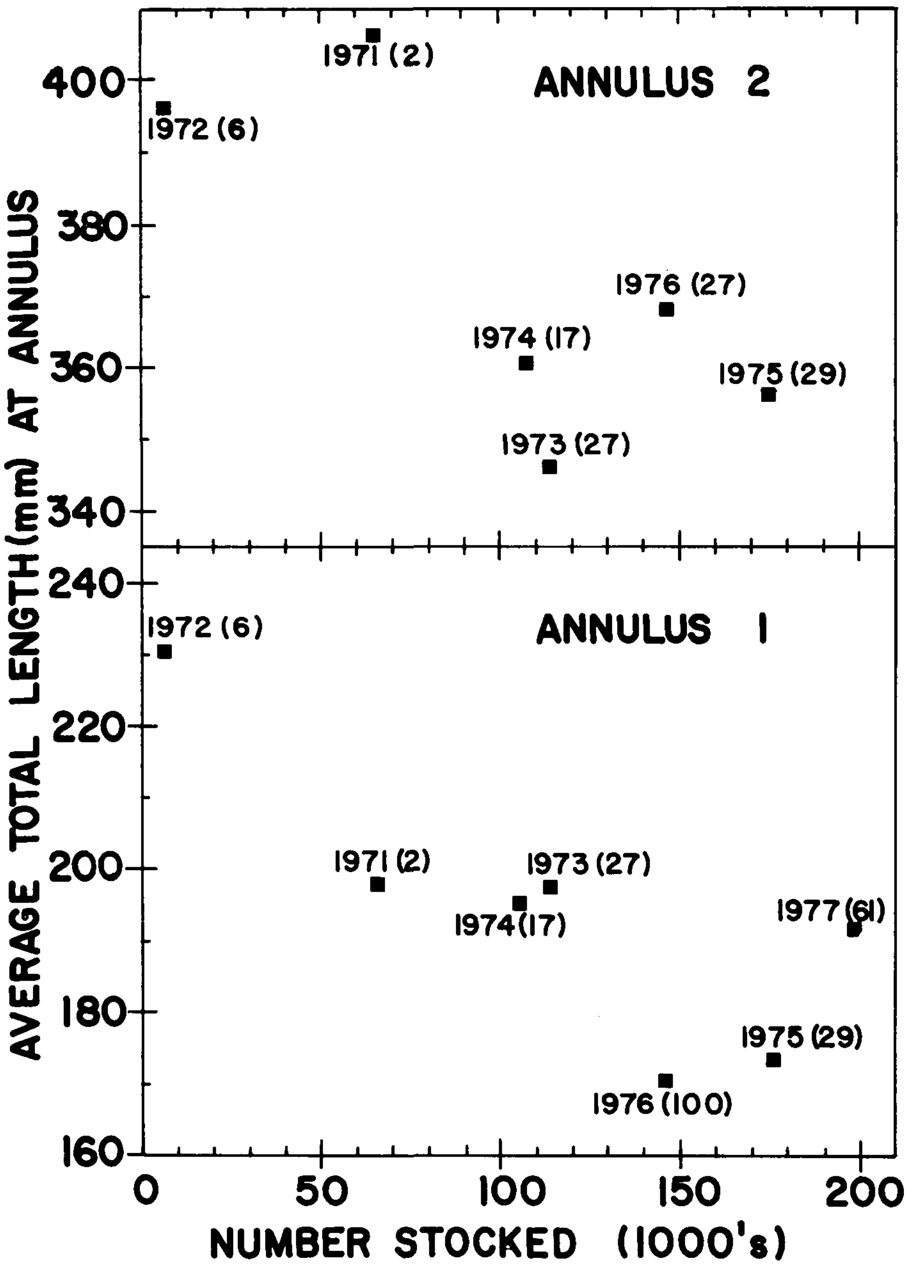

Fig. 2. Back-calculated total lengths at annulus 1 and 2 versus stocking density of striped bass in Watts Bar Reservoir. Year classes and sample sizes (in parentheses) are indicated for each average.

TABLE 3. Numbers stocked (Ns), numbers caught (Nc), and relative mortality rates (RM) for the 1971-1975 year classes of striped bass in Watts Bar Reservoir.

Year Stocked	Ns	1977	1978	Total	Average Years Elapsed	RM
1971	65,000	0	2	2	7.00	1.48
1972	17,100	5	1	6	5.17	1.37
1973	112.850	5	22	27	4.81	1.73
1974	106,300	1	16	17	3.94	2.22
1975	174,850	11	18	29	2.62	3.32

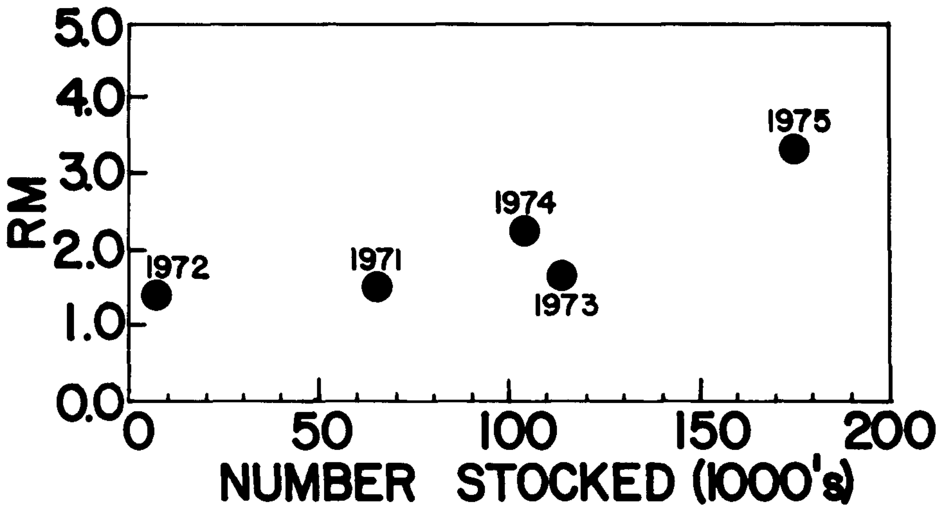

Fig. 3. Relative mortality rates (RM) versus stocking density for the 1971-1975 year classes of striped bass in Watts Bar Reservoir.

DISCUSSION

Striped bass survival and lengths attained at ages 1 and 2 were inversely related to the annual stocking rate in Watts Bar Reservoir. Since high stocking densities were accompanied by low average sizes of introduced fingerlings, the effects of the 2 variables could not be distinguished. We believe, however, that the size at stocking, rather than density-dependent mechanisms, was primarily responsible for the observed relationships.

The principal advantage of stocking large fingerlings was improved survival. Average lengths at ages 1 and 2 were related to stocking size, but there was no detectable effect on age 3 or older fish.

A significant positive correlation between average catch rates and numbers stocked at seven sites in 1978 indicated that the fingerlings tended to remain within the general area into which they were stocked for at least 5 months. Variability of relative catch rates, however, indicated that site-specific factors other than stocking density were also important in regulating fingerling survival or abundance. In Keystone Reservoir, Oklahoma, striped bass stocked in June 1969 showed a well-defined migration pattern from one area of the reservoir into another as the summer progressed (Mensinger 1970).

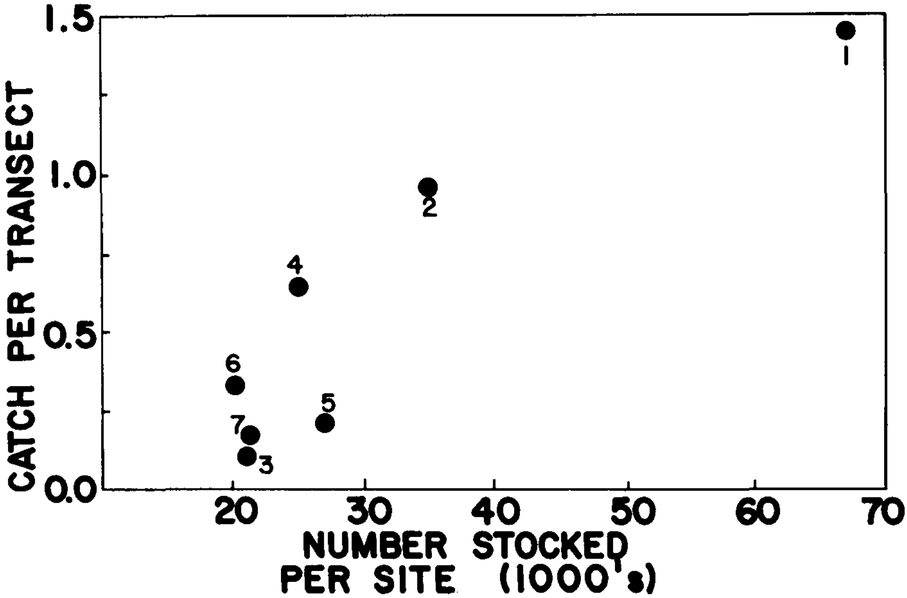

Fig. 4. Mean number of young-of-the-year striped bass collected per transect versus numbers stocked at seven sites in Watts Bar Reservoir, 1978. Stocking sites are indicated for each point.

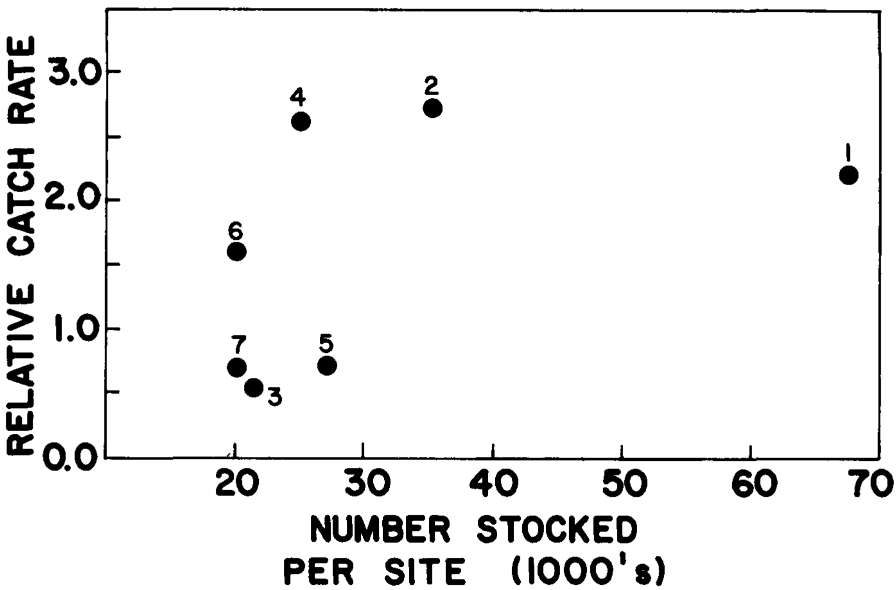

Fig. 5. Relative catch rates (mean catch per transect per 100,000 stocked) of young-of-the-year striped bass versus the number stocked at seven sites in Watts Bar Reservoir, 1978. Stocking sites are indicated for each point.

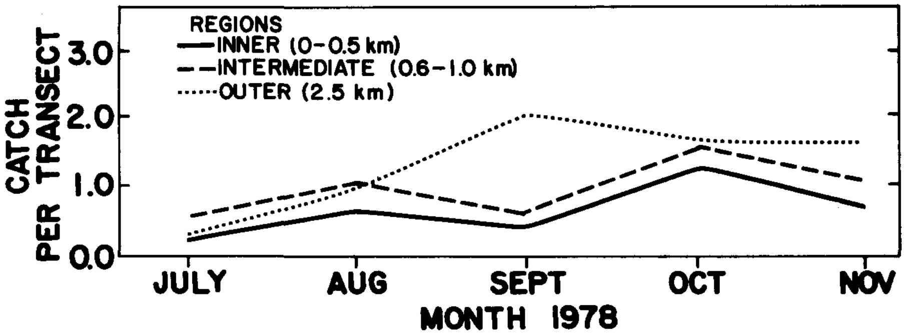

Fig. 6. Mean catch rates of young-of-the-year striped bass per transect from three sampling regions in Watts Bar Reservoir, 1978.

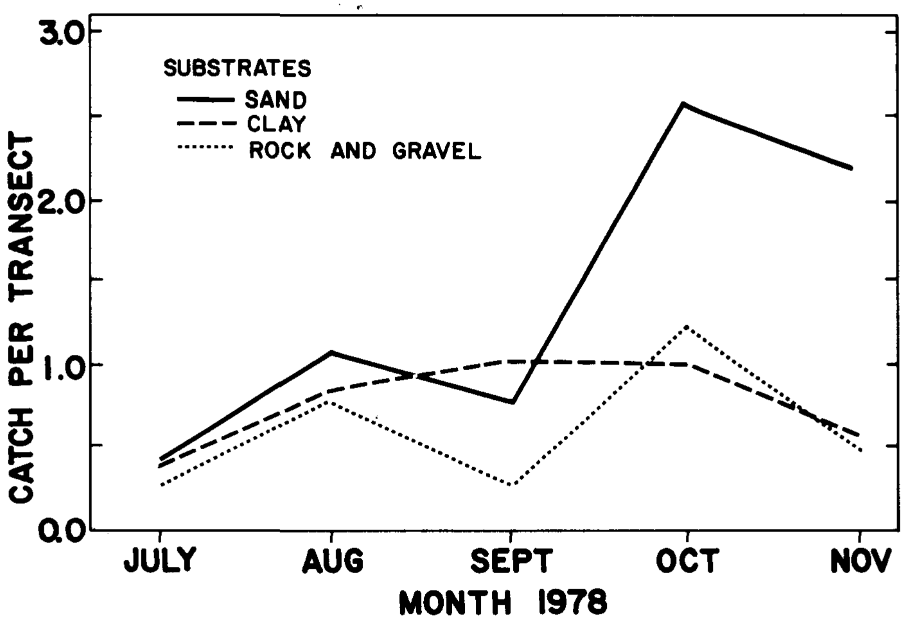

Fig. 7. Mean catch rates of young-of-the-year striped bass per transect from three substrates in Watts Bar Reservoir, 1978.

High average catches from transects established in the intermediate and outer regions indicated that dispersal within each stocking area was rapid. Average catch rates increased from July through November 1978, which suggested that the fish were not highly vulnerable to shoreline electrofishing soon after stocking. Increased catches apparently were due to an inshore movement as time progressed. During October and November 1978, catch rates were consistently highest in sand transects, which indicated a preference for this habitat at that time. Mensinger (1971) reported that seining for juvenile striped bass was most successful in sandy areas of Keystone Reservoir.

Stocking of larger fingerlings in areas that include preferred habitats could enchance striped bass survival. Additional research on the effects of competition and predation is also needed to better define suitable stocking sites. All stocking programs should evaluate the costs and benefits associated with survival and growth in the receiving waters as well as hatchery costs. This study indicates that the increased costs associated with producing larger fish for stocking are at least partially compensated by improved survival.

LITERATURE SITED

Bishop, R.D. 1968. Rockfish egg introduction and evaluation. Job Prog. Rep. Tenn. D-J F-27-3. 13 pp.

Churchill, M.S. 1967. Effects of streamflow regulation on water quality, the TVA experience. Presented at Int. Conf. Water for Peace, Washington, D.C., May 23-31, 1967. 13 pp.

Heitman, J.F., and M.J. Van Den Avyle. 1978. Species composition, catch rates and impact of a commercial fishery on striped bass in Watts Bar and Chickamauga Reservoirs, TN. Proc. Annu. Conf. Southeast. Assoc. Fish Wildl. Agencies 32:576-587.

Higginbotham, B.J. 1979. Growth, food habits, maturation and distribution of the striped bass (*Morone saxatilis*) in Watts Bar Reservoir, Tennessee. M.S. Thesis, Tenn. Univ., Cookeville. 82 pp.

Lagler, K.F. 1956. Freshwater fishery biology. Wm. C. Brown, Dubuque, Iowa. 421 pp.

Mensinger, G. 1970. Observations on the striped bass, *Morone saxatilis*, in Keystone Reservoir, Oklahoma. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 24:447-463.

Moss, D.D. 1967. Handbook of Tennessee Reservoirs. Unpublished ms, Tenn. Tech. Univ., Cookeville. 144 pp.