Chordi, A., K. W. Walls, and I. G. Kagan. 1964. Analysis of *Toxoplasma gondii* antigens by agar diffusion methods. *J.* Immunol., 93:1034-1044.
Eichenwald, H. 1949. Experimental toxoplasmosis. II. Effect of sulfadiazine and antiserum on congenital toxoplasmosis in mice. *Proc. Soc. Exp. Biol. Med., 71:* 45-49.
Feldman, H. A. 1968. Toxoplasmosis. *New Eng. J. Med., 279:* 1370-1375, 1431-1437.
Foster, B. G., and W. F. McCulloch. 1968. Studies of active and passive immunity in animals inoculated with *Toxoplasma gondii. Can. J. Microbiol.,* 14: 103-110.
Frenkel, J. K. 1948. Dermal hypersensitivity to *Toxoplasma* antigens (toxoplasmins). *Proc. Soc. Exp. Biol. Med., 68:* 634-639.
Frenkel, J. K. 1967. Adoptive immunity to intracellular infection. *J. Immunol., 98:* 1309-1319.
Gill, H. S., and O. Prakash. 1970. A study on the active and passive immunity in experimental toxoplasmosis. *Indian J. Med. Res., 58:* 1157-1163.
Hafizi, A., and F. Z. Modabber. 1978. Effect of cyclophosphamide on *Toxoplasma gondii* infection: reversal of the effect by passive immunization. *Clin. Exp. Immunol., 33:* 389-394.
Jacobs, L., and M. N. Lunde. 1957. A hemagglutination test for toxoplasmosis. *J. Parasitol., 43:* 308-314.
Jacobs, L. 1967. *Toxoplasma* and toxoplasmosis. *In:* Dawes, B. (Ed.): Advances in Parasitology. Academic Press, London, pp. 1-45.
Jacobs, L. 1976. Serodiagnosis of toxoplasmosis. *In:* Cohen, S. and Sadun, E. H. (Ed.): Immunology of Parasitic Infections, Chap. 8. Blackwell Scientific Publ., Oxford, pp. 94-106.
Kagan, I. G., and L. Norman. 1970. Serodiagnosis of parasitic diseases. *In:* Blair, J. E., Lennette, E. H. and Truant, J. P. (Ed.): Manual of Clinical Microbiology, Chap. 51. Williams and Wilkins Co., Baltimore, pp. 457-458.
McCluskey, R. T., and P. D. Leber. 1974. Cell-mediated reactions *in vivo. In:* McCluskey, R. T. and Cohen, S. (Ed.): Mechanisms of Cell-Mediated Immunity, Chap. 1. John Wiley and Sons, New York, pp. 1-24.
Ourth, D. D. 1971. The production of monospecific antibody to a single antigen-antibody complex of *Toxoplasma gondii. Immunology, 20:* 323-326.
Ourth, D. D., M. N. Lunde, and R. R. Watson. 1976. Cell-mediated hypersensitivity in guinea-pigs infected with *Toxoplasma gondii. Immunobiology, 151:* 254-262.
Thiermann, E., F. Knierim, and G. Niedmann. 1964. Vergleichende untersuchungen über die Sabin-Feldman reaktion und den haemagglutations test bei infektionen mit *Toxoplasma gondii. Z. Bakt. I. Orig., 192:* 230-260.
Uhr, J. W., and M. S. Finkelstein. 1963. Antibody formation. IV. Formation of rapidly and slowly sedimenting antibodies and immunological memory to bacteriophage ΦX 174. *J. Exp. Med., 117:* 457-477.
Uhr, J. W., and M. S. Finkelstein. 1967. The kinetics of antibody formation. *Prog. Allergy, 10:* 37-83.
van Knapen, F., and S. O. Panggabean. 1977. Detection of circulating antigen during acute infections with *Toxoplasma gondii* by enzyme-linked immunosorbent assay. *J. Clin. Microbiol., 6:* 545-547.

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DISTRIBUTION OF YELLOW BASS, *Morone mississippiensis*, IN THE TENNESSEE RIVER

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ABSTRACT

The yellow bass, *Morone mississippiensis* Jordan and Eigenmann, is known to have occurred naturally in the lower Tennessee River drainage. Early cove rotenone records of the Tennessee Valley Authority document yellow bass occurrence from Kentucky to Guntersville Reservoirs. Prior to 1964, there were no records for yellow bass above Guntersville Reservoir even though they were collected annually and in large numbers in the lower portion of the river. Since 1964, yellow bass have been collected from every reservoir accessible through lock and dam in the Tennessee River system. The possible reasons for this increase in range are discussed.

INTRODUCTION

The native range of the yellow bass, *Morone mississippiensis* Jordan and Eigenmann, was restricted to the Mississippi River and its tributaries extending from the southern portions of Wisconsin and Minnesota through Louisiana and eastern Texas (Greene 1935). This range included parts of the lower Tennessee River (Clay 1975) but apparently did not include tributaries or upstream reaches of the Tennessee River (Stroud 1947). The biology of yellow bass has been reported to be similar to that of the white bass (*Morone chrysops*) except that they prefer clearer water and more lentic habitat (Kuhne 1939, Pflieger 1975, Smith 1979). Compared to white bass, there is relatively little published information about yellow bass biology.

During the 1930's and early 1940's, the Tennessee River was changed from a free flowing river to a series of impoundments. Forbes and Richardson (1920) state that yellow bass are primarily lake species. Yellow bass occur in larger streams, but Smith (1979) states that these individuals are probably temporary residents from backwaters, overflow areas and pools. Since they prefer lentic habitats, Stroud (1947) found it unusual that yellow bass did not respond to mainstream impoundments on the Tennessee River (e.g., by rapidly expanding their range as did white bass). Although yellow bass did eventually extend their range to all of the mainstream Tennessee River impoundments, it took much longer than Stroud anticipated. The purpose of this

study is to describe the expansion of the yellow bass by examining historical fisheries data and to examine reasons for the slow rate of their range extension into the upper Tennessee River.

METHODS AND MATERIALS

Yellow bass data analyzed in this study were obtained from annual Tennessee Valley Authority (TVA) cove rotenone collections (Table 1). These data have been supplemented with published data and Tennessee Wildlife Resources Agency verified angling records (e.g., creel census). TVA biologists have established criteria for conducting cove rotenone collections. Sampling is usually conducted between July and September when water temperatures of 24-29°C promote maximum toxicant effectiveness. Selected coves range in area from 0.3 to 1.6 hectares (ha) with a preferred size $\geq$ 0.5 ha and 7.5 meters (m) or less in depth. These relatively standardized techniques have been utilized since 1960. Prior to that time, there was some experimentation with use of block nets, shoreline samples and open water sampling, but, overall, techniques were similar to post-1960 methods.

RESULTS AND DISCUSSION

After completion of Fort Loudoun Reservoir in 1943, the Tennessee River became a cascade of reservoirs (Table 1); yet yellow bass remained restricted to the lower Tennessee River where they had existed prior to impoundment. Stroud (1947) stated that TVA biologists expected yellow bass, because of increased optimal habitat, to extend their distribution and increase their numbers in the Tennessee River impoundments. Since there were no yellow bass stocking programs within the Tennessee Valley, any changes in distribution must result from natural expansion. The syntopic white bass increased its range and, with the completion of Watts Bar Dam and Lock in 1942, migrated in vast numbers upstream to the base of Norris Dam (Eschmeyer, 1944).

The anticipated expansion of yellow bass populations did occur (Stroud 1947), but it took longer than expected. Table 1 lists the reservoirs and first documented occurrence of yellow bass in each. While the pre-impoundment distribution of yellow bass in unknown, Stroud (1947) reported them restricted to the lower four reservoirs in the system (Kentucky, Pickwick, Wilson and Wheeler Reservoirs). When TVA initiated cove rotenone samples in the late 1940's, yellow bass occurred only in these same four reservoirs. In 1951, yellow bass were first collected in Guntersville Reservoir in relatively large numbers (43 per ha). Although absent from samples taken in 1949 and 1950, the numbers collected in 1951 indicate they were established in the reservoir prior to 1951 but not abundant enough to appear in the earlier samples.

TABLE 1. *Summary of Reservoir Completion Dates, Years of Tennessee Valley Authority Cove Rotenone Sampling and Year of First Occurrence of Yellow Bass Collected From Kentucky Reservoir at the Mouth of the Tennessee River Upstream to Fort Loudoun, Melton Hill, and Tellico Reservoirs.*

Reservoir	Date Reservoir Filled	Years of TVA Cove Rotenone Sampling	Distance from Ohio (km)	Elevation Normal Maximum Pool (m)	First Documented Occurrence	Source
Kentucky	1944	1949-61, 1963, 1974-79	36.0	109.4	1944	Stroud (1947)
Pickwick	1938	1949-61, 1971-79	332.6	126.2	1944	Stroud (1947)
Wilson	1924	1949-62, 1976-77	417.4	154.7	1944	Stroud (1947)
Wheeler	1936	1949-61, 1968-79	398.9	169.5	1944	Stroud (1947)
Guntersville	1939	1949-61, 1971-79	561.5	181.4	1951	TVA
Hales Bar/ Nickajack [1]	1913/1967	1949-51, 1953, 1958, 1960, 1972-79	683.3	193.2	1964	TVA
Chickamauga	1940	1947-59, 1970-79	757.8	208.0	1969	Myhr (pers comm)
Watts Bar	1942	1949-51, 1953, 1957-60, 1964, 1973, 1975-76, 1978	852.6	225.9	1973	TVA
Fort Loudoun	1943	1949-50, 1953, 1956-61, 1972	969.1	247.8	1980	Starnes (pers comm)
Melton Hill	1963	1964, 1972, 1974-76, 1977-79	950.5*	242.3	1977	TVA
Tellico	1979	1980	969.6**	247.8	1980	Bivens (pers comm)

[1] Nickajack lock and dam replaced Hales Bar in 1967.
Melton Hill Dam is located at Clinch River km 37.2.
** Tellico Dam is located at Little Tennessee River km 0.5.

The next reservoir upstream is Nickajack which replaced Hales Bar Dam and Reservoir in 1967. Thirteen years after the Guntersville Reservoir record, a single yellow bass was collected in a series of life history studies conducted by TVA in 1964. Yellow bass were recorded by creel census in 1968 (Myhr, pers comm). In 1972, they were first collected in TVA cove rotenone samples. Yellow bass apparently began expansion in Nickajack Reservoir in 1964 and by 1968 were abundant enough to be regularly taken by anglers.

The first documented occurrence of yellow bass in Chickamauga Reservoir was from 1969 creel census (Myhr, pers comm). They first occurred in rotenone samples in 1971. While no cove rotenone samples were taken between 1960 and 1969, 12 cove rotenone samples were collected in 1970 and did not include any yellow bass. Thus, the population prior to 1971 was restricted

Tennessee Valley Authority cove rotenone sampling recorded yellow bass in 1973 in Watts Bar Reservoir, and, in 1977, in Melton Hill Reservoir. The yellow bass has not been collected by TVA cove rotenone sampling in Fort Loudoun where no samples have been taken since 1972, but Dr. Wayne Starnes and Richard Bryant, University of Tennessee, collected it from the Little River arm of that reservoir in April 1980. In August 1980, Rick Bivens (pers comm) reported yellow bass from Tellico Reservoir approximately 4.0 km above the dam; however, no yellow bass were collected in 1980 TVA cove rotenone samples.

There appears to be a general relationship between occurrence of yellow bass and water clarity and perhaps submerged vegetation. In Illinois, changes have occurred in yellow bass populations. Forbes and Richardson (1908) in one of the first Illinois statewide river surveys recorded yellow bass as "twice as abundant as white bass." Smith (1979) states that this situation has changed with yellow bass generally less well distributed and now rare in many river systems where once abundant. While the reason for the apparent decline of the species over this 70-year period is unknown, he speculates that high turbidity may be a factor. In Missouri,

TABLE 2. *Summary and Estimated Reduction in Suspended Sediment Load in Ten Selected Streams in the Tennessee Valley.*[1]

Station	Drainage Area (sq. mi.)	Average Annual Load (tons per sq. mi.) *1935-37	1963-65	Estimated Reduction in Suspended Sediment Load (percent)
Bear Creek at Bishop, Ala.	667	650	296	35-45
Duck River at Hurricane Mills, Tenn.	2,557	796	411	35-45
Elk River nr Prospect, Tenn.	1,784	1,097	380	40-50
Sequatchie River nr Whitwell, Tenn.	384	350	207	35-45
Emory River at Oakdale, Tenn.	764	145	135	less than 10
Clinch River at Speers Ferry, Va.	1,126	336	242	less than 10
North Fork Holston River nr Gate City, Va.	672	304	210	10-15
Nolichucky River at Embreeville, Tenn.	805	981	708	less than 10
French Broad River at Bent Creek, N. C.	676	491	303	20-25

[1] Modified from TVA (1969).
* Annual loads adjusted upward for difference in samplers used in 1935-37 and 1963-65.

At first examination, there appears to be an explosive expansion of yellow bass after 1964. This may be an artifact of sporadic sampling in the 1960's; however, since yellow bass were restricted in widespread sampling in the 1940's and 1950's, the lack of 1960's data make the date of expansion (not the expansion itself) questionable. Yellow bass probably became established with low numbers in Nickajack and Chickamauga Reservoirs. and their first occurrence in 1964 and 1969, respectively was documented by creel census or cove rotenone sampling when numbers greatly increased.

Pflieger (1975) reported yellow bass as more abundant in the Mississippi River above the mouth of the Missouri than below. The Missouri River carries silt loads and may have an important influence on this distribution. In western Tennessee, yellow bass are abundant in clear, vegetated, lentic habitat (such as oxbow) along the course of the Mississippi River but are uncommon in turbid backwaters of the main channel.

With regard to historical conditions governing water clarity in the Tennessee River impoundments, the Soil Conservation Service and TVA have had programs to

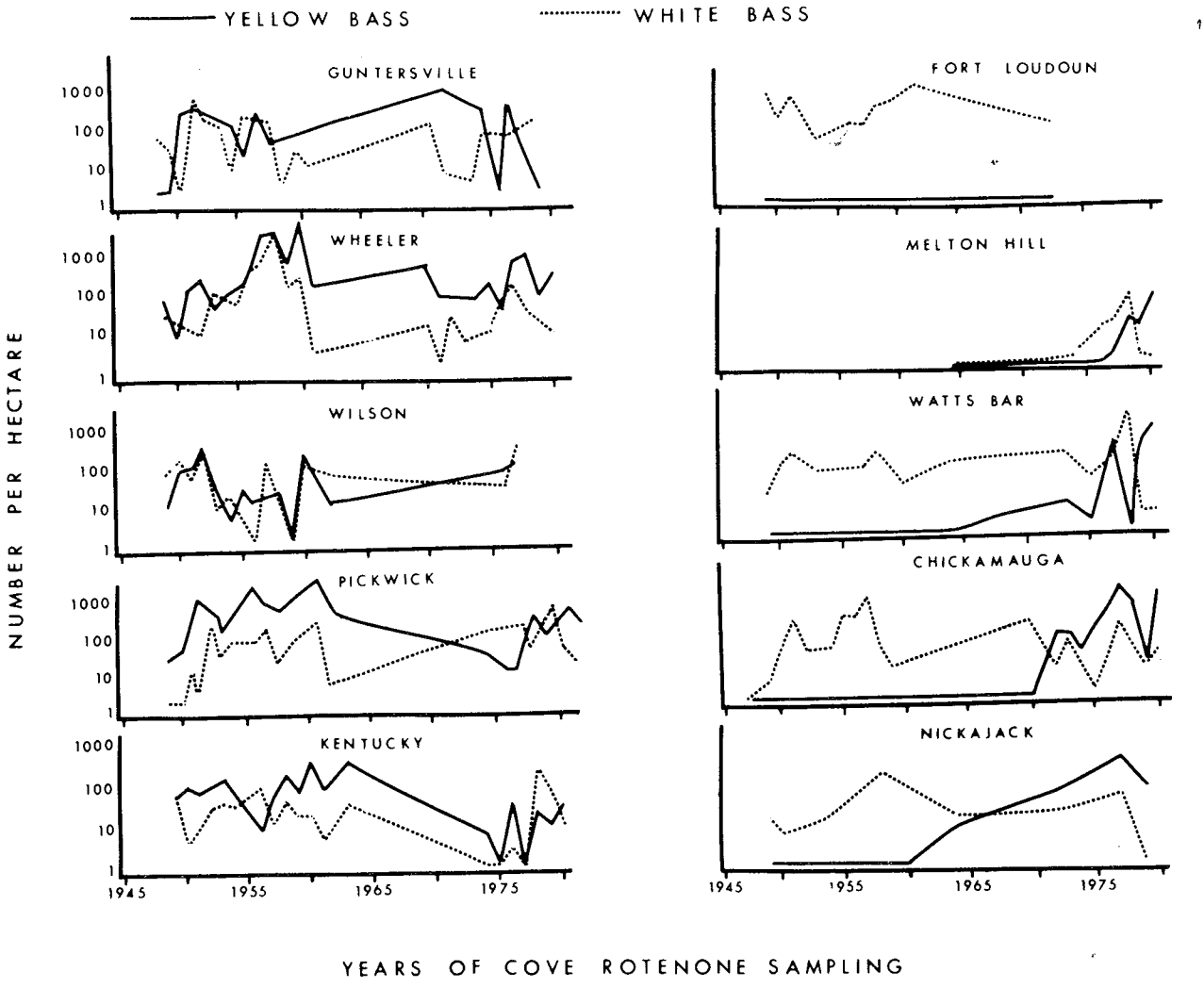

FIG. 1. *Density Relationships of Yellow Bass and White Bass in Tennessee Valley Reservoirs.*

encourage farming practices which minimize soil erosion. The programs, together with changes in land-use patterns, have resulted in improved water quality.

TVA (1969) resurveyed suspended sediment loads in ten streams (nine applicable to this report) in the Tennessee Valley (Table 2) which indicate sedimentation trends for the entire Valley. Without exception, between the first survey in 1935-1937 and the second in 1963-1965, there were reductions in the suspended sediment load. In rivers such as the Duck that drain areas with heavy farming activity and sedimentation, there was an overall sediment load reduction of 35-45 percent. With tributaries contributing less sediment, reservoirs should be experiencing reductions in turbidity, thereby encouraging yellow bass range expansion.

Another expansion-enhancing factor to be considered is the introduction of Eurasian watermilfoil (Myriophyllum spicatum L.), a vascular plant. First observed in the Piney River embayment (Bates and Cooney, 1980) of Watts Bar Reservoir around 1953, milfoil spread up and down the Tennessee River with the heaviest infestation occurring from 1968 to 1969. The first record of watermilfoil in Guntersville and Nickajack Reservoirs was 1964, with the heaviest infestation occurring in Guntersville in the spring of 1969. While thick shortline beds of milfoil create problems for recreation, the plants may provide an additional resource to be exploited by yellow bass. The milfoil provides protection, habitat and substrate for yellow bass and for food items they utilize. Additionally, milfoil reduces water flow through beds, allowing solids to settle out of the water column, thereby increasing clarity. A result of the milfoil introduction is a localized habitat unlike other portions of the reservoir.

The number per ha of white bass and yellow bass was examined at each mainstream reservoir over all periods of collection for evidence of possible density relationships between these two species. In Figure 1, yellow bass and white bass in Kentucky, Pickwick, Wilson, Wheeler and Guntersville Reservoirs appear to increase

or decrease at the same time, maintaining approximately the same dominance relationship despite annual population fluctuations. Environmental factors appear to elicit the same sort of increase or decrease in both species rather than one species responding positively while the other responds negatively. With the migration of yellow bass into Nickajack, Chickamauga, Watts Bar and Melton Hill Reservoirs, the numbers of white bass remained the same (with expected annual fluctuations); however, yellow bass increased in number to the point that they equaled and eventually exceeded white bass. Thus, while these species may occur syntopically, it does not appear that they compete.

Conclusion

While yellow bass occur naturally in the lower Tennessee River, they were not recorded in the upper portion of the system prior to 1964. Between 1964 and 1980 yellow bass expanded to all available (i.e., with lock access) mainstream reservoirs. The Tellico Reservoir completed in 1980 has direct access to Fort Loudoun Reservoir, and yellow bass were collected by angling but were not collected in 1980 cove rotenone samples. The yellow bass probably expanded into the upstream reservoirs in low numbers prior to increasing in abundance and being recorded in cove rotenone samples.

Yellow bass expansion was probably the result of a combination of several factors. Impoundment of the river system created more favorable lentic conditions, while land-use changes and public awareness of conservation resulted in an overall decrease in soil erosion and reservoir turbidity. The infestation of aquatic weeds, principally Eurasian watermilfoil, altered the Valley reservoirs by adding a different type of habitat which provided additional food and protection from predators. Milfoil beds also provide a localized area of reduced flows which decrease suspended solids, creating greater water clarity. Thus, it appears that water of greater clarity was available to the yellow bass in the late 1960's and 1970's. These factors, coupled with enhanced reproductive success of existing populations in downstream reservoirs, may have promoted upstream range expansion. The yellow bass appears to have exploited a newly evolved niche in upper Tennessee River reservoirs and to have done so without negative impact on white bass or other established species.

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Literature Cited

Bates, A. L. and J. C. Cooney. 1980. Aquatic Weed Control and Mosquito Control Programs with Special Reference to Wolftever Creek and Savannah Bay, Chickamauga Reservoir. TVA Division of Water Resources, Knoxville. pp. 13.

Clay, W. M. 1975. *The fishes of Kentucky*. Kentucky Dept. of Fish and Wildlife Resources, Frankfort. pp. 415.

Eschmeyer, R. W. 1944. Fish migration into the Clinch River below Norris Dam, Tennessee. J. Tennessee Acad. Sci. 19(1) 31-41.

Forbes, S. A. and R. E. Richardson. 1908. *The fishes of Illinois*. Illinois State Lab. of Nat. Hist. pp. 357.

———. 1920. *The fishes of Illinois*. 2nd ed. Illinois Nat. Hist. Surv. pp. 357.

Greene, C. W. 1935. The distribution of Wisconsin fishes. Wisconsin Conserv. Comm. Madison. pp. 235.

Kuhne, E. R. 1939. A guide to the fishes of Tennessee and the mid-South. Tennessee Dept. of Conserv., Div. Game and Fish. Nashville. pp. 124.

Pflieger, W. L. 1975. *The fishes of Missouri*. Missouri Dept. of Conserv. pp. 343.

Smith, P. W. 1979. *The fishes of Illinois*. University of Illinois Press. Urbana. pp. 314.

Stroud, R. H. 1947. The status of yellow bass in TVA waters. J. Tennessee Acad. Sci. 22(1):79-86.

Tennessee Valley Authority. 1969. Summary report suspended sediment investigations 1935-1937 and 1963-1965. Data Service Branch, Knoxville. pp. 6.

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OCCURRENCE OF THE AMERICAN EEL IN THE HOLSTON RIVER, TENNESSEE

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Eel Collection and Description

While participating in a bass tagging study in the spring of 1981, an American eel (*Anguilla rostrata*) was collected near the confluence of the French Broad and Holston Rivers at HRM 0.2 in Knox County, Tennessee. The specimen was taken in the late afternoon of May 4 using a 230-volt electrofishing apparatus. It was a female weighing 2.1 kg and measuring 91.4 cm in length (Fig. 1). Examination of the gut contents revealed the remains of at least six crayfish (one *Orconectes*, two *Cambarus*, the remainder unidentified) and one otolith from an unidentified fish. Age was not determined due to the inaccuracies of scale reading (Liew, 1974) and otolith examination (Facey and LaBar, 1981) of unknown-age eels.

Adult eels are found in inland waters in Eastern North America. They are migratory into Tennessee waters from the Ohio and Mississippi Rivers; however, movements are restricted by dams on mainstream and tributary systems. While eels are scarce in Tennessee, they

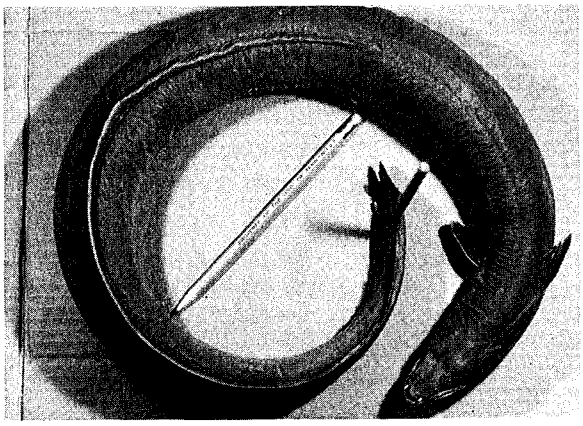

FIG. 1. *American eel* (Anguilla rostrata) collected from the Holston River, Tennessee. The female eel weighed 2.1 kg and measured 91.4 cm.

have been recorded in both major river drainages. The Tennessee Valley Authority Regional Heritage Program has data on two eels taken from the Obey River and Barkley Lake in the Cumberland River and two from the Buffalo River and Chickamauga Reservoir in the Tennessee River systems. (TVA, 1981). Another specimen was taken in 1960 on a trotline from Fort Loudon Reservoir (D.A. Etnier, personal communication) and is in the University of Tennessee Ichthyological Collection (UT Ct. No. 49.2). The present finding notes the easternmost collection record of the American eel in the Tennessee River System.

LITERATURE CITED

Facey, D.E., and G.W. LaBar. 1981. Biology of American Eels in Lake Champlain, Vermont. Trans. Amer. Fish. Soc. 110: 392-402.

Liew, P.K.L. 1974. Age determination of American eels based on the structure of their otoliths. *In* The Ageing of Fish. T.B. Bagenal, editor. Unwin Brothers Limited, Surrey, England, 124-136.

Tennessee Valley Authority. 1981. Regional Heritage Program, Norris, Tennessee. Unpublished report.