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**A Biotelemetry Study of
Spring and Summer Habitat
Selection by Striped Bass
in Cherokee Reservoir,
Tennessee, 1978**

Barbara A. Schaich
Charles C. Coutant

ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1441

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A BIOTELEMETRY STUDY OF SPRING AND SUMMER HABITAT SELECTION
BY STRIPED BASS IN CHEROKEE RESERVOIR, TENNESSEE, 1978¹

Barbara A. Schaich and Charles C. Coutant

ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1441

(440) *Shaw*

¹Submitted as a thesis by Barbara A. Schaich to the Graduate Council of the University of Tennessee in partial fulfillment of the requirements for the degree of Master of Science. Present address: Department of Zoology, North Carolina State University, Raleigh, NC 27650.

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ABSTRACT

SCHAICH, BARBARA A., and CHARLES C. COUTANT. 1980. A biotelemetry study of spring and summer habitat selection by striped bass in Cherokee Reservoir, Tennessee, 1978. ORNL/TM-7127. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 220 pp.

Habitat selection of 31 adult striped bass was monitored by temperature sensing ultrasonic and radio transmitters in Cherokee Reservoir, Tennessee, from March through October 1978. This study sought to corroborate summer data obtained by Waddle (1979) in 1977 and to examine mechanisms of habitat selection by observing establishment of the summer distribution. During the spring and early summer months (March through early July), the striped bass ranged throughout the study area in the downstream half of the reservoir. Temperature preference ranged from 10.5 in March to 15.8 C in May and corresponded to the warmest temperatures available at 1 to 3 m. Fish stayed near the bottom at the preferred temperatures throughout the whole study, and no individuals were observed in open water. Movement rates of up to 2.6 km/day were estimated, and rates of 1 km/day were common in the spring.

As the temperatures increased during the summer, the striped bass selected temperatures in the range 15.5 to 25.0 C at depths to 8 m and more. By late July they were apparently avoiding low dissolved oxygen (D.O.) concentrations (< 3 mg/l) near the bottom of the main reservoir and epilimnion temperatures greater than 22 C, and they moved into cool, oxygenated spring or creek channels (refuges). These refuges, approximately 4% of the total reservoir area, were less than 10 m deep

and had temperatures of 15 to 25 C and D.O. concentrations of > 5 mg/l. Temperatures selected remained between 15.5 to 25.0 within these refuges, and little movement within or migration between the refuges was observed. Low movement rates of 0 to 25 m/day within these refuges occurred. The rates of the few migrations between refuges could not be estimated. Tagged fish moved out of the refuges 3 to 4 weeks after the fall overturn when reservoir temperatures approximated 22 to 24 C. Some indication of an ontogenetic change in temperature preference was seen. Older striped bass seemed to prefer cooler temperatures (16 to 20 C) than the younger striped bass (20 to 23 C).

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INTRODUCTION

The striped bass (Morone saxatilis), once thought to be a totally anadromous species, was discovered to successfully inhabit freshwater environments and reproduce without entering saltwater in the Santee-Cooper Reservoir in South Carolina (Scruggs 1955). Because of their value as a large sport fish and as a predator on clupeids (threadfin and gizzard shad), populations of striped bass have been stocked throughout most of the southeastern United States and part of the south central states. Cherokee Reservoir was the first reservoir stocked in Tennessee, with Norris, Watts Bar, Percy Priest, Barkley and Kentucky Reservoirs following. Only Barkley and Kentucky Reservoirs have since established natural reproduction of striped bass (Hogue et al. 1977).

The success of these stockings led to additional studies on the striped bass--age and growth, food habits, temperature preference, and other parameters. Evaluations of unstocked lakes and reservoirs were made for stocking striped bass. At first, the major consideration was a sufficient food source--i.e., large populations of shad. In recent years, however, it has become apparent that this parameter is not sufficient. In Cherokee Reservoir extensive habitat problems with striped bass showed up in early 1970's, even with a large shad population available. Mass mortalities of striped bass in late summer have indicated a problem that has since been repeated in Percy Priest Reservoir in Tennessee and in Keystone Reservoir in Oklahoma (Coutant, personal communication).

There has been some evidence that temperature preference of the striped bass may be important for determining habitat suitability.

Previous studies have shown striped bass prefer temperatures near 22 C in one study and 19 to 23 C in another study (Coutant and Carroll, submitted; Waddle 1979). Water quality surveys of Cherokee Reservoir have shown low dissolved oxygen (D.O.) concentrations at temperatures near 20 C and high D.O. where temperatures are >26 C. The study by Coutant and Carroll (personal communication) showed high mortality of fish captured in Cherokee Reservoir in summer except when they were released in the cool waters of Mossy Creek Cove. Waddle (1979) showed that adult striped bass were congregated in coves where cool, oxygenated springs or creeks (refuges) were located in the late summer. Temperature preference in relation to available temperatures should influence the selection of lakes and reservoirs in which to stock striped bass. Power plants to be built on reservoirs stocked with striped bass might have an adverse effect on the distribution of fish population and this would influence the decisions on the cooling systems (straight-through cooling or cooling towers) and the decision on where to place a power plant site.

This present study sought to corroborate and expand upon Waddle's (1979) study which found fish avoiding high temperatures and low dissolved oxygen in the late summer. It was also designed to examine the mechanisms of habitat selection by observing establishment of the summer distribution of the fish in refuges as seasonal patterns of temperature and dissolved oxygen changed. Spawning movements in the spring were to be observed and followed if possible.

I. STUDY AREA

This study took place in Cherokee Reservoir, a multipurpose storage impoundment located on the main stem of the Holston River in Northeast Tennessee (Figure 1). Dam construction began in 1940 and the reservoir began filling in 1941. At full pool (elevation 327 m above mean sea level), the reservoir extends from the dam at Holston River Mile (HRM) 52.3 to the base of John Sevier Dam at HRM 106.3. The reservoir fills a major southwest to northeast valley for 87 km (54 miles) in East Tennessee's Ridge and Valley Province and spills slightly into a second valley. Surface area at full pool is 12,222 ha. Tennessee Valley Authority 1977), and normal minimum elevation is 311 m, which reduces surface area to approximately 5,002 ha. Cherokee Dam hydro-electric generation capacity, with all four units operating, is 120,000 kilowatts. Flow through the turbines ranged from 0 to 458.9 cubic meters per second (CMS) with a mean of 136.7 CMS per day during the study in 1978.

Drainage area above the dam is 8,879 km². Cover of the watershed is approximately 40% forest, 40% pasture and 20% cultivated crops (USDA--SCS 1970). The only major inflow is in the Holston River which drains a large part of Southwest Virginia and Northeast Tennessee. Only tiny intermittent creeks enter the reservoir from the flanking ridges. Groundwater springs drain solution channels in the region which is underlain by strata of limestone and dolomite (the region has a karst topography). The most conspicuous inflow other than the Holston River is Mossy Creek, which enters the reservoir near the dam (Figure 2). Mossy Creek has a small but steady flow because much of its water is

Figure 1. TVA map showing location of Cherokee Reservoir in northeast Tennessee on the Holston River.

Figure 2. Lower end of Cherokee Reservoir showing location of Mossy Creek.

derived from a large spring and mineshaft pumping at several deep-shaft zinc mines that lie in its drainage area. The Jefferson City Sewage Treatment Plant also has its outfall in the Mossy Creek Cove. It is a secondary waste water treatment plant which empties 1.9 MLD (million liters per day) of effluents into Mossy Creek Cove. Treatments of these effluents have been described as being inadequate to protect the present water quality of the cove (DWQC 1977).

The Holston River Basin drains several major industrial areas in Virginia and East Tennessee. Its water carries nutrients from chemical manufacturing, synthetic fiber plants, agricultural runoff, and municipal sewage. In the lower reservoir Morristown and Jefferson City also add sewage and urban runoff. Cherokee Reservoir is eutrophic, with heavy plankton growth. Algal blooms reach nuisance proportions in the upper reservoir according to the Tennessee Division of Water Quality Control.

The Holston River as it enters Cherokee Reservoir (full pool) is impounded by a small dam that provides cooling water for the John Sevier Steam Plant, a 846.5 MW (electrical) generating station owned by the Tennessee Valley Authority (TVA). The dam prevents upstream migration by reservoir fishes. The cooling water discharge ensures that the Holston River inflow is slightly warmer than normal. Ungate (1976) found through mathematical modeling that the steam plant warms the average Cherokee Dam discharge by 1.3 C (2.3 F) in October and 2.6 C (4.7 F) in March.

Cherokee pool elevation greatly affects habitat downstream of John Sevier Dam. During periods of low elevation (usually fall, winter and

early spring), habitat is shallow riverine with exposed shoals for about 16 km downstream from the plant. Even at full pool (usually late spring through early summer) the habitat is still somewhat riverine in the immediate vicinity of the plant.

Seasonal variations in temperatures and dissolved oxygen levels have been shown by Ungate and Hsieh (1976) and from March through October, 1977, by Waddle (1979). During the winter the reservoir is typically isothermal and dissolved oxygen levels are high at all depths. Stratification begins in March, becoming more severe during April and May with a surface layer increasing in depth from 13 to 20 m as the reservoir begins to warm due to solar radiation. Depletion of dissolved oxygen occurs at this time in the deepest waters. By early September there exists little temperature gradient from top to bottom from solar radiation and turbine discharges of the cooler waters. Dissolved oxygen levels are low (<5 mg/l) below depths of 5 to 10 m. The fall overturn occurs in late September and the reservoir has only slight vertical temperature gradient. Temperatures are dropping and dissolved oxygen levels are rising at this time. By November the winter conditions of isothermal temperatures and high D.O. levels prevail over the entire reservoir.

II. HISTORY OF THE STRIPED BASS PROBLEM IN CHEROKEE RESERVOIR

The Tennessee Game & Fish Commission [Tennessee Wildlife Resources Agency's (TWRA) predecessor agency] began stocking Cherokee Reservoir with striped bass in 1964. Hybrids (striped bass x white bass) were stocked in 1965. By the fall of 1966, fishermen were harvesting several hybrids and a few striped bass. No problems were seen prior to 1971 and a large fishing effort for striped bass developed over the years. In the fall of 1971 a few dead striped bass were seen in heavily fished areas (Bishop 1978). By late summer of 1972 there were not only dead fish in heavily fished areas, but there were dead and dying fish in areas where there was no fishing. Red skin lesions on other species of fish were seen in the upper end of the reservoir and by TVA crews in cove rotenone studies. That same year large concentrations of striped bass were seen in a long, spring-fed cove at Cedar Hill Boat Dock (Bishop 1978). An estimated 50 fish had died during one 2-week period. An electrofishing unit was used in August in this cove and approximately 200 fish were found to be concentrated in a 0.2 hectare area near the spring. Several alive, but dying fish were sent to Auburn University for disease and parasite analysis. Fish pathologists at Auburn University did not discover any pathogen that would account for the mortality. Large concentrations of Epistylis were found on open lesions, but not on all carcasses. The most conspicuous abnormality was enlarged gallbladders now believed to indicate lack of feeding of the striped bass (Coutant 1978). The 1972 die-off continued into October until the fall turnover occurred. The die-off was generally confined to striped bass in the 3 to 9 kg range. Mercury

analyses were done at Oak Ridge National Laboratory and while there were high levels in some tissues, the concentrations were inadequate to explain mortality (Coutant 1978).

Die-offs since that summer have followed basically the same pattern with deaths beginning in late July and ending in October.

Pesticides were assayed in carcasses in 1973, but no levels high enough to explain the mortalities were found. Water quality investigations that year by Tennessee Division of Water Quality Control showed that in late summer dissolved oxygen levels above 5 ppm were confined to the top 5 m of the reservoir, and that all of this water was above 27 C. At that time there was only a 2 C differential in water temperature from top to bottom in 33 m of water. Since the die-offs occurred when the water quality was poorest, the problem was assumed related to low dissolved oxygen conditions (Bishop 1978). Laboratory studies have shown that the lethal high temperatures for striped bass are considerably higher than 26 C, a temperature that was available in oxygenated waters (Coutant 1978). This indicated that the problem was not just that of lethal temperatures.

A new pattern showed up in the winters of 1976--77 and 1977--78. Mortality continued through these particularly cold winters even with high dissolved oxygen levels (Coutant 1978, Waddle 1979). Fish deaths were almost continuous in 1977, a year of extreme high summer temperatures, although there was a peak in late summer (Waddle 1979). Deaths occurred in early 1978 during this study, but dropped off by May. Dead and dying fish reappeared in late July and followed the same pattern thereafter as previous years. These winters were colder than normal,

with ice cover appearing on the reservoir. Large die-offs of shad were seen in this reservoir by the author and in other local reservoirs during these winters (McLean and Singley, personal communication).

The nutritional state of the fish began to show deterioration in 1977 and 1978 (Bishop 1978). TWRA observations of spawning brood stock in early spring both years noted poor condition, many sores on some fish but not all fish, and always enlarged gallbladders and yellowish, spongy livers. The staff at ORNL also noted the large, dark gallbladders and the shrunken, yellow livers (Coutant 1978). At the same time, striped bass from Norris Reservoir showed good body condition and normal livers and gallbladders.

Growth of striped bass in Cherokee has been slower than that in other Tennessee reservoirs. Cherokee has had few fish over 9 kg in size and the fish do not seem to be living beyond 7 years of age (Bishop 1978). On the other hand, Norris Reservoir (stocked 2 years later than Cherokee) has produced numerous fish over 18 kg and a few 27 kg (50 lb) fish have been seen.

To address the problem of the health of fish populations in Cherokee, an interagency Cherokee Reservoir Task Force was organized through the auspices of the Tennessee Department of Public Health, Division of Water Quality Control. The objectives of the task force were to coordinate efforts of individual agencies and to stimulate expansion of studies in areas needing more attention. Agencies involved include:

Tennessee Department of Health

Division of Water Quality Control

Environmental Protection Agency

Athens Laboratory

Oak Ridge National Laboratory

Environmental Sciences Division

Tennessee Eastman Company

Tennessee Wildlife Resources Agency

Tennessee Valley Authority

Division of Forestry, Fisheries, and Wildlife Development

Division of Environmental Planning

Division of Water Management

University of Tennessee

Department of Forestry, Wildlife, and Fisheries

East Tennessee State University

Carson Newman College

Biology and Chemistry Departments

During the past few years the heavy metal content in the waters of Cherokee Reservoir and especially Mossy Creek Cove have been examined by the staff at ORNL and at Carson Newman College. Water content of zinc, cadmium and manganese were in the parts per billion, but slightly higher concentrations were found in Mossy Creek than in the reservoir. Zinc assays of striped bass livers showed concentrations of 24.2 to 71.0 ppm (L. Deal, personal communication). The possibility of a detrimental effect of the zinc and other metal accumulations in the striped bass on their metabolic processes after abnormal aggregations of the fish in thermal refuges fed by groundwater has been discussed by Coutant (1978).

In 1977, Waddle (1979), using biotelemetry methods, tracked striped bass from June until October, observing habitat and temperature preference. He found that except for two fish in June most fish did not move long distances. The others remained in cool, oxygenated spring-fed or creek-fed coves. Temperature preference of all fish averaged 20.4 C, and ranged from 19 to 23 C. These temperatures were only available in the refuges in the late summer. Earlier in the summer these temperatures were available, but D.O. concentrations were low (<3 mg/l) at these temperatures. Fish movement in the spring and the fall was not observed, so that it was unknown if the fish remained in these refuges for most of the year.

III. MATERIALS AND METHODS

Transmitters and Monitoring Equipment

Water temperature preference of the striped bass was determined through the use of temperature-sensing ultrasonic and radio transmitters. The ultrasonic transmitters were developed at Oak Ridge National Laboratory (Rochelle and Coutant 1973, 1974) and operated at carrier frequencies that ranged from 70-100 KHz. The tags were cylindrical, varying in size from 1.8 by 5.0 cm to 1.8 by 8.0 cm with a thermistor probe 10.0 to 12.5 cm long. These tags weighed from 26.2 to 38 g (dry weight) and 15.6 to 26.1 g (wet weight) with a volume of 11 to 20 ml. The tags coded temperature with a pulse rate that varied from one to three beats per second with an isothermal accuracy within ± 0.2 C. These tags had a lifespan of at least six months at 20 C, although tags were found in the field that were still operating after one year.

Ultrasonic sound waves emitted by a transmitter in pulses were received by a Smith-Root Model SR70-H hydrophone, which was directional and handheld. Sonic receivers used were Smith-Root Model TA-60 and TA-25.

The radio transmitters were developed and built at the University of Minnesota at the Cedar Creek Bioelectronics Laboratory. They operated at carrier frequencies spaced between 150 to 152 MHz. The cylindrical tags were 2.0 by 8.0 cm with an antenna approximately 34.4 cm long protruding from the end. They weighed 42.2 g (dry weight) and 15.2 g (wet weight) with a volume of 27 ml.

All tags were marked with an identification number at time of manufacture. These numbers were used as reference to individual fish throughout the study. When tags were reused on more than one fish, the number was followed by a letter (e.g., 157A, 157B, etc.) to provide a unique identity for individual fish.

Radio signals were received by a hand-held, directional Yagi antenna (Wildlife Materials, Inc.) or a 40.0 cm (16 inch) whip, omnidirectional antenna. The omnidirectional antenna was clamped to a small boat with C clamps or permanently attached to the roof of a larger boat and was used to pick up the signals for recording. This freed a hand from holding the antenna and allowed better adjustment of the receiver and interval counter. The directional antenna was used to pinpoint location of the fish.

The radio receiver used was Wildlife Materials, Inc., Model TRX-24A receiver. Range of the receiver was from 150.85 to 151.45 MHz with 24 channels in intervals of 0.025 MHz. Headphones were used as an aid to the receiver in locating the radio tags.

A Hewlett Packard 5300A 50MHz Universal Counter was used to measure and display the time interval between signals from either ultrasonic or radio transmitters. The time intervals could later be compared against a non-linear calibration curve of each tag and the temperature calculated.

A portable magnetic cassette tape recorder with a built-in interval counter was developed by the staff at ORNL for field work. It recorded the time intervals between signals onto digital cassettes (Texas Instruments Data Interchange Digital Cassette). These cassettes could then be read into a computer for data analysis.

Data analysis was accomplished through the use of a hand calculator and ORNL's data management system consisting of PDP-10 and IBM 360/91 computers. A program using a Hewlett-Packard HP-65 desk calculator was developed for use in the field to calculate temperatures while tracking the fish (Coutant 1977). Interval data was converted to temperature data, and mean, standard deviation, and standard error were computed. At the laboratory the hand data were punched on cards and then the Statistical Analysis System (SAS) (Barr et al. 1976) was used to compute several parameters (mean, minimum, maximum, standard deviation, skewness, and kurtosis), to graph results (temperature versus time), and to calculate frequency distributions for each hour and cumulative period of data. The cassette tapes were read onto 7-track tape and then transferred to the PDP-10 computer, on which a set of programs were used to edit the data (Waddle 1979, Watts 1978). All observations outside a range of time intervals, corresponding to the minimum and maximum temperatures available in the area where a fish was monitored (usually between 15 and 30 C), were determined erroneous and deleted. Statistical analysis and graphical representation of the cassette data could then be done using SAS on the IBM 360/91 computer. The same calculations were made on the cassette data as on the manually collected data.

Temperature and dissolved oxygen readings were taken every week when possible. Because of time and manpower restrictions, only 5 sites in the main reservoir were sampled--Point 1, Cherokee Dam, Point 8, Gilmore Brothers Dock (HRM 65) and German Creek (HRM 70), all approximately 8 km apart. Mossy Creek Cove was also sampled in 2 to 3 sites depending on water levels and the presence of fishermen.

Temperature data were taken with a YSI telethermometer Model 46 TUC. Some surface temperatures were measured with a mercury thermometer. Dissolved oxygen readings were taken with a YSI Model 51B oxygen meter. Isotherms and isopleths of dissolved oxygen were drawn on a longitudinal section of Cherokee Reservoir using a computer program (DeAngelis 1978).

Water samples were taken at different times during this study and evaluated for certain heavy metals. On 26 May, water samples from Mossy Creek, Byrd Springs, and the dam were evaluated for mercury content. On 2 August a total of 30 water samples were taken from Mossy Creek, Byrd Springs, and in front of the dam. Surface and bottom samples were taken at each site where possible, or at 8 m when the bottom could not be reached with the sampler. Analysis was made for zinc, cadmium, and manganese in filtered and unfiltered samples.

Collecting Procedure

All of the fish used in this study were collected by electroshocking. A 6 m shocking boat (Smith-Root Electrofisher) with two suspended booms (anode and cathode) was used. From the booms 6 to 8 electrodes of 3 to 5 m wire were suspended into the water, forming an electrical field. A gasoline powered generator produced up to 800 volts of pulsed direct current. As the fish were shocked, they were netted and placed in the boat's livewell. Fish were held no longer than 20 minutes before being tagged. In late summer the boat was positioned at the Mossy Creek, Byrd Springs, or Cedar Hill inflows, so water pumped into the livewell was kept cool. Collecting by shocking resulted in the fish being in a state of electronarcosis.

Tagging Procedure

In previous studies many ways of implantation of tags have been used. Insertion into the stomach has been used successfully in striped bass (Koo and Wilson 1972), American shad (Leggett and Jones 1971) and white bass (Hasler et al. 1969). However, the tags were regurgitated when used with black basses (Coutant and Rochelle, Peterson 1975), flat-head catfish (Hart and Summerfelt 1973), walleye (Ager 1976), and striped bass (Dudley et al. 1977). Premature failures of tags with thermistors were experienced in a study by Coutant and Carroll (submitted) with striped bass. Another method that has met with success was the surgical implantation of ultrasonic tags into the coelomic cavity. Black bass (Coutant 1975, Peterson 1975), walleye (Ager 1976), striped bass (Summerfelt and Mosier 1976; Dudley et al. 1977; Stooksbury 1977; Coutant and Carroll, submitted), and crappie (Rumancik 1977) have been successfully tagged this way. McCleave and Stred (1975) found that small ultrasonic transmitters surgically planted in salmon smolts did not significantly affect swimming performance. Another study, though, found that surgically implanted ultrasonic tags significantly affected the behavior patterns of Guadalupe bass (Manns and Whiteside 1979). A problem using surgical implantation was encountered in Waddle's (1979) study on striped bass. The fish in Cherokee Reservoir were easily stressed and the surgical procedure had a high mortality rate when the water temperatures were above 20 C. A fast and efficient tagging method was sought. The back-pack tagging method (Winter 1976, Fossum 1975, Waddle 1979) was found to be fast and efficient, and fish survival increased. Drawbacks to this method were that it probably

caused a constant hydraulic drag (Hart and Summerfelt 1975) and had a high likelihood of snagging upon objects. A study by Chamberlain (1979) compared internal tagging with external tagging at two places--one centered in front of the dorsal spiny fin as in Bahr (1977), and the second site on the posterior side of the soft dorsal fin. It was concluded that for long term studies internal tagging was best with external tagging in front of the dorsal fin being the best external site. The external site on the side of the dorsal spiny fin was not examined, but in Winter (1976), and Waddle (1979), the fish tagged this way had high percentage of survival and behaved normally in comparison to other fish at the same sites.

In the early months of this study when water temperatures were 10 to 15 C, striped bass were tagged internally with the ultrasonic tags using surgical procedures similar to Coutant and Rochelle (1973), Hart and Summerfelt (1973), and Peterson (1975). The fish were anesthetized with tricaine-methane-sulfonate (MS-222) and placed ventral surface up in a rectangular box. They were supported by a cloth sling which held the midventral region out of the water. An incision was made approximately 2 to 3 cm long anterior to the vent. The transmitter was placed into the coelum with the thermistor outside the body. The incision was closed and the thermistor secured with a 0000 atraumatic cutting needle attached to black braided silk. Stitches were used in a blanket stitch pattern on the incision and half hitch knots secured the thermistor to the body. After surgery the fish was placed back into the livewell until it recovered (approximately 5 min) from the anesthetic. All of the fish were then released close to their capture

sites, usually into the cool waters of Mossy Creek to insure that the fish would find their preferred temperatures.

After the water temperatures neared 20 C and the fish did poorly in the livewell (lost equilibrium) before and after surgery, the ultrasonic tags were attached using the back-pack method used by Waddle (1979). Surgical wire was connected to the ultrasonic tags by means of three plastic bands that were placed around the tag (Figure 3). Two 16 gauge needles were inserted directly below the spiny dorsal fin approximately 5 to 6 cm apart. The wire ends were then pulled through the two needles, the needles removed, and the wire ends were twisted together to secure the tag (Figure 4). This procedure was fast (less than 5 min) and required no anesthetic. The fish were still under electronarcosis from the electroshocking and no difficulty in attaching the tag was encountered.

All of the radio tags were attached by a back-pack method similar to Winter (1976) and Waddle (1979). The wire was a rubber-coated 13 gauge wire that came attached to the radio tag at one end. At the other end of the tag near the antenna, a hole was provided to thread the wire through the tag. A 13 gauge needle was used to thread the wire through the supporting tissue under the spiny dorsal fin (Figure 5). The needle was removed and reinserted 5 to 6 cm away from the first site on the tag side of the fish to bring the wire back through the tissue. The needle was then removed, and the wire threaded through the tag itself and secured with an overhand knot. This procedure also took less than 5 min and the fish were released immediately at the same area where they were collected (Figure 6).

Figure 3. Sequence of ultrasonic transmitter attachment to a fish's back. Fish and tag are not drawn to scale (tag size is exaggerated to show details).

Source: Waddle, H. R. 1979. Summer habitat selection by striped bass (*Morone saxatilis*) in Cherokee Reservoir, Tennessee, 1977. M.S. Thesis, University of Tennessee, Knoxville. 191 pp.

Figure 4. Striped bass tagged with ultrasonic transmitter on back.

ORNL-DWG 79-14211

Figure 5. Sequence showing radio transmitter attachment to the back of a striped bass. Fish and tag are not drawn to scale (tag size is exaggerated to show details).

ORNL-PHOTO 2888-79

Figure 6. Striped bass tagged with radio transmitter on its back.

Scales for aging the fish were taken from below the dorsal spiny fin and above the lateral line before the fish were released. A minimum of two scales was taken for each fish and later aged using an Eberbach scale reader and the technique from Lagler (1956) and Richer (1971).

Data Collection

Frequent monitoring periods, at least one per week, were attempted for each fish. When located, pulse intervals were recorded by hand once every 10 sec for a half hour. Location of each fish was noted and temperature profiles from the site and surrounding areas were taken when possible. During the spring and early summer months when the fish were moving actively, a search pattern was made. Beginning in the area where the fish was last seen, a thorough search was made of the immediate area, and then a more general search of coves, islands, and submerged islands was made. Generally, about a 13 km long area of shoreline was the most that could be covered adequately in one day by one tracking boat, and since the reservoir was 87 km long, it was not surprising that certain fish "disappeared" for weeks before being relocated.

Later in the summer when fish remained in the refuges constantly, the receiver, automatic recorder, and power source were placed in a metal locker in a boat and an antenna attached to the boat connected through the locker to the receiver. The boat was anchored in the cove near the fish, and the equipment turned on to record once every minute, and left for long periods (20 to 48 hrs). Radio tags were monitored very effectively this way. We had difficulties in receiving

the ultrasonic signals when this equipment was left unattended. Only once was an ultrasonic tag monitored in this way and then it was fully manned during the 24 hrs of data collection to prevent the recording of erroneous data.

Pulse interval data obtained either by hand or by recorder were transformed to temperatures using tag calibration curves obtained in the laboratory before fish tagging and release (Waddle 1979). The curve was determined in the laboratory from pulse rates at eight temperatures--0, 5, 10, 15, 20, 25, 30, and 35 C. Best fits to calibration data (± 0.1 C) were obtained with second-order or logarithmic equations.

The automatic recordings simplified data collection, but they had a major drawback in the form of spurious readings. Especially in the case of radio tags where boats driving by (motor static), lawnmowers on shore, and even citizens band (CB) radio would render up to 99% of the readings in some time periods bad (Figure 7). Some editing of the cassette data was possible, but some data removed may have represented legitimate fish movements. Also in the case of cassette recordings where up to 3000 data points a day were collected, detailed manual editing was only worthwhile if the error being corrected was significant. Data sets with a high degree of scatter were not used in the results.

THERMAL HISTORY OF RADIO TAG 151.063C

PLOT OF TEMP*TIME_H LEGEND: A = 1 OBS, B = 2 OBS, ETC.

Figure 7. Computer graph of automatic recording showing high degree of scatter during some time periods.

IV. RESULTS

A total of 31 fish were tagged, twenty-nine of which were followed from 1 to 108 days with an average monitoring period of 36.3 days (fish descriptions and range maps are to be found in Appendix A). The other two fish were not relocated after tagging and release. Mean temperatures selected by the fish ranged from 12.2 C in the early spring to 15.2 C during late spring and from 16.9 to 23.6 C during the summer and early fall (Figure 8, Table 1). Modal temperatures ranged from 12.2 C in early spring to 15.8 C in late spring and from 15.5 to 24.2 C during the summer and early fall. Grand mean for all fish excluding the spring data was 20.5 C, possibly the final preferendum. The spring data was excluded because there was not a wide range of temperatures for the fish to choose from. These statistics were compiled from all manual time interval data sets (100 hrs) and from the recorded data sets (111 hrs).

These fish were followed from 21 March through 12 October 1978 (Table 1). A total of five fish were caught by fishermen and the tags returned. Nine tags were found on dead fish floating in the water or lying on the bank. Seven tags were classified as loose - not moving from one spot on the lake bottom. Several of these were recovered, but it was not possible to tell whether a fisherman had removed the tag, or if the fish had the harness snagged on rocks and pulled loose, or if the fish had died and decomposed, leaving only the tag. Two of the tags appeared to have a sharp cut through the wire harness, possibly by fishermen. The ten remaining fish disappeared in the reservoir and could not be located. Some tags malfunctioned and operated at a high pulse rate which exhausted their battery supply quickly.

Figure 8. Temperatures experienced by 26 tagged striped bass in Cherokee Reservoir during 1978. Fish are ranked in order of the warmest temperatures that were available to them. Spring classification denotes the months March through May, Summer classification denotes May through August, Fall denotes cooling in September.

Table 1. Summary of Biotelemetry Data from the 31 Adult Striped Bass in Cherokee Reservoir in 1978 from Manual Data Sets

Tag I.D.	Date Tagged	Time Monitored	Comments	Approx. Weight of Fish (kg)	Age (years)	Area(s) Fish was Located	Temperature Data °C			No. of Half Hour Data Sets
							Range	Mode	Mean	
Sonic tag 158	21 March '78	21 March '78 to 30 March '78	Located 12 April '78 near Point 8, loose tag	4.5-5.4	4	Byrd Springs; Mossy Creek; Point 8	5.5-14.7	12.2 13.7	12.2	5
Sonic tag 156	29 March '78	29 March '78 to 7 April '78		4.5-5.4	4	Black Oak; Mossy Creek	8.9-16.6	13.3	13.0	4
Sonic tag 157	29 March '78	29 March '78 to 10 May '78	Found dead fish 9 June '78	4.5-5.4	4	Black Oak; Point 1; Mossy Creek; Byrd Springs; Point 3 to Point 4	10.8-15.3	13.3	13.1	2
Sonic tag 166	9 May '78	9 May '78 to 31 May '78		3.6	3	Mossy Creek; point between Byrd Springs and Mossy Creek; between Byrd Springs and Black Oak; Byrd Springs; Point 2	14.9-26.7	Evenly distributed	19.1	7
Sonic tag 169	11 May '78	11 May '78 to 18 May '78	Found dead fish 24 May '78	3.6	5	Mossy Creek; Byrd Springs	14.5-16.0	14.6 15.8	15.2	2
Radio tag 151.063A	16 May '78	16 May '78 to 23 May '78	Found dead fish 23 May '78	5.4	4	Mossy Creek	-	-	-	0
Radio tag 151.330A	16 May '78	16 May '78 to 1 June '78	26 July '78 recovered loose tag	2.25	2	Mossy Creek; Byrd Springs; Point between Byrd Springs and Mossy Creek	16.4-22.3	22.0	19.8	3
Radio tag 151.421	16 May '78	16 May '78 to 12 July '78	Tag cut off of fish; recovered 21 August '78	2.25	2	Mossy Creek; Byrd Springs	17.2-24.3	19.5 21.1 21.5	20.5	7
Radio tag 150.913A	18 May '78	18 May '78 to 2 June '78	20 June '78, dead fish	4.05	4	Mossy Creek; Cedar Hill	17.2-20.9	18.0 19.4	18.9	2
Radio tag 150.947	23 May '78	23 May '78 to 6 July '78		2.25	4	Mossy Creek	18.1-26.5	22.4	22.5	5
Radio tag 151.137	23 May '78	23 May '78 to 5 June '78	5 June '78--tag went bad; 9 July '78--dead fish	2.25	4	Mossy Creek; Black Oak	23.4-24.4	23.6	23.8	2
Radio tag 151.046	23 May '78	23 May '78 to 5 June '78	30 May '78--tag went bad	2.25	4	Mossy Creek; Black Oak	17.8-23.5	21.6 22.3	21.8	2

Table 1 (Continued)

Tag I.D.	Date Tagged	Time Monitored	Comments	Approx. Weight of Fish (kg)	Age (years)	Area(s) Fish was Located	Temperature Data °C			No. of Half Hour Data Sets
							Range	Mode	Mean	
Radio tag 151.2404	23 May '78	23 May '78 to 6 July '78	6 July '78--caught by fisherman	2.25	4	Mossy Creek; Point 3; Black Oak; Byrd Springs	17.2-25.0	21.1	20.9	3
Radio tag 151.084	13 June '78	13 June '78 to 6 Sept. '78	8 August '78--tag went bad; after 6 Sept. '78 dead battery	4.5	no scales taken	Mossy Creek	16.3-25.7	17.0 18.0 19.9 20.8	19.1	25
Radio tag 151.392	13 June '78	13 June '78 to 13 July '78	Tag cut off of fish located 20 July '78 on shore	3.6	no scales taken	Mossy Creek	15.6-28.4	evenly distributed	22.2	12
Sonic tag 165A	27 June '78	27 June '78 to 10 July '78	11 July '78--caught by fisherman	3.6-4.5	5	Mossy Creek	17.5-21.0	19.4 19.6	18.9	3
Radio tag 151.053E	27 June '78	27 June '78 to 30 June '78	5 July '78--dead fish	3.6-4.5	5	Mossy Creek	19.3-25.5	20.0 20.4	21.7	1
Radio tag 150.884	27 June '78	27 June '78 to 12 Oct. '78	Recovered loose tag 17 October '78	4.5	5	Mossy Creek	15.9-26.5	21.6	20.4	15
Radio tag 150.913B	27 June '78	27 June '78 to 12 Oct. '78		4.5	4	Mossy Creek	15.9-26.7	23.1	21.3	16
Radio tag 151.152	12 July '78	12 July '78 to 12 Oct. '78	17 Oct. '78--loose tag; recovered 3 Oct. '78	4.5	4	Mossy Creek	17.2-24.9	21.8	20.8	13
Radio tag 151.063C	12 July '78	12 July '78 to 5 Oct. '78		11.25+	7	Mossy Creek	14.3-24.7	18.1	18.8	25
Radio tag 151.240B	12 July '78	12 July '78 to 5 Oct. '78	30 Aug. '78--tag went bad	9	6	Mossy Creek	21.9-24.5	23.3 24.2	23.6	4
Radio tag 151.035	12 July '78	12 July '78 to 26 July '78		6.75	5	Mossy Creek	21.0-25.1	21.7	22.7	3
Sonic tag 164	18 July '78			2.25-3.15	4	Mossy Creek	-	-	-	0
Sonic tag 157B	20 July '78		29 July '78 caught by fisherman	5.75	5	Mossy Creek	-	-	-	0

Table 1 (Continued)

Tag I.D.	Date Tagged	Time Monitored	Comments	Approx. Weight of Fish (kg)	Age (years)	Area(s) Fish was Located	Temperature Data °C			No. of Half Hour Data Sets
							Range	Mode	Mean	
Sonic tag 163	20 July '78	20 July '78 to 22 Aug. '78	21 August '78 loose tag; recovered 31 Oct. '78	4.5	4	Mossy Creek	15.9-18.4	17.1	16.9	2
Sonic tag 165B	20 July '78	20 July '78 to 24 Aug. '78	29 August '78 caught by fisherman	7.2	5	Mossy Creek	15.3-23.6	18.0 19.8 21.2	19.6	12
Radio tag 151.330B	14 Aug. '78	14 Aug. '78 to 8 Sept. '78	26 Sept. '78--dead fish	2.25-2.7	3	Cedar Hill; Point 1	18.6-22.5	19.5	20.1	3
Radio tag 151.272	23 Aug. '78	23 Aug. '78	1 Sept. '78--caught, not returned	4.5	4	Byrd Springs	-	-	-	0
Sonic tag 157C	23 Aug. '78	23 Aug. '78 to 24 Aug. '78	Found dead fish 24 Aug. '78	5.4	4	Mossy Creek	-	-	-	0
Radio tag 151.448	23 Aug. '78	23 Aug. '78 to 5 Oct. '78	26 Sept. '78--tag went bad; found dead fish 11 Oct. '78	4.5	4	Cedar Hill; Mossy Creek	15.3-21.6	15.5	17.1	1

The study results can be grouped into three phases, which are described in detail in the following sections. The first phase--March through early May--was characterized by fish selecting the warmest temperatures available at >1 m depth (Figure 9). Some longitudinal movement was observed, although congregations of striped bass in the refuges were still seen when shocking for fish to tag. The second phase--May through early July--was identified by long distance movements longitudinally in the reservoir and a slow movement downwards in the water column as the reservoir became stratified and the fish followed the isotherms of 20 to 22 C (Figure 9). The third phase began in mid-July when fish began to move into the refuges, apparently to find oxygenated water at 20 to 22 C which was no longer available in the reservoir. This phase ended between October 5 and 17 when the reservoir had been oxygenated by the fall overturn and had become isothermal at temperatures of 24 and 20 C respectively. The tagged fish moved out of the refuges at that time and were lost in the main reservoir.

First Phase--March to Mid-May

Movements

During the early spring months of March and April the tagged fish swam at speeds up to 1200 m/hr with the majority of sightings between Black Oak Cove and Mossy Creek Cove (Figures A-1, A-4, A-5). The fish tagged with sonic tags 158 and 166 were both monitored during a move from Byrd Springs Cove into Mossy Creek Cove. The fish tagged with sonic tag 158 took 2.5 hrs to move approximately 200 m from Byrd Springs out to the point between the two coves. The other fish on the

Figure 9. Depth distribution of striped bass.

other hand, took 0.5 hrs to move 600 m from the same point into Mossy Creek Cove. Often the fish were found moving a distance of 2.5 km from Black Oak Cove to Mossy Creek Cove or back in one day (Figures A-3, A-4, A-5, A-9). The rates of 2.5 km/day were underestimated as the time intervals between sightings were usually 20 to 24 hrs apart. The distances were measured in straight lines from one site to the next. However, individuals when monitored during short periods of time commonly showed zigzag patterns and much backtracking, indicating much greater distances were actually traversed during the 24-hr period. The fish tagged with radio tag 151.240A was a good example of this type of movement. It was found swimming in the area between Point 3 and Black Oak Cove one day, moving back and forth along the shoreline. It would swim approximately 50 m along the shoreline in one direction, then reverse its direction for a few minutes, and then continue in the original direction. It would repeat this sequence, all the time gradually moving up the shoreline. Although straight distance covered would be only several hundred meters, the total distance covered by the fish could be up to a kilometer. Exact total distances were never calculated because of the inability to pinpoint the fish, especially radio tagged fish, without disturbing them in the shallow water during the spring.

In this study the fish seemed to remain at one site for several hours up to several days (Figures A-1, A-3, A-4, A-5). When movement commenced, it was a quick, continuous motion until the next site was reached where another "rest" period began. This "rest and go" movement was also seen in the Chesapeake and Delaware Canal (Koo and

Wilson 1972), although the time scale was shorter, usually in hours instead of days. After one fish (sonic tag 158) moved into Mossy Creek Cove from Byrd Springs, it remained there two days (Figure A-1). Another fish (sonic tag 166) also had rest periods (Figure A-5). When monitored this fish would stay in one area, as in Byrd Springs on 18 and 22 May. Especially on 22 May, this fish moved very little, and we were not positive that it was still alive. However, by 24 May the fish had moved to a submerged island between Black Oak Cove and Mossy Creek Cove and was found "resting" there.

Temperature Preference

During the spring months the striped bass were found close to the surface in the warmest water available at depths greater than about 1 m (Figures 8,9). Sonic tags 158 and 166 are examples of the temperatures experienced in March and May (Figures A-2 and A-6). The warmest temperatures between 1 and 3 m in depth were chosen. Mean temperatures selected ranged from 11.0 to 13.0 C in March (sonic tag 158), 11.0 to 14.0 C in April (sonic tag 156), and 14.0 to 15.0 C (sonic tag 169) and 16.0 to 23.0 C (sonic tag 166) in May.

Second Phase--Mid-May to Early July

Movements

Nomadic travels were common through the early months of this phase. Observations of fish in the main reservoir between Point 3 and Mossy Creek Cove were common. The fish with radio tag 151.913A was tagged in Cedar Hill Cove, but appeared 13 days later in Mossy Creek Cove (Figure A-11). Another fish, radio tag 151.046, moved from

Mossy Creek to Black Oak Cove within five days (Figure A-14). The fish tagged with radio tag 151.240A was observed moving during several observations. On one day between Sites 2 and 3 (Figure A-15), this fish was seen moving at a rate of 1 km/hr over the straight distance between sites. From Site 3 to Site 4, however, it took 3.5 hrs to move a total of 1 km. The back and forth, rest and go movements described in the first phase were still present and again resulted in underestimated rates of movements. Some fish during the early summer months remained in one cove and showed very low rates of movement while being observed, similar to the movements of fish in late summer and early fall. The low rates of movement actually observed in some fish may have been measurements of a rest period in one cove, with extensive, untracked movements occurring when the fish were lost. For example, the fish tagged with radio tag 150.947 was only observed in Mossy Creek Cove, but there was a period from 2 June to 29 June when this fish was not found. Another fish (radio tag 151.392) had a similar history where it was tracked from 13 June to 15 June in Mossy Creek Cove, disappeared until 5 July and then reappeared in Mossy Creek Cove.

Temperature Preference

By late May and early June temperature selection was in the range from 17.0 to 23.0 C, the maximum and minimum (plus or minus) one standard deviation from the mean temperatures selected (Figure 8). These temperatures were available at 3 to 4 m deep (Figure B-8), although fish were occasionally noted at temperatures that occurred only at depths of 7 m. The fish swam close to shore and fishermen were

catching striped bass off points of islands and near submerged islands. By the end of June, however, these temperatures were available only at depths from 8 to 10 m (Figures B-10 to B-14) (Figure 9). Many tagged fish "disappeared" or were lost during this month because radio signals could not be received at these depths unless the boat was directly above the fish. The fish tagged with radio tag 151.240A was one of the few fish found during this period. On 20 June it was found near Black Oak Cove at an estimated 10-m depth. The signals were too weak for the interval counter to measure. Signals were received only within a 10-m radius on top of the fish's location. The fish remained in the reservoir at these depths until late June and early July.

Third Phase--July to October

Movements

Beginning in late June to early July, tagged striped bass began to appear in coves identified as refuges in a previous study (Waddle 1979). Also, striped bass electroshocked and tagged in the refuges did not swim out into the reservoir, but spent their tracking lives in a refuge. Radio tag 151.240A was the first fish to return to Mossy Creek Cove and Byrd Springs Cove from being lost in the reservoir.

Movement rates in refuges were only 200 m/day maximum when movement was noted. During July it was not unusual to observe the tagged fish swimming actively between two or even three submerged waterfalls in Mossy Creek Cove. Radio tag 150.884 exhibited this type of movement on 3 July at a rate of 200 m/hr (Figure A-21a). Actual rate of

movement was much higher because of rest periods in the submerged waterfalls. As more fish moved into the refuges, these movements decreased and came to almost a complete halt by mid-August. It was not unusual for a fish to remain at one submerged waterfall in Mossy Creek Cove for several weeks, especially by late August. The only reason they moved away from one site at that time was because of the dropping water level. When the water depth at a site dropped below 1 m, the striped bass would move and usually to the next submerged waterfall downstream.

There were several fish that were exceptions to this general pattern. Radio tags 151.330B and 151.448 were tagged and released into Cedar Hill Cove. After a short period (approximately 1 week), they moved out of Cedar Hill Cove. Both were not located for approximately three weeks and then they were found in Mossy Creek Cove. Only the decaying carcass of the fish with radio tag 151.330B was found in Mossy Creek Cove, but the other fish, radio tag 151.448, was alive. After approximately two weeks (dates could not be pinpointed) in Mossy Creek Cove, this fish also died. The deaths of these two fish may have been an indication that the stress of moving between two distant refuges was extreme. Two other fish, tagged with radio tag 151.272 and sonic tag 157C, were released into Byrd Springs Cove. Radio tag 151.272 moved into Mossy Creek Cove in less than a week where it was caught by a fisherman. The sonic tagged fish, on the other hand, moved away from Byrd Springs into Byrd Springs Cove after release, but did not return to the springs or swim to Mossy Creek Cove. It was found dead early the next morning.

Temperature Preference

Mean temperatures experienced from mid-July to October ranged from 15 to 24 C (Figure 8). Fish had moved into the shallow refuges and were monitored at depths from 8 m near the main reservoir to 1 m near the creek confluence. The majority of tagged fish were monitored at depths of 3 to 4 m. Often the fish were found in the coolest water available, indicating they were swimming just above the bottom. Radio tag 151.063C was an example of this cool water orientation (Figure A-31). Occasionally a fish that had selected cool temperatures on the bottom was monitored at slightly warmer temperatures 1 m or more above the bottom. This happened to radio tag 150.913B (Figure A-26) and radio tag 151.063C (Figure A-31) on 2 August. It is hypothesized that these fish were pressured by other striped bass crowding into the submerged waterfalls and were forced to swim above the other fish. By late summer the number of fish in the small refuges probably necessitated layers of striped bass in the holes below the waterfalls. Excellent fish catches from these small areas during the late summer also indicated large numbers of fish present.

Winter Attraction

During mid-March, large concentrations of striped bass were shocked in Mossy Creek Cove. These concentrations were similar to those seen in July. Reports of fishermen catching striped bass all winter were received. The first few fish that were tagged moved into Mossy Creek Cove and remained there for long periods of time (Figures A-1, A-3, A-4). Shad were found in large numbers during the winter in

the warm refuge waters, possibly further attracting the striped bass to the refuges.

Diurnal Variations

No consistent diurnal variation in mean temperature selection by striped bass was seen in this study. The manual data sets were plotted by means against time and no pattern emerged. Several of the automatic recordings in Mossy Creek, however, resulted in some interesting temperature data (Figures 10 and 11). These graphs showed a trend of warming during the day until approximately 1900 hr. A varying period of a constant temperature then occurred, leading into a cooling trend that lasted until 0700 to 0800 hr the next morning. Then the warming trend began again. Because this cyclic trend was only noticed in Mossy Creek Cove when fish were moving very little, it was concluded that this was a phenomena restricted to Mossy Creek Cove. Further study of these same fish showed that the fish, especially sonic tag 165B, moved very little and the change in temperatures could not be correlated to the movements. The change in temperature did follow the cooling and warming trend of the inflowing water from Mossy Creek and the surface water cooling. The striped bass apparently were remaining at one location and the water temperature around them was changing. Further evidence was when fish changed position, temperatures changed abruptly (within minutes), not gradually.

Excursions by the fish were recorded by manual and automatic data, and are shown as vertical lines or scattered A's (Figures 10 and 11). Manual data also showed similar excursions on the same scale,

PLOT OF TEMP*TIME_H LEGEND: A = 1 OES, B = 2 OES, ETC.

Figure 10. Computer plot of automatic recorded data of Radio Tag 151.240B showing cyclic trend. A - 1 observation, B - 2 observations, etc.

Figure 11. Computer graph of automatic recorded data of Sonic Tag 165B on August 1 to August 2 showing cyclic variation.

and other excursions on a smaller scale. Some small excursions within a 10-sec span between data recordings were heard as the signal intervals shortened drastically and then returned to the original interval. These movements were not recorded in most automatic recordings which were set at 60-sec intervals. Some of the small excursions could have been pockets of warmer or cooler water passing by the stationary fish. The other excursions possibly represent short, 1 to 5 min feeding forays into warmer temperatures. The less frequent forays into cooler waters were for unknown reasons. It was hypothesized that space competition from other fish might have caused these forays, but in another study it was seen that solitary striped bass commonly made excursions to cooler water (Coutant and Carroll, submitted). The cool water forays might just have been part of the striped bass' random movements.

Ontogenetic Change

During the study, it was noted that the very large striped bass that were tagged were always in very cool (16 to 20 C) water compared with other tagged fish at the same time. Mean temperatures selected by the fish in this study and previous studies (Coutant and Carroll, submitted; Waddle 1979) were plotted against weight and a decrease was noted (Figure 12). A definite change was apparent when the results from laboratory studies on temperature preference of juveniles (Meldrim and Gift 1971) were plotted (Figure 12). The apparent ontogenetic change was very distinct between 1 to 5 kg weight. Above 5 kg there was not a large enough sample size to make any conclusion.

Figure 12. Mean preferred temperature by fish weight.

Water Quality

Temperatures in Mossy Creek Cove ranged from 7.8 to 23.6 C during the study while Cherokee Reservoir ranged from 5.1 to 31 C (Appendix B). Temperatures in the reservoir were isothermal in the early spring near 5 C (Figure B-1). As warmer spring days occurred, a range of temperatures from 8 to 18 C were found (24 March--12 May) (Figures B-2 to B-7). Late May found a range of temperatures from 12 to 24 C and in June the range warmed to 16 to 28 C (Figures B-8 to B-14). By late July the range of temperatures 18 to 28 (Figure B-17) was present, with the higher temperatures predominating in the whole body of water. In August the 18 to 22 C water was gone from the main reservoir, leaving a temperature gradient from 24 to 28 C (Figure B-19). September temperatures varied from 25 to 27 C and from 24 to 28 C. On 21 September, temperatures ranged from 26 to 29 C (Figure B-24) with the major portion of the reservoir at 26 C. By 28 September the fall overturn had occurred and temperatures ranged from 24.5 to 25 C (Figure B-25). On 5 October temperatures were isothermal near 24.2 C, on 12 October isothermal between 21 and 22 C, and on 19 October temperatures were near 19.0 C with pockets of 18 and 20 C (Figures B-26 to B-28).

Mossy Creek inflow generally ranged from 12 C in the winter to 17 C in the summer. This cooler water created an underflow in the submerged creek channel where the cool water followed the channel underneath the warmer reservoir water and pooled in the holes below the submerged waterfalls. On 4 August this underflow pattern could be seen extending into the reservoir on the isotherm graph (Figure B-18). Later in September the reservoir water was too warm, and the underflow

became less apparent in the reservoir (Figures B-19 to B-24). The underflow was restricted to the channel as shown by a temperature survey of Mossy Creek Cove by a summer student project (Student Science Training Program, Carson Newman College). Beyond the channel, the cove registered the same temperature profile as the reservoir. This same underflow condition occurred at Byrd Springs Cove and Cedar Hill Cove but was much less obvious because of the smaller volume of inflow.

It was observed at the very beginning of the study that while the reservoir was isothermal near 5 C, the inflow at Byrd Springs and Mossy Creek was approximately 12 C. Ice cover did not extend very far into these coves, although the rest of the lower reservoir had considerable ice cover.

Dissolved oxygen in the Mossy Creek inflow was always high (10 ppm or more). Dissolved oxygen levels in Mossy Creek Cove in the submerged creek channel were also high--no readings below 5 ppm were taken. Outside of the creek channel and in the reservoir D.O. levels varied with the season. Springtime D.O. levels were above 5 ppm everywhere in the reservoir (Figures B-1 to B-8). By the end of May oxygen became limited in the deepest waters (>15 m) (Figure B-9). By the end of June, less than 2 ppm of dissolved oxygen was available at 10 m (Figure B-14). Surface waters during the summer and fall were always oxygenated. Throughout August the area of oxygenated water became smaller and averaged 7 to 8 m deep. In September this trend continued and by 21 September, D.O. levels above 3 ppm were found only in the top 5 to 7 m (Figure B-24). Between 21 and 28 September the fall overturn occurred and D.O. levels throughout the reservoir ranged from 3 to 7 ppm

(Figure B-25). In October these values rose to 8 and 9 ppm throughout the water column.

The water samples for zinc, cadmium, and manganese taken during the study showed higher concentrations of all the metals, filtered and unfiltered, in Mossy Creek Cove than in the other two areas (Table 2). Byrd Springs was lower in zinc than Cherokee Reservoir for both filtered and unfiltered samples, but was higher in cadmium and manganese in filtered samples and lower in unfiltered in comparison with Cherokee Reservoir samples. This variation in filtered and unfiltered results could be caused by the small samples sizes. The samples were primarily taken to see if there was any pattern or concentration of a heavy metal in the refuges that might affect the striped bass. Zinc was the only one found to be in larger concentrations in a refuge than in the reservoir. The reservoir mean for zinc was influenced by one sample with 22 ppb (only one above 5 ppb). Mossy Creek Cove, on the other hand, had several samples above 10 ppb.

The few samples analyzed for mercury showed a range from 0.0006 to 0.0102 ppb. The higher values (0.0092 to 0.0102 ppb) came from Mossy Creek Cove and Byrd Springs Cove. There were so few samples taken, however, that the differences in the refuges and in the reservoir could be individual variations and not an indication of the actual water content. If the refuges have consistently higher values, though, this may be an important consideration in the health of the striped bass.

Table 2. Results of Chemical Analyses of 30 Water Samples
from Mossy Creek, Byrd Springs, and
Cherokee Reservoir, 1978

Site	Zinc			Cadmium			Manganese		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Unfiltered (ppb)									
Mossy Creek	2.9	15	7.5	0.08	2.2	0.61	0.70	15	2.26
Byrd Springs	1.1	4.4	2.8	0.07	1.1	0.32	0.79	4.5	1.83
Cherokee Reservoir	1.6	22	4.6	0.06	0.31	0.12	0.81	1.1	0.98
Filtered (ppb)									
Mossy Creek	2.8	7.3	4.4	0.02	1.3	0.35	0.69	4.1	1.25
Byrd Springs	2.6	3.3	2.9	<0.01	0.05	<0.02	0.58	0.82	0.75
Cherokee Reservoir	2.1	11	3.6	<0.01	0.45	<0.12	0.76	1.5	0.95

V. DISCUSSION

Transmitters

Two different types of transmitters, ultrasonic and radio, were used and comparisons of the two were made. Advantages were described previously by Winter et al. (1973) and Bahr (1977) of radio and ultrasonic transmitters. Radio transmitters were inexpensive to build, had long transmitter battery life, tracking could be done from a boat, from shore, or from the air, and transmitter range was not interfered by fast water. Also there was not as much interference by underwater structures as with sonic tags. Ultrasonic transmitters had the advantages of signal intensity not affected by depth and no external antenna required on the transmitter. It was also found that receiver tuning was not as critical for sonic tags as it was for radio tags. Once a sonic tag was audible to the ear, the signal was usually easily received and interpreted by the interval counter.

Disadvantages of these systems were noted in Bahr (1977) and observed in this study. The major disadvantages of the radio transmitter system were hindrance of the signal with increasing depth, salinity, or conductivity, interference by power lines, unshielded ignition systems and large metal objects, snagging of the external antenna, and poor directionality. The depth disadvantage was especially pronounced in our study during the early summer when the striped bass were at depths >8 m, the maximum effective depth for the radio tags in Cherokee Reservoir. The radio tags in this study did not seem to be affected by power lines, but were definitely affected by unshielded ignition

systems (boat motors, lawnmowers on shore). We noticed a problem with citizen's band (CB) radio interference, especially on certain frequencies. Reception of the radio signal was also a problem. If the receiver was not tuned exactly on the frequency of the tag, no signal was received. This problem and the bleed-over of signals from a tag to several channels on the receiver may have been a disadvantage of a sensitive radio receiver rather than that of a radio transmitter. Some of the tags malfunctioned early in their tracking history, possibly because of water leakage and/or an electric short in the system. Ultrasonic transmitter systems' disadvantages noted by others consisted of short battery life, interference of the signal by turbulent water, boat traffic, and underwater structures, tracking only from the water, limited number of tags in one area for individual identification, and expensive equipment. The first disadvantage did not apply in this study as the sonic tags were equipped to last at least 6 months and one fish was located one year after release from a previous study (see sonic tag 154, p. 174, Appendix A). The tags were large, but the striped bass from 2 to 11 kg were large enough to carry them without an observable effect. Both radio and sonic tags were essentially the same size. Smaller species of fish would have a problem with these bigger tags and would have to use smaller, shorter life tags.

Final analysis of both systems led to the conclusion that the sonic tags would be the better choice for deep water fish like striped bass, but that the radio tags were preferred whenever possible because of easy reception from long distances, especially when the fish were in shallow water. Most of the striped bass tracked in this study

tended to orient near structures--submerged creek channels, concrete rubble, points of islands, and submerged islands--which lowered the effective distance of sonic tag reception. Also, once a radio signal was received, the signal could be perceived over the noise of the boat's motor, thus allowing the tracker to maneuver closer to the tagged fish without stopping and starting several times.

Temperature Preference

During the springtime the fish selected the warmest temperatures available, up to 1 m in depth, although usually between 2 to 3 m depth. They were also located in shallow water near shore which was generally warmer from solar heating than water in the deeper sections of the reservoir. Although daily fluctuations in water temperatures prevented a day by day warming trend in the preferred temperatures of each fish, a trend was apparent over longer periods of time (Figures A-2 and A-6). This same pattern was seen in quarry lakes by a study by Coutant and Carroll (submitted). The fish in the quarry chose the warmest temperatures available at depths greater than 1.5 m. The mean temperatures selected during this time were from 10.5 to 15.8 C, gradually warming from March to mid-May.

The summer and early fall temperature selection was from 17 to 23 C, averaging 20.5 C. This agreed with the results of Waddle's (1979) study of striped bass in Cherokee Reservoir in 1977 and with the quarry study by Coutant and Carroll (submitted). The final preferendum of the smaller quarry fish was higher (22 C) than that of Waddle's (20.4 C) and the author's (20.5 C).

The cooling of the waters in the fall as the study ended may have caused slightly lower mean temperatures. Possibly the fish remained at the same depths where they were located in the summer and the water cooled around them. There were not enough observations in the fall to determine if this was the case, and the fish moved out of the refuges and were lost before enough data could be collected to verify the trend. It may be possible that the preferred mean temperature in the fall was lower than the summer and spring preferred temperature.

Temperature--Dissolved Oxygen Squeeze

This study provided support for the hypothesis (Waddle 1979; Coutant 1978; Coutant and Carroll, submitted) that the fish moved into the refuges because of a temperature-oxygen squeeze. No fish remained in the refuges for long periods until mid-July, when D.O. levels were less than 2 ppm at temperatures below 24 C in the reservoir. Tagged fish began moving into the refuges from the reservoir. Fish tagged in July and later spent all of their tracking lives within the refuges. Electroshocking showed more fish in the refuges by the first of August when most of the cool water had disappeared in the reservoir. Fishing catches had increased substantially from Mossy Creek Cove, and by late August large concentrations of striped bass were seen and caught in Cedar Hill Cove. Afterwards, the increasing fishermen's catches and sightings of striped bass could be correlated to the dropping dissolved oxygen. Especially when there were slight increases in the D.O. levels from rainstorms, fish catches would drop off and several tagged fish would move into deeper waters outside of the refuges.

Avoidance Temperatures

Fish in this study avoided temperatures of 25 to 27 C and higher. Short excursions were occasionally made into the warmer water, but no standard deviation of the temperatures selected exceeded 25 C. This observation agreed with Merriman's (1941) early observation of a 25 to 27 C upper avoidance range. Coutant and Carroll (submitted) and Waddle (1979) also observed the same upper avoidance temperature. Dudley's (1977) hypothesis that post-spawning behavior of striped bass was influenced largely by temperature was supported by our findings. He proposed that the fish moved upstream in the Savannah River, Georgia, to the cooler tailwaters of reservoir discharges rather than toward the warmer coastal waters at 26 to 30 C. Movements of striped bass in Tennessee reservoirs (Watts Bar, Cherokee, Loudon) towards the tailwaters of reservoirs have been seen by fishermen for several years.

Even after the fall overturn had occurred and D.O. levels were not limiting in the reservoir, the fish remained in the refuges at temperatures from 18 to 23 C while temperatures were above 24 C in the reservoir. Some fish moved out when the temperature dropped from 24 to 22 C, the rest during the next week when temperatures dropped below 20 C in the reservoir.

The Cherokee striped bass followed the 20 to 22 C isotherms as they moved downward in the water column in the reservoir and into the refuges in late summer. This effectively separated them from their food source, shad, in a similar manner to that of Momot, Erickson, and Stevenson's (1977) walleye. The shad in both reservoirs had a higher temperature preference and lethal limit than the predators since

they were adapted to surface feeding. This made them less available as prey to the striped bass and walleye. Feeding forays were never observed in late summer in Mossy Creek Cove where shad were only a few meters above the fish. Apparently the temperature preference of cooler temperatures and avoidance of temperatures above 25 C was a stronger influence than feeding. This might be part of the reason why striped bass in Cherokee have not reached the growth that other reservoirs' striped bass have attained. Separated from a food source almost all summer and having normal slow growth during the winters would restrict the striped bass to feeding and growth during the spring and fall only.

Ontogenetic Change

It was observed during this study that several fish consistently chose cooler temperatures than others. Also mean temperature selected by adult striped bass was approximately 20.5 C in 1977 (Waddle 1979) and 1978, which was lower than the final preferendum of 22 C for 2-year-old fish in the field (Coutant and Carroll, submitted) and the 25 C temperature preference of juvenile striped bass studied by Meldrim (1971) in the laboratory. These results agreed with other studies which had shown discrepancies in the laboratory and field results. Barans and Tubb (1973) found consistent differences in temperature selection between young and adults of yellow perch and emerald shiners. Young-of-the-year perch usually selected higher temperatures than adults at all seasons, and adult emerald shiners usually selected higher temperatures all seasons except winter when they selected

cooler temperatures than the young. McCauley and Read (1973) found that yellow perch adults selected temperatures that were lower than those selected by Juveniles. Reynolds and Casterlin (1978) observed a lower temperature preference in adults compared to juvenile perch. Brandt (1978) also saw that adult alewife in Lake Michigan occupied cooler temperatures than the young. Ontogenetic changes in salinity gradients selected in grunion was observed by Reynolds and Thomson (1974). Some species, however, did not show an ontogenetic change in preferred temperature--i.e., bluegill (Beitinger and Magnuson 1975).

These ontogenetic changes in temperature preference may lead to a partitioning of thermal resources (Magnuson et al. 1979), intraspecific niche segregation and reduction of cannibalism as well as competition between age classes. In this study fish under 2 kg were rarely electroshocked in the same area as the bigger fish. The ontogenetic change may also explain why the problem in Cherokee Reservoir took several years to appear. The young striped bass with a higher temperature preference could exist very well in Cherokee Reservoir. The problem might have arisen with the older bass which needed cooler temperatures, but found them unoxygenated, or in late summer, totally unavailable. The die-off in Cherokee would represent the excess numbers of fish which could not find the cooler temperatures in the refuges or were excluded from the refuges by competition.

The separation of the striped bass from their food source, shad, may lead to further temperature selection changes. Javaid and Anderson (1976) found an upward shift in temperature preference of starved Atlantic salmon and a downward shift in starved brook trout and rainbow

trout. Thus the distinct decrease in temperature preference (Figure 9) of the striped bass may have been magnified in Cherokee Reservoir by starvation.

Also fluctuating temperature may have lowered the optimum growth temperature. Preliminary data from Cox (personal communication) indicated that with fluctuating ± 4 C around 18, 24, and 30 C, the optimum growth for striped bass occurred at 24 C, but the lowest maintenance ration occurred at 18 C. With constant temperatures the highest growth rate and the lowest maintenance ration occurred at 24 to 25 C. In Cherokee Reservoir with the normal daily temperature fluctuation near ± 4 C, especially in Mossy Creek Cove, the starved striped bass may be selecting cooler temperatures because of the lower maintenance ration required. The combination of age, starvation, and fluctuating temperature may be acting together to cause the distinct downward shift in selected temperatures by the larger and older fish.

Winter Attraction

Early in March large concentrations of striped bass were seen in refuges, similar to the concentrations in July. Temperatures of Mossy Creek and Byrd Springs were higher (12 to 14 C) than those of the open reservoir (4.5 to 7 C). This apparent winter attraction was probably an attempt to stay at temperatures closer to their final thermal preferendum. Especially in very cold winters when considerable ice cover formed over the reservoir, the fish might be attracted to the warmer refuges. A similar phenomenon of winter attraction has been at many power-plant-heated discharges in winter (Coutant 1978). A

hypothesis that some striped bass in Cherokee may migrate up the reservoir to the warm John Sevier Steam Plant discharge during the winter has been suggested. Another attraction in these refuges during the winter was the large populations of shad crowded into the warmer influent waters. Such a large food source in one small area would be reason in itself for congregations of striped bass within the refuges. Fishermen have shown that fish can be caught all winter from Mossy Creek Cove, so there was a population of striped bass that can be found in the refuge in the winter. Whether fish moved in and out of the refuge all winter as they appeared to do early in this study, or if the fish were a distinct population with a definite home range was not known.

Movements

The striped bass nomadic movements in the spring and early summer were far-ranging and apparently restricted only by temperature preference. No home range behavior was seen, although most of the fish successfully tracked remained between Cedar Hill Cove and Mossy Creek Cove, possibly a preferred territory. The same nomadic activity was observed in Coutant and Carroll (submitted) and Stooksbury (1977), although not in Waddle (1979). Only two of Waddle's fish which were tagged early in his study showed similar nomadic activity.

Spawning movements in the spring could not be verified, but all the fish tagged in March could not be found in the lower reservoir by mid-April. It was possible that the fish began moving up the reservoir in their spawning run during this time. Also few fish were shocked in the refuges and coves where they were easily located earlier.

Movements within the refuges was restricted and of short durations in the late summer. The exposed creek channel revealed the limited amount of space in which the striped bass could move. The majority of movements were upstream and downstream in the channel. By late summer the large numbers of fish in the refuges probably restricted movements even more. The crowded conditions were revealed when shocking for fish. It was not unusual for fishermen to catch fish by snagging their gill covers during late summer, indicating the fish could not avoid the hook possibly because of the crowded conditions in the small refuge areas.

It was noted in this study that all fish tagged outside Mossy Creek Cove in late summer eventually moved into Mossy Creek Cove. Even fish in Cedar Hill Cove moved to Mossy Creek Cove this year whereas in the previous study fish remained in Cedar Hill Cove (Waddle 1979). Fish did not move into Cedar Hill Cove in large numbers until late August. The boat dock, under new management, was much busier and had more water activity than the previous year, possibly shrinking the refuge area and forcing the fish into other refuges.

Although movements occurred between refuges, they were rare occasions. Fish from Byrd Springs would move to Mossy Creek Cove, but usually would stay there and not move back. The Cedar Hill Cove fish also moved to Mossy Creek Cove. None of the fish from Mossy Creek Cove were known to have moved to the other refuges. The stress of the trip from one refuge to another must have been great. One fish died from the trip, another fish died within a week, and a third fish never made it to a refuge before it died. The third fish might have survived if

it had made it to a refuge. This gave support to the belief that the refuges might be necessary for striped bass survival as was indicated in the previous study (Waddle 1979).

Waddle's (1979) study did not see any movement from Cedar Hill Cove to Mossy Creek Cove as this study did, but he did observe movements between Byrd Springs Cove and Mossy Creek Cove. We did not observe any movements from Mossy Creek Cove to Byrd Springs, but that might have been caused by the fact that the majority of our fish were tagged with radio tags and for the fish to move to Byrd Springs required that they swim through deep (>8 m) waters where their signal would be lost.

When the fish were observed, moving or stationary, they were oriented close to the bottom. Fish were always observed swimming along shorelines, submerged islands, on the points of land, or in late summer, in submerged spring or creek channels approximately 1 m or less above the substrate. No fish was ever observed in open water, which seemed to indicate that the striped bass in Cherokee Reservoir were not pelagic fish, at least not during the spring or summer.

In October the fish moved out of the refuges and were lost in the reservoir. It was assumed the fish moved throughout the reservoir in the fall as they did in the springtime. Fishermen reported catching striped bass of the same island points where they were found in the spring, but at much greater depths.

Heavy Metal Toxicity

During all of 1977 and the first part of 1978, striped bass mortality was almost continuous. Since dissolved oxygen was not limited during the winter months and temperature would not be a major factor, other causes must be involved. It was hypothesized that chronic heavy metal toxicity could be causing the fish mortalities (Coutant 1978). Metal-stressed fish would be less able to cope with the handling effects of being caught by fishermen, less able to tolerate high temperatures and low dissolved oxygen outside the refuge areas, and more disease prone than healthy individuals.

Striped bass spend a large amount of time in the refuges during the summer and possibly during the winter, especially the very cold winters. Even in the springtime there was some residence time of fish in the refuges. These refuges were all characterized by groundwater sources in an area rich in dolomite, and in tailing piles of mined zinc ore. Water quality analyses of the tributary water in Mossy Creek did show a higher concentration of metals than in the main body of the reservoir. These higher concentrations and long residence times in the refuge may lead to bioaccumulation of the metals. Preliminary results from an analysis of zinc in striped bass liver showed 24.2 to 71 ppm (L. Deal, personal communication). The highest concentration was from a large striped bass (14 kg) with most of the other concentrations between 20 and 40 ppm in the smaller fish. Zinc has been found to concentrate readily in the liver and it was the liver that seemed most abnormal in Cherokee striped bass. The shrunken, yellow livers may be an indication of zinc affecting the liver metabolism. Low levels

of zinc and cadmium could disrupt the energy production of the liver (Hiltibran 1971; Jackim et al. 1970). These metal stressed fish would be susceptible to mortality in Cherokee Reservoir. They would be less able to survive outside of the refuge because their lethal temperature was probably lower than for a normal fish and their tolerance for low D.O. levels reduced (Coutant 1978). They would also be less likely to recover from handling during hook and release by fishermen. Most of the fish kills in the late summer of 1978 could be explained by hook and release mortality if this was the case. Some fish may actually be dying as a direct result of chronic metal toxicity. The poor condition of the striped bass observed in the past few years may be a direct effect of the damaged livers and poor energy metabolism.

Another possibility for explaining the poor condition of the striped bass is the Jefferson City treated sewage outfall in Mossy Creek Cove. The outfall corresponds with the cool water flowing down the submerged creek channel, exposing the fish to the chemicals in the sewage. Also the shad are highly attracted to the outfall and are in large numbers in Mossy Creek Cove all summer long. They may pass the chemicals along the food chain to the striped bass. More research is being planned to examine these hypotheses by the Cherokee Reservoir Task Force.

VI. SUMMARY

1. Thirty-one striped bass were successfully monitored for their habitat preference, twenty-nine for their temperature selection over a period of 1 to 108 days, averaging 36 days.
2. Mean temperature selected in the spring ranged from 10.5 C in March to 15.8 C in mid-May. These temperatures were the warmest available at depths greater than 1 m.
3. Mean temperature selected during the summer and fall was 20.5 C. Temperatures selected ranged from 15 C to 25 C during this time.
4. Movements throughout the reservoir occurred in the spring and early summer.
5. Striped bass moved into the refuges in mid-summer. At this time temperatures <20 C in the open waters of the reservoir had limited D.O. (<2 ppm) concentrations. By late summer no cool (<24 C) temperatures were available in the main reservoir. Movements in late summer were short and infrequent and were nearly always within the refuges.
6. Several weeks after the fall overturn, when water temperatures had cooled to a range of 20 to 24 C, the striped bass left the refuges and dispersed in the open reservoir.
7. Congregations of striped bass at the end of winter were observed in Mossy Creek and apparently represented a winter attraction to the warmer influent water.
8. An ontogenetic change in temperature selection was observed, with older striped bass selecting cooler temperatures (16 to 20 C) than the younger striped bass (20 to 23 C).

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APPENDIX A
DETAILED DESCRIPTIONS OF THE RESULTS
FOR EACH TAGGED FISH

DETAILED DESCRIPTIONS OF THE RESULTS
FOR EACH TAGGED FISH

Sonic Tag 158

On 21 March 1978, the first striped bass of the study was shocked at 1545 hr in Byrd Springs (Site 1, Figure A-1). A thunderstorm came up at the same time and refuge was sought at Black Oak Dock. As the storm let up, the 4.5 to 5.4 kg fish was surgically tagged at the dock and then taken back to Byrd Springs and released at 1645 hr. By the time the fish was released, the tag thermistor had slipped into the body cavity. Taking data every 30 sec for 2.5 hr, a mean temperature of 8.9 C (Table A-1) and a mode of 11.2 C was experienced by the fish. The fish remained in the warmer water when first released, then began to move out of Byrd Springs by 1820 hr and into the colder waters around the point of land separating Mossy Creek Cove from Byrd Spring Cove. By 1910 hr, it had moved into the mouth of Mossy Creek Cove and was again in slightly warmer waters. During this period of movement (~ 400 m/hr), this fish experienced a wide range of temperatures, almost all that were available to it (Figure A-2). This may have been caused by the reaction to the stress of tagging. The next day, 22 March, this fish was up in the head of Mossy Creek Cove (Site 2, Figure A-1) and temperatures chosen were in a narrow range close to the maximum temperature available (Figure A-2). A mean temperature of 13.7 C was experienced over a half an hour with temperature data being taken once every 10 sec. On 23 March, it was still at Site 2, as far up Mossy Creek as was possible. Site 2 was at the base of a partially

Figure A-1. Map showing observed locations of the fish tagged with Sonic Tag 158.

Table A-1. Thermal History of Sonic Tag 158
in Degrees Celsius with Location Data
from Figure A-1 (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
March 21	1	1645	8.9 ^a	11.2	6.5-13.9	1.7
March 22	2	1930	13.7	13.7	13.1-14.7	0.1
March 23	2	0750	12.2	12.2	11.9-12.3	0.1
March 27	3	1510	11.0	11.0	10.9-11.2	0.1
March 30	2	1540	13.0	12.7	12.7-13.4	0.3

^aTemperature data taken every 30 sec for 2.5-hr period.

Figure A-2. Graph showing temperatures [minimum, maximum, mean(-), mode(---), plus and minus one standard deviation] selected by Sonic Tag 158. Half-hour data sets.

submerged waterfall. Signals were weak and erratic at this time indicating that the fish may have been swimming in the rocky banks at Site 2 which would block the sonic signals. A mean temperature of 12.2 C was experienced during the half hour monitoring period. In the lake water temperatures ranged from 6.6 to 13.6 C near the dam and from 12.9 to 19.2 C at German Creek confluence (28 km on Figure B-1). Mossy Creek temperatures at the same time ranged from 8.4 to 13.6 C. By 27 March this fish had moved out to the area around Site 3. The fish moved back and forth within a 20 to 30 m area along an island while being monitored and was swimming in temperatures averaging 11.0 C. This was a cold, overcast day and surface temperatures in the area ranged from 10.8 to 11.8 C. The fish appeared to be approximately 2 to 3 m deep near the island. By 30 March it had moved back near Site 2 into the submerged creek channel area. Mean temperatures experienced this day was 13.0 C although surface temperatures had warmed to 16.9 to 17.9 C. Not as much movement was noted that day in comparison with the previous days. During the next several days this fish was not found in the Byrd Springs--Mossy Creek area nor up to Point 2. On 11 April the east side of the lake up to Cedar Hill Cove was checked, but no fish was located. On 12 April, the tag was located at Site 4 in approximately 8 m of water. Either the tag had come off the fish or the fish had died because the temperature data was very constant and only showed a slow warming trend as the lake water warmed throughout the day. An attempt to recover the tag was made by a diver in May, but the bottom was covered with silt greater than 1 m in depth and the tag could not be pinpointed.

Sonic Tag 156

This 4.5 to 5.4 kg striped bass was shocked in Black Oak Cove at Site 1 (Figure A-3) on 29 March 1978. Tagged internally with the thermistor external to the body, this fish was released near Site 1 at 0930 hr. No temperature data was collected because the connection to the hydrophone broke. On 30 March, this fish was not located from Black Oak Dock down to Mossy Creek Cove. On 31 March, however, it was found in Site 2 in Mossy Creek Cove near the bank. Mean temperature experienced was 13.3 C (Table A-2). This temperature was available near the surface on a warm, sunny day. The range of temperatures in Mossy Creek Cove was from 7.8 to 14.5 C or higher in late afternoon. At the German Creek confluence temperatures were warmer and ranged from 9.8 to 17.2 C. On 5 April, this fish was found in the area of Site 3, moving back and forth along the bank in 1 to 2 m of water. Mean temperature experienced at this site was 14.6 C. Temperatures in the area ranged from 11.6 C at 7 m to 19.4 C at the surface in shallow water near shore. The next day, 6 April, the fish was found in the same area. While being monitored, it moved from Site 3 along the shoreline towards Mossy Creek, a distance of approximately 100 m (200 m/hr). Mean temperature experienced was 13.2 C which was a cooler mean than the previous day. The monitoring period was earlier in the day and the day was overcast so solar heating was not present. On 7 April this fish was located again at Site 3. Mean temperature on this day was 11.3 C. The fish was at a depth of 2 to 3 m and water temperatures ranged from 10.6 C at 3.5 m (bottom) to 17.6 C at the surface. Water from Mossy Creek was near 18.0 C at this time. On 11 April, the lower

Figure A-3. Map showing observed locations of the fish tagged with Sonic Tag 156.

Table A-2. Thermal History of Sonic Tag 156
in Degrees Celsius with Location Data
from Figure A-3 (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
March 31	2	1340	13.3	13.3	11.9-14.5	0.2
April 5	3	1530	14.6	14.7	14.2-14.8	0.2
April 6	3	1020	13.2	13.3	12.4-16.6	0.5
April 7	3	1050	11.3	11.4	8.9-11.8	0.4

reservoir below Cedar Hill was searched, but this fish was not found. Further searches of German Creek on 12 April and up to Holston River Mile 79 (45 km from dam) on 17 April did not locate this fish.

Sonic Tag 157A

The first time this tag was used was on 29 March on a 4.5 to 5.4 kg fish shocked from Black Oak Cove at Site 1 (Figure A-4), tagged internally and released into Site 1 by 1050 hr. No immediate data was collected because of a bad connection on the hydrophone. Temperature of the water in Black Oak Cove ranged from 10.8 to 12.0 C in shallow (<3 m) water. The next day this fish was found near Site 2, swimming around the N.E. point of the island. Mean temperature on 30 March was 12.2 C (Table A-3) at 1400 hr. Temperatures in the area ranged from 8.1 to 15.3 C. Determined from the temperature profile, this fish was at a depth of 1 to 2 m. By 1420 hr on 30 March, this fish had moved into Mossy Creek Cove in the area of Site 3. A mean temperature of 13.8 C was experienced by this fish during a half hour observation. These temperatures were available at 1 to 2 m deep in Mossy Creek Cove. After this date the fish was not sighted in any of the searches of Cherokee until on 10 May some numbers were taken on this fish mistakenly. At the time it was thought to be sonic tag 166, but temperature calculations showed it to be sonic tag 157A. This spot check showed the fish at an average temperature of 14.9 C as it moved from Site 4 to Site 5. After this date no signals were heard from this fish. On 9 June, a check on a floating dead fish at Site 6 showed it to be this fish. The carcass was in good condition, indicating that the fish

Figure A-4. Map showing observed locations of the fish tagged with Sonic Tag 157A.

Table A-3. Thermal History of Sonic Tag 157A
 in Degrees Celsius with Location Data
 from Figure A-4 (Half-Hour
 Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
March 30	2	1400	12.2	12.5	10.8-15.3	0.7
March 31	3	1420	13.8	13.8	11.6-14.4	0.3
May 10	4-5	1420	14.9 ^a	15.1 ^a		

^aSpot check--less than half an hour observation.

had died shortly before being found. By this time, the surgical incision had almost completely healed and internally the tag was enveloped by viscera membrane that had grown around it. No sign of infection was present, and it appeared not to have been the direct cause of the fish's death although it may have been an added stress.

Sonic Tag 166

On 9 May 1978 a 3.6 kg striped bass was shocked in Mossy Creek Cove at Site 1 (Figure A-5). Tagged internally and released at Site 1 by 2125 hr, it remained in the submerged creek channel while being monitored. It experienced a mean temperature of 16.5 C (Table A-4). This was at a depth of approximately 2 m in water ranging in temperature from 14.5 to 18.0 C. On 10 May, numbers were taken for a while on sonic tag 157A near Site 2 which was mistaken for this fish. This fish was actually at Site 2. Temperature data was collected on this fish as it moved from Site 2 to Site 3. Moving steadily at approximately 1200 m/hr or 20 m/min this fish experienced a mean temperature of 16.2 C. Water temperatures in this area ranged from 14.5 to 17.3 C. The next day, 11 May, this fish was located in Site 4 where a submerged island was located. The signals were lost several times, indicating the fish was swimming around the island and blocking the tag's signal. This day the fish was at a mean temperature of 16.7 C. Temperatures in the area ranged from 16.2 C on the bottom to 16.7 C at 3 m to 20.1 C on the surface. This fish was not located in Mossy Creek Cove on 12 May, which was the only area searched. On 18 May, this fish reappeared at Site 5, the submerged foundation of Byrd Springs. While

Figure A-5. Map showing observed locations of the fish tagged with Sonic Tag 166.

Table A-4. Thermal History of Sonic Tag 166
in Degrees Celsius with Location Data
from Figure A-5 (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
May 9	1	2130	16.5	15.0 17.0	14.9-17.3	0.8
May 10	2-3	1550	16.2	16.0	15.2-17.1	0.3
May 11	4	1700	16.7	16.7	16.4-16.9	0.1
May 18	5	1910	18.1	18.0	16.8-19.1	0.5
May 22	5	1140	19.9	19.9	18.7-22.8	0.5
May 25	5-2-6	1420	21.2	evenly distributed	16.9-24.0	1.4
May 31	7	2140	23.6	evenly distributed	20.1-26.7	1.5

being monitored it moved from the spring area out along the neck of land between Byrd Springs and Mossy Creek Coves, then back towards the spring again. Mean temperature was 18.1 C and surface temperature at the spring was 20.2 C. On 19 May, this fish had left the area and was not found between Mossy Creek and Black Oak Coves. On 22 May, it was back in the spring at Byrd Springs Cove (Site 5). Moving only in the area of the spring, it experienced a mean temperature of 19.9 C. Temperature at the spring ranged from 17.8 to 24 C. On 24 May, this fish was noted at Site 6 off the points of a submerged island at 0940 hr. By 25 May, this fish had moved back to Site 5 in Byrd Springs. At this time it experienced a mean temperature of 21.2 C while moving from Site 5 to Site 2 to Site 6 when monitored. Maximum surface temperature in the area was 25.5 C. On this day the fish had no distinct mode (Figure A-6) and during the half-hour observation remained in warming waters at a constant depth. On 31 May, this fish had swum to Site 7 where it was observed in a mean temperature of 23.6 C. The fish at the time appeared to be moving off an island point into the channel and back, but later examination of the area during low water levels revealed that this fish was moving along a submerged island. No further contact was made with this fish although searches were made periodically for it in the reservoir below Cedar Hill Cove.

Sonic Tag 169

On 11 May, 1978, this female striped bass weighing 3.6 kg was shocked, tagged, and released in Site 1 (Figure A-7) in Mossy Creek. This was the last fish that had a tag surgically placed in its body

Figure A-6. Mean(-), mode(---), standard deviation($\square$) of Sonic Tag 166. No mean(-) was drawn when mean and mode were equal. Plus one standard deviation on May 9 exceeded maximum temperature. Half-hour data sets.

ORNL-DWG 79-13722

Figure A-7. Map showing observed locations of the fish tagged with Sonic Tag 169.

cavity. This fish was weak, floating belly up after the tagging surgery, but seemed to recover when placed back into the creek channel. On 12 May, this fish was found at Site 2 in a submerged waterfall. From 0810 to 0825 hr this fish moved from Site 2 to Site 1. No temperature data was taken, but water temperatures in the area ranged from 13.9 to 14.2 C. By 15 May, this fish had moved to Site 3 where it remained at a constant temperature near 14.6 C (Table A-5). A check was made to determine if the fish was alive and movement around the point of land was seen. Water temperatures at the site were 14.2 to 14.7 C indicating that the fish was near the surface. The next day, 16 May, this fish was again found at Site 3 and experienced a mean temperature of 15.8 C. Water temperatures on this day ranged from 14.8 to 16.6 C at this site. This fish was noted at Site 3 on 17 May. A spot check on 18 May at Site 3 showed an average temperature of 17.3 C at 1445 hr. On 24 May, the dead body of this fish was found at Site 4. Decomposition had set in so cause of death could not be determined.

Radio Tag 151.063A

On 16 May 1978 this 5.4 kg striped bass was shocked, tagged by the back pack method, and released at Site 1 (Figure A-8) at 2030 hr. The radio receiver needed to be recharged and no signals were picked up. On 17 May this fish was noted at Site 1, but its signals were very sporadic and weak. No further contact was made with this fish until the dead carcass was found floating in Mossy Creek Cove at Site 2 on 23 May. There was no sign of infection around the puncture sites nor was there any indication of being hooked by a fisherman. The stress

Table A-5. Thermal History of Sonic Tag 169
in Degrees Celsius with Location Data
from Figure A-7 (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
May 15	3	1450	14.6	14.6	14.5-14.6	0.02
May 16	3	1550	15.8	15.8	15.5-15.9	0.08
May 18	3	1445	17.3 ^a			

^aSpot check--less than half an hour observation.

ORNL-DWG 79-13725

ELEVATION - 318 METERS

Figure A-8. Map showing observed locations of the fish tagged with Radio Tag 151.063A.

from the tagging only a week before may have been a factor in this fish's death.

Radio Tag 151.330A

This 2.25 kg fish was shocked, tagged, and released on 16 May, 1978, in Site 1 (Figure A-9). It was not located from 17 May to 22 May, but reappeared on 23 May at Site 1. It was still in the area on 24 May, but the radio receiver had used up its power charge by the time it was located and no temperature data was taken. It was not found on 25 May in Mossy Creek Cove, but was located at Site 1 on 30 May. At this time, temperature data was taken and the mean temperature of this fish was 17.9 C (Table A-6). Water temperatures near this site ranged from 16.0 to 24.6 C. The next evening on 31 May, this fish was monitored at a mean temperature of 19.7 C. On 1 June, this fish had moved to Site 2 by 1200 hr. At this time it experienced a mean temperature of 21.8 C. Water temperatures in the site ranged from 15.4 C on the bottom to 24.8 C at the surface. From this data, the fish was determined to be near 6 m deep. On 26 July, this fish was heard from the bank in Mossy Creek Cove. Later in the boat the signal was traced across the lake to Site 3 on the bank near the dam. Only the tag was found and the harness was intact indicating the fish may have decomposed entirely.

Radio Tag 151.421

On 16 May, 1978, a 2.25 kg striped bass was shocked, tagged, and released at Site 1 (Figure A-10). This fish disappeared from the Mossy Creek area by 17 May and was not located in the area again until 23 May.

ORNL - DWG 79-13719

Figure A-9. Map showing observed locations of the fish tagged with Radio Tag 151.330A.

Table A-6. Thermal History of Radio Tag 151.330A
 in Degrees Celsius with Location Data
 from Figure A-9 (Half-Hour
 Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
May 30	1	1410	17.9	17.3	16.4-21.1	1.3
May 31	1	2050	19.7	20.1	17.2-22.1	0.9
June 1	2	1140	21.8	22.0	19.9-22.3	0.4

ORNL-DWG 79-13723

Figure A-10. Map showing observed locations of the fish tagged with Radio Tag 151.421.

On this day, it was at Site 2 in the Byrd Springs Cove directly over the spring. By 24 May, it had moved out of Byrd Springs Cove. No searches in the lake below Cedar Hill Cove located this fish until 14 June when it appeared at Site 3. At this time, it experienced a mean temperature of 21.5 C (Table A-7). Water temperatures in Mossy Creek Cove ranged from 16.2 to 23.8 C. The next morning on 15 June, this fish was monitored at Site 3 again and was found in a mean temperature of 21.0 C. This fish moved out of the Mossy Creek Cove by 20 June, and no searches in the lake found it until 3 July. During this period other tracked fish were in deep waters of 8 m or more and this fish may have been in the area of searches, but too deep for the receiver to pick up signals from the tag. A spot check on this day showed the fish in average temperature of 18.7 C at Site 1. On 5 July, this fish was heard in the mouth of Mossy Creek Cove at Site 4. Temperature data showed a mean temperature of 19.9 C. Water temperatures at the mouth were 18.4 C at 3 m to 22.0 C at 2 m to 29.0 C at 1 m and the surface. The next day, 6 July, it was still at Site 4 and mean temperature was 20.5 C. On 7 July, still at Site 4, this fish experienced a mean temperature of 20.4 C. The next monitoring period was on 11 July at Site 4 and the fish's mean temperature was 19.1 C. Water temperatures ranged from 17.5 C in the creek itself to 29.5 C on the surface in the cove. This fish was still at Site 4 on 12 July when it experienced a mean temperature of 20.3 C. This fish was noted in Site 4 on 13 July and the automatic recorder was set from 13 July until 14 July. Later analysis of this recording showed gradual warming and cooling trends indicating the tag was not on a fish and was recording the

Table A-7. Thermal History of Radio Tag 151.421
in Degrees Celsius with Location Data
from Figure A-10 (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
June 14	3	1800	21.5	21.5	18.6-23.9	0.5
June 15	3	0730	21.0	21.1	20.0-21.8	0.3
July 3	1	1620	18.7 ^a			
July 5	4	1510	19.9	19.5	19.2-23.4	0.8
July 6	4	1140	20.5	19.5	17.4-24.3	1.3
July 7	4	1510	20.4	20.4	19.0-22.3	0.7
July 11	4	1650	19.1	19.0	17.9-20.2	0.4
July 12	4	1610	20.3	evenly distributed	17.2-24.2	2.0

^aSpot check--less than half an hour observation.

diurnal changes in the water itself. This tag was located on 28 July, pinpointed near Site 4. Water on this date was too deep (2.5 m) to recover the tag. On 21 August when the water level had dropped to 0.5 m, the tag was recovered and the harness wire looked as if it had been cut, possibly by a fisherman who had thrown the tag back into the creek.

Radio Tag 150.913A

This 4.05 kg striped bass was shocked, tagged, and released in Cedar Hill Cove (Site 1, Figure A-11) on 18 May 1978. It remained in the cove for approximately 30 minutes, then began swimming out of the cove. On 19 May, no signals of the fish were heard, and on 22 May a search of the lake from Mossy Creek to Point 5 did not find this fish. Not until 31 May did this fish reappear in Site 2 and experienced a mean temperature of 19.5 C (Table A-8). Water temperatures in Mossy Creek ranged from 16.2 to 25.8 C. On 1 June, the fish was still in Mossy Creek, but had moved to Site 3. It experienced a mean temperature of 18.4 C near a submerged waterfall. In the area temperatures were available from 16.2 to 24.4 C. On 2 June, it had moved up to the head of Mossy Creek Cove at Site 2. This fish moved out of the Mossy Creek area by 12 June. Searches extended up past Point 8, but no signals were heard from this fish. During this period other tracked fish that were found were in deep (>8 m) water which attenuated the signals. Fish had to be very close to the receiver to be heard at that depth. On 20 June, signals were heard in Mossy Creek Cove, but the fish had died and its body had washed up on shore at Site 4. The body had decomposed to the point that cause of death could not be determined.

Figure A-11. Map showing observed locations of the fish tagged with Radio Tag 150.913A.

Table A-8. Thermal History of Radio Tag 150.913A
in Degrees Celsius with Location Data
from Figure A-11 (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
May 31	2	1950	19.5	19.0	18.4-20.9	0.6
June 1	3	1010	18.4	18.0	17.2-19.5	0.5

Radio Tag 150.947

On 23 May, 1978, this 2.25 kg striped bass was shocked, tagged, and released in Mossy Creek Cove at Site 1 (Figure A-12). Monitored several hours after release, this fish was found at a mean temperature of 22.9 C (Table A-9). Early the next morning this fish was found in Site 2, a submerged waterfall. Mean temperature at this time was 22.4 C. Water temperatures in the cove ranged from 16.2 to 27.0 C. On 25 May, it was noted in Site 2, though no temperature data was taken. By 30 May, it had moved upstream to Site 1, another submerged waterfall. Mean temperature was 21.9 C on this day and water temperature at the waterfall ranged from 18.6 to 25.0 C. On 31 May, at the same site this fish was found in a mean temperature of 21.5 C. By 1 June, it had moved upstream to Site 3, a deep submerged waterfall. In this site, it experienced a mean temperature of 23.7 C and no movement of the fish within the site was observed. This fish moved out of Mossy Creek by 2 June and further searches of the lake did not locate this fish until 29 June when it was heard in Mossy Creek Cove. Signals from this fish were heard on 5, 6, and 10 July, in Mossy Creek Cove, but by the 10th the signals were fast and indicated temperatures of 26 to 28 C. Most likely all the signals beginning on 29 June were overlap signals from 150.884 and 150.913B which were tagged on 27 June.

Radio Tag 151.137

On 23 May, 1978, this 2.25 kg striped bass was shocked, tagged, and released in Mossy Creek Cove at Site 1 (Figure A-13). Early the next morning this fish was monitored for half an hour and was found in

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Figure A-12. Map showing observed locations of the fish tagged with Radio Tag 150.947.

Table A-9. Thermal History of Radio Tag 150.947
in Degrees Celsius with Location Data
from Figure A-12 (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
May 23	1	0010	22.9	23.4	20.5-25.1	0.8
May 24	2	0920	22.4	22.4	18.1-26.6	0.9
May 30	1	1445	21.9	22.4	19.3-24.9	1.4
May 31	1	2030	21.5	21.5	21.2-22.4	0.2
June 1	3	0940	23.7	23.8	22.9-24.6	0.3

Figure A-13. Map showing observed locations of the fish tagged with Radio Tag 151.137.

water averaging 23.6 C (Table A-10). Water temperatures in the submerged creek channel ranged from 16.2 to 25.5 C. This temperature profile indicated that this fish was near the surface while being tracked. On 25 May, this fish was again found at Site 1 and experienced a mean temperature of 23.9 C. This fish was not found on 30 May, 1 or 2 June but was detected on 5 June swimming from Site 2 to Site 3. At this time the pulsed signals from the tag were greater than 1 second apart. These were temperatures less than 5 C which were not available so the tag was assumed to be malfunctioning. By 6 June, it had moved out of Black Oak Cove. On 9 July, it was found dead floating in Mossy Creek Cove at Site 4. No indication of the cause of death was present and it could not be determined whether the fish died in Mossy Creek or if it floated into the cove from the lake.

Radio Tag 151.046

On 23 May, 1978, a 2.25 kg striped bass from Mossy Creek Cove was tagged with a radio tag and released into Site 1 (Figure A-14) at 2230 hr. A monitoring period at 2340 hr on this fish showed it to be in water temperatures from 19.5 to 23.5 C with an average of 22.2 C (Table A-11). The next day, 24 May, this fish was still in the area of Site 1, but was in slightly cooler water averaging 21.5 C. Water temperatures in Mossy Creek Cove ranged from 16.2 to 27.0 C. On 25 May, this fish was noted in the area of Site 1 at a submerged waterfall. By 30 May, it had moved up the lake to Black Oak Cove into Site 2. At this time the tag signals were very slow (<1 sec apart) and were not temperature sensitive. This fish was still in Site 2 on 31 May and on

Table A-10. Thermal History of Radio Tag 151.137
in Degrees Celsius with Location Data
from Figure A-13 (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
May 24	1	0750	23.6	23.6	23.4-24.3	0.1
May 25	1	1540	23.9	24.0	23.5-24.5	0.2

Figure A-14. Map showing observed locations of the fish tagged with Radio Tag 151.046.

Table A-11. Thermal History of Radio Tag 151.046
in Degrees Celsius with Location Data
from Figure A-14 (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
May 23	1	2340	22.2	22.3	19.5-23.5	0.4
May 24	1	0845	21.5	21.6	17.8-22.9	0.4

1 June. The signals were slower and loosing strength as the days passed. Still present in Black Oak Cove on 5 June, it was closer to the lake in Site 3. On 6 June no signals were heard in Black Oak Cove from this tag and later searches did not find this fish again.

Radio Tag 151.240A

On 23 May, 1978, a 2.25 kg striped bass was shocked, tagged, and released in Mossy Creek Cove at Site 1 (Figure A-15). Early the next morning this fish was monitored for half an hour and was observed in a mean temperature of 20.5 C (Table A-12). Water temperatures at the submerged waterfall in Site 1 ranged from 16.2 to 27.0 C. This fish was still at Site 1 on 25 May but was not located in the area on 30 May. On 31 May it was found moving between Site 2 and Site 3. At 1200 hr it experienced a mean temperature of 21.3 C. By 1540 hr it had moved to Site 4 towards Black Oak Cove. A spot check on 1 June found this fish near Site 3 at a mean temperature of 21.8 C before the fish moved to Site 4 where the signal was too weak to receive. Water temperatures in the area near the dam ranged from 10.7 C at 30 m to 27.6 C at the surface. From this temperature profile the fish was determined to be approximately 6 to 7 m deep. On 2 June this fish was found swimming between Site 5 and Site 6 and then disappeared in the direction of Point 2. No searches on 6, 12, 13 or 15 of June found this fish between Point 3 and Mossy Creek Cove. On 20 June, this fish was heard faintly at Site 4. The signals were too weak for temperature determination, but the fish was estimated to be 10 m deep. Fishermen were catching striped bass at this time elsewhere in the lower reservoir at

Figure A-15. Map showing observed locations of the fish tagged with Radio Tag 151.240A.

Table A-12. Thermal History of Radio Tag 151.240A
in Degrees Celsius with Location Data
from Figure A-15 (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
May 24	1	0815	20.5	21.3	17.2-24.3	0.9
May 31	2-3	1200	21.3	21.0	19.4-25.0	0.9
June 1	3	1250	21.8 ^a			
July 3	1	1550	21.1	21.1	20.9-21.5	0.06

^aSpot check--less than half an hour observation.

depths of 9 to 11 m. On 3 July this fish reappeared in Mossy Creek near Site 1 at another submerged waterfall. On this date it experienced a mean temperature of 21.1 C. Water temperatures in this site ranged from 19.6 to 29.4 C. Not located on 5 or 6 July in Mossy Creek Cove, this fish was found on 6 July at Site 7 in Byrd Springs at 1130 hr. The same evening a fisherman caught this fish from Byrd Springs. The fish was apparently in pretty good shape and no trauma or infection was seen at the site of tagging.

Radio Tag 151.084

At 2100 hr on 13 June 1978 in Mossy Creek, a 4.5 kg striped bass was shocked, tagged, and released in the area of Site 1 (Figure A-16a), a deep submerged waterfall. Above Site 1 the creek was less than 1 m deep, preventing fish movement further upstream. During the observation period this fish moved from Site 1 to Site 2 and back several times. It experienced an average temperature of 18.9 C (Table A-13) at depths of 1 m near Site 1 to 3 m near Site 2. This fish apparently left Mossy Creek because it was not located for 2 weeks. On 27 June it was again located in Mossy Creek at Site 2. A spot check on 28 June at Site 2 showed the fish in water of 19.0 C. At Site 2 in 4.5 m of water it was in average temperature of 20.2 C. At this time Site 2 was approximately 5.5 m deep and water temperatures ranged from 19.6 to 28.6 C. By the next day, 30 June, this fish moved downstream into Site 3, the base of a series of submerged small waterfalls. At depths of 8 to 9 m, this fish was too deep to receive the temperature signals although the signals were audible to the ear. This fish moved into deeper water or

Figure A-16. Maps showing observed locations of the fish tagged with Radio Tag 151.084. Elevation: (a) 318 m, (b) 313 m, (c) 312 m, (d) 310 m.

Table A-13. Thermal History of Radio Tag 151.084
in Degrees Celsius with Location Data
from Figures A-16a-e

Date	Site	Time	Mean	Mode	Range	S.D.
June 13	1-2	2130	18.9	evenly distributed	15.6-23.4	2.5
June 28	2	1450	19.0 ^a			
June 29	2	1420	20.2	20.5	19.3-22.8	0.6
July 3	4	1450	19.1	19.2	18.4-19.9	0.3
July 6	4	1350	21.3	21.3	20.6-22.3	0.3
July 7	2	1610	20.8	20.8	17.9-24.1	0.8
July 11	4	1430	20.9	20.7	18.0-24.0	0.5
July 12	4	1000	19.1	19.1	18.5-19.8	0.2
July 14	2	1600	20.8	20.8	20.7-21.6	0.1
July 17	2	1410	21.5	21.5	20.9-23.2	0.4
July 20	2	1630	22.1	22.1	21.3-22.9	0.1
July 21	2	1430	20.2	19.9	19.6-22.6	0.4
July 24	2	1400	20.2	20.0	19.9-20.9	0.2
July 26	4	1520	19.8	19.6	17.5-23.7	0.9
July 27	2	1100	17.9	18.0	17.5-19.9	0.3
	4	1530	19.9	19.9	19.7-20.5	0.1
July 28	4	1150	16.9	16.9	16.5-17.6	0.3
Aug. 1	4	1820	18.2	18.2	17.8-18.4	0.1
		1900	18.2	18.1	17.7-18.6	0.2
		2240	18.2	18.0	17.2-21.9	0.7
		2330	18.7	17.1	15.7-25.7	2.4
Aug. 2	4	0130	18.4	18.1	15.6-21.6	1.2
		0740	16.7	16.5	14.9-19.1	0.5
		0950	17.3	16.7	14.9-21.6	1.2
		1230	18.1	18.0	17.4-20.6	0.4
Aug. 7	4	1250	17.1	17.1	16.5-18.3	0.2

^aSpot check--less than half an hour observation.

out of Mossy Creek altogether on 2 July because no signal was located. On 3 July it had moved upstream to Site 4. Although the signal was sporadic, suggesting the fish might be swimming among the concrete ruins of a farm silo, the mean temperature experienced was 19.1 C. Still at Site 4 on 5 and 6 July, monitoring on 6 July showed the fish in an average temperature of 21.3 C. Water temperatures in Site 4 ranged from 18.3 to 29.6 C. Moving upstream to the submerged waterfall at Site 2 on 7 July, it experienced temperatures of 17.9 to 24.1 C. Temperatures in Site 2 ranged from 16.5 to 29.4 C in 5 m of water. By 11 July this fish had moved back into Site 4 and was observed at an average temperature of 20.9 C, at the bottom of the submerged channel. Still at Site 4 on 12 July, this fish experienced a narrow range of temperatures from 18.5 to 19.8 C. By 13 July, it had moved upstream to Site 1 in water less than 2.5 m deep. On 14 July it moved downstream to Site 2 and experienced an average temperature of 20.8 C at a depth of approximately 4 m. Water temperatures at Site 2 ranged from 16.5 to 27.4 C. After the weekend this fish was still at Site 2 on 17 July. A higher mean temperature of 21.5 C was observed and the calculated depth of the fish was 3.5 m. A higher mean of 22.1 C was experienced on 20 July at the same site at a depth of 3 m. The next day, 21 July, this fish at Site 2 experienced an average temperature of 20.2 C at an estimated depth of 4 m. Temperatures of water at this site ranged from 18.5 C at the bottom to 29.2 C at the surface. Another weekend passed and on Monday, 24 July, this fish was located again at Site 2 and experienced the same average temperature as on 21 July, 20.2 C. By 26 July this fish had moved to Site 4 in 5 m of water. Temperatures

experienced were 17.5 to 23.7 C while water temperatures ranged from 17.5 to 29.3 C. This fish was located on 27 July upstream at Site 2 and observed at a mean temperature of 17.9 C. Site 2 at this time was less than 2 m deep and had a range of temperatures from 15.6 to 30.0 C. This same day at 1530 hr it was located downstream in Site 4 and observed in an average temperature of 19.9 C at a calculated depth of 4 m. On 28 July, this fish was located slightly above Site 4 in a cool average temperature of 16.9 C. Depth of the fish was calculated to be on the bottom at 3 m. On 1 and 2 August, eight sets of observations were made on this fish. The half an hour average temperatures ranged from 18.7 C at 2330 hr 1 August to 16.7 C at 0740 hr on 2 August to 18.1 C at 1230 hr (Figure A-17). The fish remained at Site 4 during all of the observations and at a depth of approximately 4 m. The curve in temperatures selected was caused by the cooler waters inflowing during the night. Water temperatures during this time ranged from 26.4 to 29.9 C maximum and from 14.2 to 16.1 C minimum. The next observation on this fish was on 7 August at Site 4 (Figure A-16b). This fish experienced an average temperature of 17.1 C at the bottom of 3.5 m of water. On 8 August the tag emitted very fast, non-temperature sensitive signals and no more temperature data was obtained from this fish. Location data from this fish was continued. On 8 August it was at Site 4, and was still there on 11 and 15 August. By 21 and 22 August, it had moved upstream to Site 2, but on 24 August it was again at Site 4. Water levels were dropping several inches a day, but this fish remained at Site 4 (Figure A-16c) on 30 August. At this time Site 4 was less than 1.5 m deep. On 5 September it had moved downstream to Site 5

Figure A-17. Mean(-), mode(---), standard deviation($\square$) of Radio Tag 151.084 during tracking life. No mean(-) was drawn when mean and mode were equal. Half-hour data sets.

(Figure A-16d) into 3 m of water. Located at Site 3 on 6 September, the tag signal was weak even though the water was shallow and the battery was thought to be expiring. No signals were received from this tag from 6 September to 12 October, and it was assumed that the battery had failed.

Radio Tag 151.392

On 13 June a 3.6 kg striped bass with a malformed jaw was shocked, tagged, and released at Site 1 (Figure A-18) in Mossy Creek Cove. Immediately after release this fish was monitored in the submerged waterfall at Site 1 and it experienced a cold mean temperature of 15.8 C (Table A-14). Water in Mossy Creek was near 16 C. By 14 June it had presumably recovered from the shock of handling and tagging, and was moving between Site 2 and Site 3 at mean temperature of 23.3 C. Water temperatures at Site 3 ranged from 19.7 to 25.8 C, and the fish was at a calculated depth of 4.5 m in water over 5.5 m deep. Later the same day this fish was in a mean temperature of 23.7 C. At 2030 and 2100 hr the same day this fish experienced mean temperatures of 23.5 and 23.3 C respectively while the modes were 24.6 and 24.2, slightly warmer than the means. The next morning, 15 June, this fish had moved upstream to Site 2, a shallow waterfall, and the mean temperature was 23.4 C. Searches in the following days did not locate this fish in the lower end of the reservoir until 5 July in Mossy Creek Cove. Located at Site 1, this fish experienced a mean temperature of 21.6 C. Temperatures at the mouth of Mossy Creek ranged from 18.4 to 29.0 C. Still at Site 1 the following two days, the mean temperatures surrounding the

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Figure A-18. Map showing observed locations of the fish tagged with Radio Tag 151.392.

Table A-14. Thermal History of Radio Tag 151.392
in Degrees Celsius with Location Data
from Figure A-18 (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
June 13	1-2	1010	15.8	15.8	15.6-16.2	0.1
June 14	2-3	1540	23.3	23.6	20.9-24.5	0.7
	3	1710	23.7	23.9	21.0-25.4	0.8
	3	1740	23.6	23.7	20.9-24.7	0.6
	3	2030	23.5	24.6	19.5-26.7	1.3
	3	2100	23.3	24.2	18.5-24.7	0.9
June 15	2	0800	23.4	23.2	19.9-25.2	0.8
July 5	1	1430	21.6	21.6	19.7-24.3	0.8
July 6	1	1110	21.0	evenly distributed	16.5-25.7	2.7
July 7	1	1440	21.6	evenly distributed	19.2-26.2	1.4
July 10	1	1430	22.8	evenly distributed	19.9-28.4	1.7
July 11	1	1750	20.9	20.7	19.5-22.3	0.5

fish were 21.0 and 21.6 C. On 10 July, this fish in Site 1 was found in a wide range of temperatures from 19.9 to 28.4 C with a mean of 22.8 C. Site 1 was approximately 1 m deep at this time, but had a range of temperatures from 16.4 to 29.2 C. With such a wide range in shallow depths there would be drastic temperature changes with even small vertical movements. On 11 July in Site 1 this fish experienced a mean temperature of 20.9 C. This fish was heard in Site 1 on 12 and 13 July. The automatic recorder was set upon 13 July and ran through 14 July. Later examination of the data recorded showed the tag was on land or in very shallow water. The tag was not recovered immediately because of a malfunction in the directional antennae. The tag was located on the bank at Site 4 on 20 July. The wire from the tag had obviously been cut, probably by a fisherman who caught 151.392 and threw the tag into the water sometime after 11 July.

Sonic Tag 165A

On 27 June a 3.6 to 4.5 kg striped bass was shocked, tagged, and released in Mossy Creek Cove at Site 1 (Figure A-19), a submerged waterfall at the mouth of Mossy Creek. By 28 June it had moved out of Mossy Creek Cove and a search up to Point 4 did not locate it. On 5 July it was located at Site 1 again. A monitoring period was made and found the fish in a mean temperature of 19.8 C (Table A-15). Water temperatures in the waterfall ranged from 18.4 C at 3 m to 29.0 C at the surface. The next day it was still at Site 1 and experienced temperatures from 17.5 to 19.5 C. Water temperature had dropped to 16.5 C on the bottom 6 July. On 10 July, still in the same site, this fish

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Figure A-19. Map showing observed locations of the fish tagged with Sonic Tag 165A.

Table A-15. Thermal History of Sonic Tag 165A
in Degrees Celsius with Location Data
from Figure A-19 (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
July 5	1	1530	19.8	19.6	18.5-21.0	0.4
July 6	1	0940	18.0	17.7	17.5-19.5	0.5
July 10	1	1430	19.3	19.4	17.9-19.7	0.5

was observed in water averaging 19.3 C. Water level at Site 1 had dropped until it was only 1 m deep, but it ranged in temperature from 16.4 to 29.2 C. The next day a fisherman caught this fish from Site 1. Fish was said to be in good shape and fought hard when hooked.

Radio Tag 151.063B

In the afternoon of 27 June, a 3.6 to 4.5 kg striped bass was shocked in Mossy Creek Cove, tagged and released into Site 1 (Figure A-20). It began moving back and forth between Site 1 and Site 2 while being monitored. During this time it experienced temperatures from 19.3 to 25.6 C with a mean of 21.7 C. By the end of the half-hour observation this fish was in water near 24 C. On 28 June this fish was found in deep waters at Site 3. At this time its temperature data indicated very warm (>22 C) temperatures near the fish. On 30 June this fish was still at Site 3 and its signals were too weak for the interval counter to register. No further signals were heard in the following days, but on 5 July the decaying body was found in Mossy Creek Cove at Site 4, floating by the bank. The fish had been dead several days, and it is possible that it died by 28 June and the body sank to the bottom, decomposed for a week, and then floated to the surface.

Radio Tag 150.884

On 27 June 1978 this 4.5 kg striped bass was shocked in Mossy Creek near Site 1 (Figure A-21a), a submerged waterfall. Tagged and released at 2045 hr into Site 1, it moved downstream and was found in Site 3, another submerged waterfall, at 2230 hr. On 28 June this fish was not

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Figure A-20. Map showing observed locations of the fish tagged with Radio Tag 151.063B.

Figure A-21. Maps showing observed locations of the fish tagged with Radio Tag 150.884. Elevation: (a) 318 m, (b) 313 m, (c) 312 m, (d) 310 m, (e) 309 m.

found in Mossy Creek Cove, but reappeared on 29 June at Site 2, a small submerged waterfall. At 1620 hr, it was monitored for half an hour and mean temperature occupied was 22.9 C (Table A-16). Site 2 at this time was 5.5 m deep and water temperature ranged from 19.6 to 28.6 C. From this information the fish's depth was calculated to be approximately 4 m. The next day, 30 June, the fish apparently moved out of Mossy Creek Cove or into deeper water because no signals were received. Several other tagged fish were found in very deep water at this time and their tag signals were very weak, so this fish may have been at the mouth of Mossy Creek in 10 m or more of water where its signal could not be heard. This fish was located on 2 July, slightly above Site 2 in the submerged creek channel. On 3 July it had moved downstream into Site 3. While under observation this fish moved back and forth between Site 3 and Site 4 several times. Mean temperature experienced was 21.3 C and at estimated depths of 5.5 m at Site 3 to 7 m at Site 4. Temperatures ranged from 18.3 C at the bottom to 29.6 C at the surface at both sites. Located at Site 3 on 5 and 6 July, it was monitored on the later date and average temperature calculated was 23.9 C. On 7 July it was found at Site 2 in 5 m of water and a spot check showed the fish at temperatures near 23.1 C. This temperature was available at 4 m with a minimum temperature of 20.2 C available at 5 m. Still at Site 2 on 10 July, it experienced a mean temperature of 22.2 C in 3.5 m of water. By 11 July, this fish had moved downstream to Site 3 where its mean temperature was 23.6 C. Cooler temperatures with a mean of 22.1 C were experienced the next day in Site 3. It was found again at Site 3 on 14 July, but on 17 July it had moved to Site 2.

Table A-16. Thermal History of Radio Tag 150.884
in Degrees Celsius with Location Data
from Figures A-21a-e

Date	Site	Time	Mean	Mode	Range	S.D.
June 29	2	1620	22.9	22.9	22.2-23.5	0.1
July 3	3-4	1150	21.3	21.1	18.3-22.1	0.5
July 6	3	1550	23.9	23.8	22.8-26.6	0.5
July 7	2	1600	23.1 ^a			
July 10	2	1540	22.2	21.5	20.9-25.2	0.9
July 11	3	1850	23.6	23.6	22.4-24.4	0.3
July 12	3	0930	22.1	22.1	21.6-22.9	0.2
July 28	4	1400	21.9	21.5	20.9-22.8	0.3
Aug. 2	3	0000	19.6	19.6	18.7-22.4	0.4
	3	0240	18.2	18.1	17.5-20.2	0.3
Aug. 7	3	1345	21.4 ^a			
Aug. 15	5	1440	19.7	19.6	18.8-21.2	0.5
Aug. 16	5	1430	22.0 ^a			
Aug. 24	5	1520	20.2	19.7	19.2-21.9	0.5
Aug. 30	5	1420	21.5	21.1	19.8-23.2	0.7
Sept. 13	3	1700- 2400 ^b	21.3	21.1	18.7-27.3	1.0
Sept. 14	3-4	0000- 1100 ^b	19.0	19.2	16.8-25.8	0.8
Sept. 26	4	1440	21.6	21.6	21.5-21.8	0.05
Sept. 27	7	1500- 1900 ^b	21.3	21.7	19.8-21.9	0.5
Sept. 29	4	1400	20.0 ^a			
Oct. 5	8	1300	17.8	17.9	17.5-18.2	0.1
Oct. 12	7	1120	16.2	16.2	15.9-16.4	0.1

^aSpot checks--less than half an hour observation.

^bAutomatically recorded data.

Back to Site 3 by 20 July, this fish then moved into deeper waters or out of the area by 24 July and was relocated on 26 July in Site 3. On 27 July the radio signals were weak and the fish was located midway between Site 3 and Site 4. By 28 July it was in Site 4, the base of a series of small waterfalls and rapids submerged under lake water. It was observed in a mean temperature of 21.9 C at a depth of 4.5 m. Water temperatures ranged from 20.0 C at the bottom to 29.4 C at the surface in Site 4. Minimum temperature in the cove outside the submerged creek was 25.2 C. Two sets of observations were made on 2 August at Site 3 in the early morning. At midnight, mean temperature was 19.6 C and at 0230 hr, the mean temperature was 18.2 C.

Water levels were dropping during the late summer, up to 6 inches a day at times. On 7 August this fish was at Site 3 (Figure A-21b) where water depth was only 3 m. A spot check at this time showed a mean temperature of 21.4 C experienced by the fish. Water temperatures varied from 18.0 to 28.6 C at the Site. This fish was not located on 8 or 11 August in Mossy Creek Cove, but reappeared on 15 August at Site 5, on top of the series of submerged waterfalls. Mean temperature that day for this fish was 19.7 C which occurred at approximately 3.5 m. The next day, 16 August, in Site 5 a spot check showed this fish in temperatures near 22.0 C. From 16 to 17 August the automatic recorder was set on this fish but data were too scattered to be reliable. No signals were heard on 21 or 23 August from this fish. On 24 August it was found at Site 5. An observation period at this time indicated the fish occupied a mean temperature of 20.2 C although the mode was 19.7 C. Site 5 was 4 m deep and water temperatures ranged from 19.0 to 27.4 C.

while the minimum temperature beyond the creek channel in the cove was 25.4 C. By 30 August Site 5 (Figure A-21c) was less than 3.5 m deep. Average temperature around the fish was 21.5 C. Water temperatures ranged from 16.8 to 26.8 C. This fish was not located on 6 September but on 12 September it was found at Site 6 (Figure A-21d) in water 3.5 m deep. The next day, 13 September, the automatic recorder was set on this fish and it ran through 14 September (Figure A-22). By 1200 hr on 14 September this fish had moved upstream to Site 4. Mean temperatures experienced were 21.3 C on 13 September and 19.0 C on 14 September. Located at Site 6 on 19 September, it was monitored at Site 4 on 26 September. The fish experienced a mean temperature of 21.6 C at a site where temperatures of 18.1 to 25.5 C were available. In the reservoir the fall overturn was occurring and temperatures were isothermal near 25.5 C. On 27 September the fish was found at Site 7 at the mouth of Mossy Creek Cove and the automatic recorder was set up on this fish. Only data from 1500 to 1900 hr on 27 September was accurate because by 28 September the battery failed, and the recorder malfunctioned. From 1500 to 1900 hr the fish experienced a mean temperature of 21.3 C (Figure A-23). By 29 September a spot check showed this fish in Site 4 and at temperatures near 20.0 C. Water levels continued to drop, but on 3 October this fish was still in Site 4 (Figure A-21e) in 1 m of water. It moved around a bend from Site 4 into Site 8 on 5 October. A cool mean temperature of 17.8 C was experienced. Water temperatures at Site 8 ranged from 16.5 to 23.3 C while the reservoir was isothermal near 24.2 C. By 12 October it had moved to Site 7 at the mouth of Mossy Creek into 5 m of water. Mean temperature at this

PLOT OF TEMP*TIME_H LEGEND: A = 1 OBS, B = 2 OBS, ETC.

PLOT OF TEMP*TIME_H LEGEND: A = 1 OBS, B = 2 OBS, ETC.

time was 16.2 C. This was the coolest water this fish was found in throughout its monitored history (Figure A-24). Reservoir temperatures had cooled to near 22 C. On 17 October the tag was discovered loose at Site 9. The condition of the tag did not indicate whether a fisherman had caught the fish or if the tag was torn off the fish by rocks. Fishing pressure was still high during this period and especially in the area from Site 8 to Site 7 so it was highly possible that the fish was caught and the tag thrown into the water.

Radio Tag 150.913B

On 27 June 1978 this 4.5 kg fish was shocked and captured in Site 1 (Figure A-25a) at the head of Mossy Creek Cove. Tagged and released at 2045 hr it remained at Site 1. This fish was not found on 28, 29, or 30 June in Mossy Creek Cove. On 2 July this fish was observed in Mossy Creek at Site 2. On 3 July this fish was monitored at Site 3 and experienced a mean temperature of 20.8 C (Table A-17). This fish was found again at Site 3 at 1615 hr on 5 July. Still at Site 3 on 6 July, it was monitored for half an hour and found to be in water near 23.6 C. This fish was at a depth of 4.5 m in water that ranged from 21.5 to 29.4 C. By 10 July it had moved upstream to Site 2 and at 1510 hr was found in water at a mean temperature of 22.6 C. A spot check at 1640 hr, however, showed a mean of 23.3 C. At Site 2 the fish was at a depth of 3.5 m. Temperatures were 20.2 C at 4 m and 26.8 C at 3 m with a surface temperature of 29.4 C. By the next day, 11 July, it had moved downstream to the submerged waterfall at Site 3. It was monitored at 1500 and 1920 hr and had mean temperatures of 23.0 and 23.6 C.

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Figure A-24. Mean(-), mode(---), standard deviation($\square$) of Radio Tag 150.884 during its tracking life. No mean(-) was drawn when mean and mode were equal. Half-hour data sets except where noted.

Figure A-25. Maps showing observed locations of the fish tagged with Radio Tag 150.9138. Elevation: (a) 318 m, (b) 313 m, (c) 312 m, (d) 310 m, (e) 309 m.

Table A-17. Thermal History of Radio Tag 150.913B
with Location Data from Figures A-25a-e
(Half-Hour Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
July 3	3	1130	20.8	20.8	20.4-21.3	0.1
July 6	3	1450	23.6	23.6	22.6-24.5	0.4
July 10	2	1510	22.6	22.6	21.9-23.1	0.2
July 10	2	1640	23.3 ^a			
July 11	3	1500	23.0	23.1	20.7-26.7	0.7
		1920	23.6	23.6	22.9-25.2	0.4
July 12	3	1050	22.6 ^a			
July 24	3	1550	23.6	23.4	20.1-26.6	0.7
July 27	4	1510	23.1	23.1	23.0-23.9	0.1
July 28	4	1430	21.8	21.7	21.1-22.9	0.2
Aug. 1	3	1950	21.5 ^a			
Aug. 2	3	0320	19.3	19.3	18.6-25.7	0.5
	3	0530	19.0	19.0	18.2-19.7	0.2
	3	1420	21.3	21.3	20.6-22.2	0.2
Aug. 11	3	1240	20.2 ^a			
Aug. 16	4	1430	23.2 ^a			
Aug. 21	5	1430	23.3 ^a			
Aug. 24	3	1430	21.9	21.9	21.1-23.3	0.3
Aug. 30	3	1340	22.6	21.0	20.8-24.9	1.0
				23.5		
Sept. 19	4	1300- 2000 ^b	23.2	23.2	19.0-28.7	0.8
Sept. 20	4	0800- 2100 ^b	22.9	23.4	17.7-28.9	1.3
Sept. 21	4	0900- 1700 ^b	22.5	22.9	17.1-28.6	1.2
Sept. 26	4	1510	21.5	21.6	20.3-23.8	0.5
Oct. 5	7	1345	18.6	18.6	16.8-19.2	0.2
Oct. 12	7	1230	18.0	18.1	17.5-18.7	0.2

^aSpot check--less than half an hour observation.

^bAutomatically recorded data.

respectively. On 12 July a spot check at Site 3 showed an average temperature of 22.6 C. On 14, 17, and 20 July this fish was located at Site 3. No temperature data was collected during this period. On 24 July it was monitored at Site 3, and it experienced a mean temperature of 23.6 C. This temperature was available near 3 m with temperatures ranging from 19.0 C at the bottom to 29.2 C at the surface. On 26 July this fish was located near Site 4 in deeper water where its signal was attenuated. Still at Site 4 on 27 July, an observation period showed this fish at a mean temperature of 23.1 C. At this time the fish was at a depth of approximately 5 m. Surface water temperatures were 29.4 C. On 28 July in the area of Site 4 the mean temperature experienced was 21.8 C, cooler than the previous day. By 1 August it had moved upstream to Site 3. A spot check at 1950 hr showed the fish at temperatures near 21.5 C. On 2 August three different observations were made on this fish. Mean temperatures were 19.3, 19.0, and 21.3 C, all in Site 3. Much vertical movement was noted during the first period (Figure A-26) when cooler temperatures were available. On 7 August this fish was located at Site 3 (Figure A-25b) from a vehicle on the west bank. The fish was still there when checked at 1350 hr on 8 August. On 11 August in Site 3 a spot check was made and showed temperatures near 20.2 C. Temperature of the water at this time ranged from 19.6 to 27.4 C. Another spot check was made on 16 August and warmer temperatures near 23.2 C were recorded. At Site 5 on 21 August, another spot check showed this fish at an average temperature of 23.3 C. Temperatures still ranged from 19.6 to 27.4 C but in less than 3 m of water. At 3 m water temperature was 19.6 C, but at 2 m it was 26.8 C.

Figure A-26. Mean(-), mode(---), standard deviation($\square$) of Radio Tag 150.913B during its tracking life. No mean(-) was drawn when mean and mode were equal. Half-hour data sets except where noted.

On 22 August signals from this fish were heard in the area between Site 3 and Site 4. On 24 August it had moved to Site 6 and while being monitored it moved between Site 3 and Site 5. A mean temperature of 21.9 C was experienced in water ranging from 18.5 to 28.2 C. On 30 August this fish was found in the area near Site 3 (Figure A-25c) and experienced a mean temperature of 22.6 C. Water level at Site 3 had dropped to 1.5 m deep by this time. Water temperatures outside of the submerged creek channel ranged from 25.4 to 26.9 C. On 5 September this fish was heard in the vicinity of Site 7 (Figure A-25d). By 6 September it had moved back into Site 3. At this time the automatic recorder was turned on but data recorded had too much scatter for accurate temperature data. This fish was still in Mossy Creek on the 7 and 8 September. On 12 September it was located at Site 8, but by 13 September it had moved upstream to Site 4. On 14 September it was still somewhere in the area near Site 4. On 19 September this fish was found in Site 4 and the automatic recorder was turned on. The recorder was left on until 21 September at 1700 hr. Total data is graphed on Figure A-27. Mean temperatures were 23.2, 22.9 and 22.5 C for each day. A pattern of warmer water encountered as the day progressed is seen, apparently showing the warming trend of the influent creek water. During this period water temperatures from a minimum of 16.0 to 19.0 C and a maximum of 26.5 to 29.0 C were available. On 26 September this fish was located still at Site 4. Mean temperature measured was 21.5 C. Temperatures at Site 4 ranged from 18.1 to 25.5 C in 1.5 m of water. In the reservoir the fall overturn had occurred and temperatures were near 25.0 ± 0.5 C. On 27 September this fish was located in Site 4.

PLOT OF TEMP*TIME_H LEGEND: A = 1 OBS, B = 2 OBS, ETC.

On 28 September the fish was in Site 4 and the recorder was set up, but no data was obtained because of a malfunction in the recorder. On 3 October this fish was at Site 4 (Figure A-25e) at the base of the now exposed falls. By 5 October it had moved slightly to Site 8. At this time it experienced a mean temperature of 18.6 C. In the reservoir water temperatures were near 24.2 C while in submerged Mossy Creek the temperatures ranged from 16.5 to 23.3 C. On 12 September this fish was in the area of Site 4, moving back and forth along the bend. A mean temperature of 18.0 C was experienced. Reservoir temperatures had cooled to 22.0 ± 0.5 C. By 19 October this fish had moved out of the Mossy Creek area into the reservoir. On the 19 October reservoir temperatures were approximately 20.0 C. No further contact has been made with this fish.

Radio Tag 151.152

On 12 July, 1978, this 4.5 kg fish was shocked and captured in Mossy Creek from a submerged waterfall at Site 1 (Figure A-28a). Tagged and released shortly after capture at 1140 hr into the same area, it immediately swam downstream in the submerged channel to Site 2 where another submerged waterfall was located. During a half hour observation period beginning at 1430 hr this fish experienced an average temperature of 21.9 C (Table A-18). This fish was approximately 3 m deep and experienced temperatures of 20.0 to 27.5 C in water 4.5 m deep. Still located at Site 2 on 14 and 17 July, it was monitored at 1330 hr on 17 July and an average temperature of 23.5 C was determined. During the period of 20, 21, 24 and 26 July it was found in Site 2 at a depth

Figure A-28. Maps showing observed locations of the fish tagged with Radio Tag 151.152. Elevation: (a) 318 m, (b) 313 m, (c) 312 m, (d) 310 m, (e) 309 m.

Table A-18. Thermal History of Radio Tag 151.152
in Degrees Celsius with Location Data
from Figures A-28a-e (Half-Hour
Observation Periods).

Date	Site	Time	Mean	Mode(s)	Range	S.D.
July 12	2	1430	21.9	21.8	21.3-22.7	0.2
July 17	2	1330	23.5	23.4	23.1-24.0	0.2
July 21	2	1520	22.2	22.2	20.9-22.9	0.3
July 24	2	1440	22.5	22.5	20.4-23.5	0.3
July 26	2	1440	20.3	20.2	19.9-22.5	0.2
July 28	2	1100	18.9	18.8	18.4-19.8	0.2
Aug. 2	3	0400	18.1	18.1	17.9-18.3	0.1
Aug. 2	3	1150	18.8	18.7 19.0	18.1-19.2	0.2
Aug. 11	3	1215	21.0 ^a			
Aug. 14	3	1500- 1600 ^b	21.9	21.7	17.8-28.6	1.6
Aug. 16	3	1430	21.8	21.8	21.3-22.2	0.1
Aug. 21	3-4	1440	23.7 ^a			
Aug. 24	4	1310	22.0	21.9	21.5-24.2	0.3
Aug. 30	4	1530	23.8	23.5	22.7-24.9	0.4
Sept. 13	5	1145	21.0 ^a			
Sept. 14	5	1140	23.5 ^a			
Sept. 26	5	1400	22.5 ^a			
Oct. 5	6	1400	19.2	19.1	18.8-19.8	0.2
Oct. 12	7	1200	17.7	17.7	17.2-17.9	0.1

^aSpot check--less than half an hour observation.

^bAutomatically recorded data.

of approximately 3 m. Average temperatures monitored were 22.2, 22.4 and 20.3 C while available temperatures in the site ranged from 16.9 to 30.0 C (Table A-18). By 28 July, water depth at Site 2 had dropped to 3 m, but this fish remained at Site 2 on 27 and 28 July in the deepest waters at an average temperature of 18.9 C. By 1 August however, Site 2 was nearing 2 m deep, and this fish had moved to Site 3, another submerged waterfall downstream of Site 2. Monitored on 2 August in the morning, average temperatures at two times were 18.1 and 18.8 C at depths of 3 to 4 m. Very little movement within Site 3 (Figure A-28b) was observed when this fish was found on 7, 8 and 11 August.

Recording of a 24-hr period was attempted from 14 to 15 August, but only the period from 1500 to 1600 hr on 14 August resulted in good data. Average temperature experienced by the fish was 21.9 C at a calculated depth of 2.5 m. Site 3 at this time was at a depth of 3 m and water temperatures ranged from 16.8 to 30.0 C. This fish remained at Site 3 on 16 August and average temperature of 21.8 C was experienced. Water levels were dropping (7.5 to 10.0 cm) at this time of season. This fish moved towards Site 4 by 21 August, returned to Site 3 on 22 August, and finally moved into Site 4 on 24 August. Site 4 was at the submerged base of a series of small waterfalls, 4 m deep. The fish was near the bottom at a mean temperature of 22.0 C. Available temperatures at Site 4 ranged from 21.2 to 28.2 C. Still located at Site 4 (Figure A-28c) on 30 August, it was 3 m deep at temperatures near 23.8 C. With water levels still dropping, this fish moved into Site 5 (Figure A-28d) by 6 September. Spot checks at Site 5 on 13 and 14 September showed mean temperatures of 21.0 and 23.5 C. This site was on the

submerged creek channel, because outside of the submerged channel cove temperatures ranged from 27.0 to 28.0 C. This fish was located at Site 5 again on 19 and 26 September. Spot check on 26 September showed the fish at an average temperature of 22.5 C. The automatic recorder was used during the period of 26 to 27 September, but a malfunction resulted in no data points. At this time the fall overturn had occurred and the main reservoir temperatures ranged from 24.0 to 25.5 C. Still at Site 5 on 28 September, this fish moved into Site 4 (Figure A-28e) by 3 October. Site 4 at this time was only 1.2 m deep. It moved into deeper waters at Site 6 by 5 October.

At 3 m down, an average temperature of 19.2 C was experienced. Water temperatures at this time ranged from 18.5 to 24.0 C at Site 6. By 12 October this fish swam upstream to Site 7 and was observed in average temperature of 17.7 C. Water temperatures ranged from 17.0 to 22.5 C in the channel and 20.9 to 22.0 C in the reservoir. The fall cooling of the lake waters and the response of the fish is shown clearly in Figure A-29. The tag was located near Site 6 on 17 October, where apparently it had fallen off the fish or had been thrown by a fisherman. The tag itself was recovered by diving on 31 October in about 4 m of water.

Radio Tag 151.063C

The largest striped bass tagged was an 11.25 plus kg fish shocked near Site 1 (Figure A-30a) in Mossy Creek on 12 July 1978. Tagged and released at 1320 hr into Site 1, a submerged waterfall, it moved downstream to Site 2, another submerged waterfall. At 1450 hr it was

Figure A-29. Mean(-), mode(---), standard deviation($\square$) of Radio Tag 151.152. No mean(-) was drawn when mean and mode were equal. Half-hour data sets except where noted.

Figure A-30. Maps showing observed locations of the fish tagged with Radio Tag 151.063C. Elevation: (a) 318 m, (b) 313 m, (c) 312 m, (d) 310 m, (e) 309 m.

monitored for half an hour and an average temperature of 21.7 C (Table A-19) was observed. At this time water temperatures ranged from 20.0 to 27.4 C in Site 2. On 14 July it had moved upstream to Site 3, another submerged waterfall, and was observed in mean temperature of 21.6 C at a depth of 3.8 m in 4.5 m of water. This fish remained at Site 3 on 17, 20, 21, and 24 and 26 July. Mean temperatures observed were 23.2, 20.7, 21.1, and 19.0 C at depths from 3.5 m to 4.0 m. Water temperatures at Site 3 during this period ranged from 16.9 C at the bottom to 29.2 C at the surface. On 27 July, this fish was observed in very cool, shallow water at Site 4, in the submerged creek channel. When the boat passed over it, the fish moved downstream to Site 3 and slightly warmer temperatures were experienced. Average temperature was 16.9 C where water temperature ranged from 15.5 to 30.0 C. On 28 July this fish was again at Site 4 in less than 2 m of water. Mean temperature experienced was 16.3 C, close to the average temperature of 27 July. During the period from 1 August to 2 August several observations were made at various times of the day and night. Hourly mean temperatures ranged from 14.9 to 18.5 C with the cooler mean temperatures encountered in the early morning of 2 August. The graph on Figure A-31 shows the cooling and warming trends of the water around the fish as the fish remained at Site 2 during the period of monitoring. At 0630 hr on 2 August, a wide range of temperatures was experienced by this fish, indicating vertical movement which may have been feeding movements on shad at the surface. On 7, 8, 11, 15, 16, 21, 22, and 24 August this fish was found at Site 2 (Figure A-30b) at depths of 2.5 to 3 m. By 24 August water levels had dropped so that Site 2 was only 3 m deep. Average temperatures

Table A-19. Thermal History of Radio Tag 151.063C
in Degrees Celsius with Location Data
from Figures A-30a-e

Date	Site	Time	Mean	Mode	Range	S.D.
July 12	2	1450	21.7	21.5	20.2-23.1	0.4
July 14	3	1540	21.6	21.8	20.9-22.2	0.4
July 20	3	1650	23.2	23.2	22.9-23.5	0.08
July 21	3	1510	20.7	20.7	18.5-24.7	0.5
	3	1550	20.7	20.7	20.2-21.5	0.1
July 24	3	1430	21.1	21.1	20.6-21.7	0.2
July 26	3	1400	19.0	19.1	16.9-21.2	0.6
July 27	3-4	1010	16.9	16.6	15.6-18.9	0.9
July 28	4	1130	16.3	15.9	15.3-20.9	0.8
Aug. 1	2	2040	18.5	18.4	18.3-18.7	0.1
	2	2200	15.6	15.6	15.2-17.8	0.3
Aug. 2	2	0040	14.9	14.9	14.6-15.5	0.2
	2	0630	14.9	14.6	14.4-22.0	0.9
	2	0700	18.2	17.9	17.4-21.3	0.7
	2	1330	18.9	19.0	18.1-21.9	0.3
	2	1400	17.9	17.8	17.1-19.3	0.4
Aug. 7	2	1150	18.2	18.1	17.4-18.8	0.2
	2	1220	18.1	18.1	17.9-18.5	0.1
Aug. 8	2	1400	18.8 ^a			
	2	1640	19.9	19.9	19.8-20.0	0.04
Aug. 11	2	1050	17.9	18.0	17.3-18.5	0.2
	2	1120	18.0	17.9	17.4-19.3	0.2
Aug. 21	2	1430	20.9 ^a			
Aug. 22	2	1540	21.5	21.4	21.1-22.1	0.1
Aug. 30	2	1450	20.5	20.5	20.3-20.9	0.1
Aug. 31	2	1200- 2400 ^b	19.9	19.8	16.3-29.3	1.6
Sept. 1	2	0000- 1100 ^b	18.6	evenly distributed	16.1-24.9	1.7
Sept. 5	5	1700- 2400 ^b	20.5	21.3	16.5-28.6	2.2
Sept. 6	6	0000- 1300 ^b	20.3	evenly distributed	16.3-28.9	2.5
Sept. 12	5	1200- 2400 ^b	22.6	evenly distributed	17.1-29.0	1.6
Sept. 26	5	1600	20.5 ^a			
Sept. 29	5	1200	18.7	18.5	18.4-19.3	0.2
Oct. 5	6	1240	17.8	17.7	17.3-18.7	0.2

^aSpot checks--less than half an hour observation.

^bAutomatically recorded data.

Figure A-31. Mean(-), mode(---), standard deviation($\square$) of Radio Tag 151.063C. No mean(-) was drawn when mean and mode were equal. Half-hour data sets except where noted.

experienced by this fish ranged from 17.9 to 21.5 C. No movement within Site 2 was observed during these observation periods. On 15 August an overnight recording of this fish was attempted, but receiver drift caused scattered data and no temperatures could be accurately determined. This fish was still at Site 2 (Figure A-30c) on 30 August in less than 2 m of water. Mean temperature experienced was 20.5 C. Water temperature at this time ranged from 16.8 to 26.9 C. Water levels were still dropping a few centimeters a day. The automatic recorder was set up on 31 August through 1 September at Site 2. Hourly means ranged from 18.1 to 20.6 C with a total mean of 19.9 C for 31 August and 18.6 C for 1 September (Table A-19). A computer plot of the individual data points show a slight decrease in temperatures during the night and slight increases during the days (Figure A-32). On 5 September this fish had moved to Site 5 (Figure A-30d) at the base of a series of submerged waterfalls. Water at Site 5 was approximately 3 m deep and temperatures ranged from 16.0 C at the bottom in early morning to 28.0 C at the surface in mid-day. The automatic recorder was set up from 5 September to 6 September (Figure A-33). Hourly means ranged from 18.3 to 22.3 C with a grand mean of 20.4 C. By the end of the monitoring period on 6 September, this fish had moved to Site 6 at the mouth of Mossy Creek Cove. This fish was located at Site 6 on 8 September in 4 m of water, but by 11 September had moved back to Site 5. The automatic recorder monitored this fish from 12 to 13 September in Site 5. Mean temperature for 12 September was 22.6 C (Figure A-34). On 13 September too much scatter was recorded for accurate temperature calculations and it was noted when the recorder was turned off that CB

Figure A-32. Computer plot of temperatures selected by Radio Tag 151.063C from 31 August to 1 September 1978. Letters represent number of observations (A = 1, B = 2, C = 3, etc.).

THERMAL HISTORY OF RADIO TAG 151.063C

PLOT OF TEMP*TIME_H LEGEND: A = 1 OBS, B = 2 OBS, ETC.

Figure A-33. Computer plot of temperatures selected by Radio Tag 151.063C on 5-6 September 1978. Letters represent number of observations (A = 1, B = 2, C = 3, etc.).

PLOT OF TEMP*TIME_E LEGEND: A = 1 OBS, B = 2 OBS, ETC.

Figure A-34. Computer plot of temperatures selected by Radio Tag 151.063C on 12 September 1973. Letters represent number of observations (A = 1, B = 2, C = 3, etc.).

interference was being picked up by the receiver. This fish was located at Site 5 on 14, 19, and 26 September. A spot check showed an average temperature of 20.5 C was experienced and calculated depth of the fish was 2 m or on the bottom. Still at Site 5 in water 1 to 1.5 m deep on 27, 28, and 29 September, mean temperature was 18.7 C on the later date. Water temperature at this time ranged from 18.1 to 25.5 C at Site 5 and in the main reservoir the fall overturn had occurred and temperatures were near 25.5 C and D.O. ranged from 3.0 to 4.0 at German Creek to 6.0 to 7.4 at Point 1 near Mossy Creek. On 3 October this fish was at Site 5 (Figure A-30e) in approximately 1 m of water. By 5 October it moved to Site 6 at the mouth of Mossy Creek in 5 m of water. Mean temperature experienced was 17.8 C while water temperatures ranged from 17.0 to 24.2 C in the cove and reservoir temperatures were isothermal at approximately 24.0 to 24.4 C. By 12 October it had moved out of Mossy Creek into the reservoir where temperatures ranged from 20.3 to 22.8 C. This fish throughout its monitoring history was distinguished by the cool waters it was observed in. From Figure A-31 it is noted that this fish remained nearer the coolest temperature available than any other fish monitored.

Radio Tag 151.240B

On 12 July 1978 in Mossy Creek this 9 kg fish was shocked in Site 1 (Figure A-35a), a submerged waterfall. Tagged and released at 1330 hr into Site 1, it moved to Site 2, a large submerged waterfall, by 1500 hr. The fish's occupied temperature was monitored, and an average temperature of 22.9 C (Table A-20) was determined. Water temperatures at

Figure A-35. Maps showing observed locations of the fish tagged with Radio Tag 151.240B. Elevation: (a) 318 m, (b) 313 m, (c) 312 m, (d) 310 m, (e) 309 m.

Table A-20. Thermal History of Radio Tag 151.240B
in Degrees Celsius with Location Data
from Figures A-35a-e

Date	Site	Time	Mean	Mode	Range	S.D.
July 12	2	1520	22.9	22.7	21.9-24.8	0.5
July 17	3	1450	23.5	23.6	22.8-24.1	0.1
July 27	4	1440	23.3	23.3	23.2-23.6	0.07
Aug. 21	2	1450	24.2	24.2	23.5-24.9	0.2
Sept. 14	4	1300- 2400 ^a	20.1	20.8	15.4-29.2	1.0
Sept. 15	4	0000- 1000 ^a	18.8	18.1	17.1-25.3	0.9

^aAutomatically recorded data.

this site ranged from 21.5 to 29.4 C in 5 m of water. By 14 July this fish had moved to Site 3, a smaller submerged waterfall. On 17 July, it was still in Site 3 and experienced a mean temperature of 23.5 C. In 4 m of water which ranged in temperature from 20.0 to 27.4 C would mean the fish was at a depth of approximately 3.5 m. This fish was found at Site 3 again on 20 July, but was not located in Mossy Creek or the surrounding area on 24 July. By 26 July it reappeared at Site 2, indicating that it may have been in deeper water at the mouth of the cove where the signals would have been attenuated. On 27 July it was found downstream in Site 4, the base of a series of submerged waterfalls. It experienced a mean temperature of 23.3 C at a depth of 5 m. Site 4 was 6 m deep at this time and ranged in temperature from 23.0 to 29.2 C. On 28 July, the next day, it was still present at Site 4. Between 28 July and 21 August this fish was not located in Mossy Creek Cove or the surrounding areas although searches were made every few days. On 21 August it reappeared at Site 2 (Figure A-35b) and an observation period of half an hour showed the fish in water of 24.2 C (average). Site 2 at this time was only 3 m deep but water temperatures ranged from 19.6 C at 3 m, to 26.8 C at 2 m to 27.4 C at the surface. This fish was found again at Site 2 on 22 August and then moved downstream to Site 4 by 24 August. At Site 4 (Figure A-35c) in 3 m of water on 30 August, the radio tag signals emitted were very strong and fast and not temperature sensitive. On 5 September the fish was located at Site 4 (Figure A-35d) and then moved upstream to Site 5 in the submerged creek channel by 6 September. On 9 September it was downstream again at Site 4 and then on 13 September it had moved upstream to Site 5. Water levels were

dropping several centimeters a day at this time and Site 4 was 3 m deep and Site 5 was only 1 m deep. On 14 September in Site 4 the radio tag signals appeared to be temperature sensitive. The automatic recorder was set up from 14 September to 15 September and results are plotted in Figure A-36. Average temperatures were 20.1 C for 14 September and 18.8 C for 15 September. On the graph a distinct curve is seen with rising temperatures from 1200 to 2000 hr and decreasing temperatures from 2300 to 0700 hr. As the recorder was switched off on 15 September, the signals were observed to speed up and became non-temperature sensitive, and after this date the signals never became temperature sensitive again. This fish was located in Site 4 on 19, 26, and 28 September. By the 28 September the water depth at Site 4 was only 1.5 m deep with temperatures ranging from 18.1 to 25.5 C. On 3 October it was still at Site 4 (Figure A-35e) in 1 m of water but by 5 October it had moved to Site 6 where water was somewhat deeper. After this date no signals were heard indicating that the fish had moved out of Mossy Creek into the reservoir or else the tag battery had died.

Radio Tag 151.035

On 12 July 1978 a 6.75 kg striped bass was shocked, tagged, and released at 1330 hr into Site 1 (Figure A-37), a submerged waterfall at the mouth of Mossy Creek. It moved shortly after release to Site 2, another submerged waterfall. After a half-hour observation, it was determined that the fish experienced a mean temperature of 23.2 C (Table A-21). This temperature was available at approximately 4 m in depth. Not located on 13 July, it was heard in Site 3 on 14 July. At

PLOT OF TEMP*TIME_H LEGEND: A = 1 OBS, B = 2 OBS, ETC.

ORNL-DWG 79-13730

ELEVATION - 318 METERS

Figure A-37. Map showing observed locations of the fish tagged with Radio Tag 151.035.

Table A-21. Thermal History of Radio Tag 151.035
 in Degrees Celsius with Location Data
 from Figure A-37 (Half-Hour
 Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
July 12	2	1540	23.2	22.9	22.1-25.1	0.6
July 14	3	1510	21.7	21.7	21.0-23.7	0.2
July 17	3	1620	23.6	23.6	23.0-24.4	0.2
July 26	2	1400	19.1 ^a			

^aSpot check--less than half an hour observation.

this time it was in a mean temperature of 21.7 C. Water temperatures at this site ranged from 20.0 C at 4.2 m to 27.4 C at the surface. On 17 July it was still at Site 3, but it experienced a mean temperature of 23.6 C, warmer than the previous observation. On 20 July a weak signal from Site 3 was heard although no monitoring was made. Site 2 was checked on 24 July but no signals were heard with the receiver on the bank. On 26 July from the shore signals from the fish were heard and a spot check showed average temperature near 19.1 C was experienced. After this date no searches found this fish again in the reservoir.

Sonic Tag 164

This 2.25 to 3.15 kg striped bass was shocked, tagged, and released in Mossy Creek Cove at 1530 hr on 18 July. Not followed after tagging and release, it was thoroughly searched for on 20 July in Mossy Creek Cove. This fish was never located after release.

Sonic Tag 157B

On 20 July a 6.75 kg striped bass was shocked in Mossy Creek Cove, tagged on the back with a sonic tag, and released at 1330 hr. It remained at the submerged waterfall in the mouth of Mossy Creek for a while after release, then moved into deep water at the mouth of the cove or out into the lake. No further searches in Mossy Creek Cove located this fish, however on 29 July it was caught by a fisherman at the mouth of Mossy Creek. It was said to be healthy, with no sores or lesions on its body.

Sonic Tag 163

On 20 July 1978 this 4.5 kg fish was shocked in Mossy Creek Cove at Site 1 (Figure A-38a). At 1400 hr it was tagged and released immediately back into Site 1. Shortly afterwards this fish moved to Site 2 and remained there a while, and then moved further out of Mossy Creek Cove where contact was lost. This fish was not located again until 28 July when it was found at Site 2. An observation period showed this fish at an average temperature of 16.6 C (Table A-22). Water temperatures at this site ranged from 15.5 to 29.2 C. This fish was again found on 2 August at 0500 hr when its signal was mistaken for another fish. It was located just above Site 2. The next time this fish was found was on 15 August at Site 3 (Figure A-38b). Mean temperature experienced by this fish was 17.1 C. At the minimum temperature available, this fish was over 3 m deep. Outside of the submerged creek channel water temperatures ranged from 25.4 to 29.0 C. This fish was still at Site 3 on 16 August. On 21 August at Site 4 a spot check was made on this fish, but on 22 August a complete observation period showed that the tag was on the bottom on 21 August and the temperatures were slowly warming up from the solar heat and not from the fish's movement. On 31 October this tag was recovered when the water levels had dropped to below 2 m at Site 4 and a diver found the tag on a submerged ledge underneath a tree stump approximately 75 cm from the creek channel. No explanation has been found to explain how the tag got to such an inaccessible area since there was no fish carcass in the immediate area, and the tubing around the tag was intact. Only the wire connecting the fish and the tag was missing. The only possibility would be if a

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Figure A-38. Maps showing observed locations of the fish tagged with Sonic Tag 163. Elevation: (a) 318 m, (b) 313 m.

Table A-22. Thermal History of Sonic Tag 163
in Degrees Celsius with Location Data
from Figures A-38a-b (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
July 28	2	1400	16.6	16.5	15.9-18.4	0.3
Aug. 15	3	1250	17.1	17.1	16.7-17.4	0.1

fisherman had caught the fish, pulled the wire away from the tag and threw the tag in the water where the current carried to the ledge.

Sonic Tag 165B

On 20 July, 1978 this 7.2 kg fish was shocked, tagged and released at 1430 hr near Site 1 (Figure A-39a) in Mossy Creek Cove. The fish immediately left the Mossy Creek Cove area after release. It was located at Site 2, a submerged waterfall, on 24 July. A spot check at 1430 hr in Site 2 on 26 July showed this fish in water temperature near 20.7 C (Table A-23). The fish was determined to be approximately 4 m deep in water nearly 5 m deep which ranged in temperature from 20.0 to 29.2 C. A period of monitoring at 1800 hr the same day showed the fish swimming a mean temperature of 21.9 C. On 27 July, the next day, the fish occupied a mean temperature of 20.9 C in Site 2. This fish was still at Site 2 on 28 July. Found in Site 2 on 1 August, a 24-hr tracking period was started on this fish. Temperature means for one-hour periods ranged from 19.9 C at 1740 hr to 16.8 C at 0800 hr. An hour mean of 19.5 C was determined in the afternoon of 2 August. The warming and cooling trend shown by Figure A-40 may have been the result of the cooling and warming of the creek water underflow around the fish. During the night this fish moved first into Site 3, a smaller submerged waterfall, by 0100 hr, then back to Site 2 by 0500 hr and then to Site 4 by 0830 hr. On 8 August this fish was located at Site 2 (Figure A-39b) in water 3.5 m deep. Still at Site 2 on 15 August this fish was found in an average temperature of 18.2 C. Water temperatures at Site 2 ranged from 17.5 to 28.6 C and in the cove

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Figure A-39. Maps showing observed locations of the fish tagged with Sonic Tag 165B. Elevation: (a) 318 m, (b) 313 m.

Table A-23. Thermal History of Sonic Tag 165B
in Degrees Celsius with Location Data
from Figures A-39a-b (Half-Hour
Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
July 26	2	1430	20.7 ^a			
	2	1800	21.9	22.0	21.8-22.2	0.1
July 27	2	1140	20.9	20.9	20.2-21.4	0.3
Aug. 1	2	1450	19.8	19.8	19.7-21.9	0.2
	2	1740	19.9	20.0	18.9-20.0	0.1
	2	1800- 2400 ^b	19.1	18.7	17.9-28.2	0.7
Aug. 2	2-3	0000- 0800 ^b	17.3	evenly distributed	16.2-22.3	0.4
	4	0930	17.1	17.2	16.3-17.3	0.2
	4	1050	18.2	18.0	17.7-19.3	0.3
	4	1200	18.0	18.0	17.8-18.4	0.2
				18.2		
	4	1300	18.9	18.7	15.3-20.4	0.5
	4	1400	19.5	19.4	19.2-21.6	0.3
Aug. 15	2	1220	18.2	18.1	17.9-19.2	0.2
Aug. 21	2	1520	21.3	21.3	21.1-22.4	0.2
Aug. 22	5	1530	24.9 ^a			
Aug. 23	2	1250	20.9	21.3	19.4-23.6	1.0

^aSpot checks--less than half an hour observation.

^bAutomatically recorded data.

Figure A-40. Computer plot of temperatures selected by Sonic Tag 165B on 1-2 August 1978.

temperatures ranged from 24.4 to 28.6 C. Located again at Site 2 on 17 August and 21 August, it was found at mean temperature of 21.3 C on the later date. Water depth had decreased to less than 3 m and water temperatures ranged from 19.6 to 27.4 C. On 22 August this fish was found at Site 5 and a spot check showed it to be in temperatures near 24.9 C. By 23 August it had moved upstream to Site 2 where it occupied a temperature of 20.9 C. At this time the water was only 2.5 m deep and ranged from 18.5 C at the bottom to 27.9 C at the surface. The reservoir temperatures were generally 24 to 29 C. The last location of this fish was in Site 2 on 24 August. On 29 August this fish was caught by a fisherman from Site 2 in about 2 m of water. Condition of the tag attachment sites on the fish's back could not be determined because the tag had become entangled with the fishing line when the fish was caught and the back was torn up as a result.

Radio Tag 151.330B

On 14 August a 2.25 to 2.7 kg striped bass was shocked, tagged, and released in Cedar Hill Cove over the submerged spring (Site 1, Figure A-41). During the half hour immediately after release this fish experienced a mean temperature of 20.9 C (Table A-24). On 16 August it was found on top of the spring and experienced a mean temperature of 19.5 C. Surface water temperature was 28.3 C during the time this fish was monitored. On 22 August still in Site 1 this fish was in a mean temperature of 20.0 C. On 23 August this fish was found again over the spring. On 30 August no signals from Cedar Hill Cove were heard. On 8 September, however, this fish was again found in Site 1. When the

Figure A-41. Map showing observed locations of the fish tagged with Radio Tag 151.330B.

Table A-24. Thermal History of Radio Tag 151.330B
 in Degrees Celsius with Location Data
 from Figure A-40 (Half-Hour
 Observation Periods)

Date	Site	Time	Mean	Mode	Range	S.D.
Aug. 14	1	1330	20.9	20.8	18.6-22.5	0.5
Aug. 16	1	1210	19.5	19.5	18.7-20.2	0.2
Aug. 22	1	1340	20.0	19.9	19.5-22.0	0.4

cove was checked on 11 September no distinct signal could be found, although a faint signal was thought to be detected. By 21 September this fish had moved down the lake into the Mossy Creek area and died. The body was found in a very decomposed state at Site 2.

Radio Tag 151.272

This 4.5 kg striped bass was shocked, tagged, and released in Byrd Springs Cove near the submerged spring on 23 August. It immediately moved into deep water where no signal could be heard. Searches between Byrd Springs Cove and Mossy Creek Cove during the following days did not locate this fish. It apparently was caught in Mossy Creek Cove area on 29 August although this was not discovered until 19 October. The tag was not returned, but the fisherman reported his catch to TWRA in Morristown on 18 October without leaving his name.

Sonic Tag 157C

A 5.4 kg striped bass was shocked, tagged, and released at Site 1 (Figure A-42) in Byrd Springs Cove at 1345 hr on 23 August. It moved out from Site 1 towards Site 2 during half an hour monitoring period. No data was taken because of a malfunctioning receiver. Apparently the fish swam out of the cool spring underflow into warm water because the following morning it was found dead, floating at Site 3. The shock and stress of the tagging combined with the fish moving out of the cool refuge waters may have caused this fish's death.

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Figure A-42. Map showing observed locations of the fish tagged with Sonic Tag 157C.

Radio Tag 151.448

On 23 August a 4.5 kg striped bass was shocked, tagged, and released at Site 1 (Figure A-43) in Cedar Hill Cove. After release, this fish swam out of the spring area and into deep water where it could not be located, although three searches were made of Cedar Hill Cove immediately after release. On 30 August this fish was found in shallow water near the spring sending very strong signals. During a half hour observation at 1215 hr this fish experienced a range of temperatures from 15.3 to 21.6 C with a mean of 17.1 C, but a mode of 15.5 C. This fish was not found during searches on 8, 11, and 26 September in Cedar Hill Cove, but on 26 September it was found in Mossy Creek Cove at Site 2. Tag signal intervals were very far apart, indicating cold water which was not present. The tag was assumed to be malfunctioning and only location data was recorded on this fish thereafter. This fish was found at Site 2 on 27 and 29 September and 3 and 5 October. Only a gradual movement (less than 1 m per day) towards the mouth of Mossy Creek Cove as the water levels dropped was seen. On 11 October the decomposing body of this fish was found on the bank at Site 3.

Sonic Tag 154

This 6.75 kg striped bass was part of the previous study by Waddle (1979). On 8 June 1977 this fish was shocked at Mossy Creek Cove, transported to Cedar Hill Cove and tagged. It had several red areas on its side and was not in very good condition. It had lost its equilibrium during the trip to Cedar Hill Cove and floated belly up. It seemed to revive when the water in the livewell was cooled to 18 C. It was

Figure A-43. Map showing observed locations of the fish tagged with Radio Tag 151.448.

released directly over the spring. A spot check showed the fish at an average temperature of 19.1 C. This temperature was available at the bottom (4 m) over the spring. Later the same day at 1855 hr a monitoring period showed the fish in a mean temperature of 18.4 C. This fish was not found again in 1977 and was assumed lost or dead. However, on 15 May, 1978, a monitoring period was made on a fish among the islands near Point 8. Later temperature calculations showed that it was not one of the fishes tagged previously in 1978 so fish from the 1977 study were evaluated. It was concluded that it was sonic tag 154. From the data, this fish was in a mean temperature of 15.0 C with a range of 11.9 to 15.9 C experienced. The mode was 15.3 C. Water temperatures nearby were 13.2 C at the bottom (14.5 m), 15.4 C at 8 m and 15.8 C at approximately 3 m. Surface temperatures reflected the cool, rainy day and were 15.4 to 15.6 C. This fish was moving actively around the submerged islands and points of islands. The signal from the tag was very strong and seemed to be temperature sensitive, even though a year had passed. No further contact was made on this fish in 1978.

APPENDIX B
TEMPERATURE AND DISSOLVED OXYGEN PROFILES OF
MAIN CHANNEL STATIONS, MARCH-OCTOBER, 1978

TEMPERATURE AND DISSOLVED OXYGEN PROFILES OF
MAIN CHANNEL STATIONS, MARCH-OCTOBER, 1978

Figure B-1. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 16 March 1978.

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Figure B-2. Isotherms plotted by computer on a longitudinal section of Cherokee Reservoir, 24 March 1978.

ORNL DWG 79-11385

ORNL-DWG 79-11360

Figure B-3. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 2 April 1978.

ORNL DWG 79-11386

ORNL-DWG 79-11361

Figure B-4. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 14 April 1978.

ORNL DWG 79-11387

Figure B-5. Isotherms plotted by computer on a longitudinal section of Cherokee Reservoir, 24 April 1978.

ORNL DWG 79-11388

ORNL-DWG 79-11362

Figure B-6. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 28-30 April 1978.

ORNL DWG 79-11389

ORNL-DWG 79-11363

Figure B-7. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 12 May 1978.

ORNL DWG 79-11390

ORNL-DWG 79-11767

Figure B-8. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 18 May 1978.

ORNL DWG 79-11391

ORNL-DWG 79-11364

Figure B-9. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 26 May 1978.

ORNL DWG 79-11392

ORNL-DWG 79-11365

Figure B-10. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 2 June 1978.

ORNL DWG 79-11393

ORNL-DWG 79-11366

Figure B-11. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 9 June 1978.

ORNL DWG 79-11394

ORNL-DWG 78-11367

Figure B-12. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 15 June 1978.

ORNL DWG 79-11395

ORNL-DWG 79-11368

Figure B-13. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 23 June 1978.

ORNL DWG 79-11396

ORNL-DWG 79-11369

Figure B-14. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 30 June 1978.

ORNL DWG 79-11397

ORNL-DWG 79-11370

Figure B-15. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 7 July 1978.

ORNL DWG 79-11398

ORNL-DWG 79-11371

Figure B-16. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 14 July 1978.

ORNL DWG 79-11399

ORNL-DWG 79-11372

Figure B-17. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 21 July 1978.

ORNL DWG 79-11400

ORNL-DWG 79-11373

Figure B-18. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 4 August 1978.

ORNL DWG 79-11401

Figure B-19. Isotherms plotted by computer on a longitudinal section of Cherokee Reservoir, 17 August 1978.

ORNL DWG 79-11402

ORNL-DWG 79-113 74

Figure B-20. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 25 August 1978.

ORNL DWG 79-11403

ORNL-DWG 79-11375

Figure B-21. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 1 September 1978.

ORNL DWG 79-11404

ORNL-DWG 79-11376

Figure B-22. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 8 September 1978.

ORNL-DWG 79-11405

ORNL-DWG 79-11377

Figure B-23. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 14 September 1978.

ORNL-DWG 79-11406

ORNL-DWG 79-11378

Figure B-24. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 21 September 1978.

ORNL-DWG 79-11407

ORNL-DWG 79-11379

Figure B-25. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 28 September 1978.

Figure B-26. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 5 October 1978.

Figure B-27. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 12 October 1978.

ORNL-DWG 79-11410

ORNL-DWG 79-11382

Figure B-28. Isotherms and dissolved oxygen isopleths plotted by computer on a longitudinal section of Cherokee Reservoir, 19 October 1978.

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123. O. E. Maughan, Cooperative Fishery Research Unit, Oklahoma State University, Stillwater, OK 74074
124. Helen McCammon, Director, Ecological Research Division, Office of Health Research, Department of Energy, Washington, DC 20545
125. J. A. McCann, National Fishery Research Laboratory, Bldg. 737, University of Florida, Gainesville, FL 32611
126. R. W. McCauley, Biology Dept., Wilfred Laurier University, Waterloo, Ontario, N2L 3C5, Canada
127. W. J. McConnell, Cooperative Fishery Research Unit, Colorado State University, Fort Collins, CO 80521
128. J. H. McCormick, Environmental Protection Agency, Environmental Research Laboratory, Duluth, MN 55800
129. J. McMahon, Atomic Energy of Canada, Ltd., Chalk River, Canada
130. Tom McMahon, Fish and Wildlife Service, Division of Ecological Services, Project Impact Evaluation, 2625 Redwing Road, Fort Collins, CO 80526
131. J. W. Meldrim, Ichthyological Associates, 100 S. Cass St., Middletown, DE 19709
132. D. Miller, Environmental Protection Agency, Environmental Research Laboratory, Narragansett, RI 02882
133. J. S. Morris, Tennessee Valley Authority, Division of Environmental Planning, Chattanooga, TN 37401
134. D. Mount, Environmental Protection Agency, Duluth, MN 55804
135. H. Mullican, Tennessee Division Water Quality Control, Nashville, TN 37202

136. R. J. Muncy, Cooperative Fishery Research Unit, Iowa State University, Ames, IA 50010
137. G. W. Naylor, Dougherty Science Bldg., Carson-Newman College, Jefferson City, TN 37760
138. W. Neill, Dept. of Fisheries and Wildlife, Texas A & M University, College Station, TX 77840
139. J. G. Nickum, Cooperative Fishery Research Unit, Cornell University, Ithaca, NY 14850
140. D. A. Owens, Tennessee Division of Water Quality Control, 1522 Cherokee Trail, Knoxville, TN 37920
141. G. B. Pardue, Cooperative Fishery Research Unit, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061
142. T. Patterson, Dougherty Science Bldg., Carson-Newman College, Jefferson City, TN 37760
143. M. Payson, 2760 First Pl., Baldwin, NY 11510
144. D. Peterson, Tennessee Wildlife Resources Agency, Morristown, TN 37814
145. E. A. Pyle, U.S. Fish and Wildlife Service, 63 Keystone Avenue, Room 207, Reno, NV 89503
146. J. S. Ramsey, Cooperative Fishery Research Unit, Auburn University, Auburn, AL 36830
147. R. Raschke, Environmental Protection Agency, Ecology Branch, Athens, GA 30601
148. P. Reed, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555
149. R. J. Reed, Cooperative Fishery Research Unit, University of Massachusetts, Amherst, MA 01002
150. R. E. Reinert, Cooperative Fishery Research Unit, University of Georgia, Athens, GA 30601
151. J. M. Reutter, F. T. Stone Laboratory, Put-In-Bay, OH 43456
152. W. Reynolds, Marine Biology Program, 605 Pool Road, University of New England, Biddeford, ME 04005
153. F. P. Richards, Ecological Analysts, Melville, NY 11746
154. Kevin Richards, Fisheries Biologist, 1104 S. Grand St., Sedalia, MO 65301
155. J. Richardson, Department of Forestry, Wildlife and Fisheries, University of Tennessee, Knoxville, TN 37916
156. Paul G. Risser, Department of Botany and Microbiology, University of Oklahoma, Norman, OK 73019
157. B. Saul, Department of Forestry, Wildlife and Fisheries, University of Tennessee, Knoxville, TN 37916
- 158-177. B. A. Schaich, Department of Zoology, P.O. Box 5577, North Carolina State University, Raleigh, NC 27650
178. W. Schikarski, Nuclear Research Center, Karlsruhe, Federal Republic of Germany
179. M. Schneider, Ecosystems Department, Battelle Northwest, Richland, WA 99352
180. C. B. Schreck, Cooperative Fishery Research Unit, Oregon State University, Corvallis, OR 97331
181. W. Seawell, Tennessee Valley Authority, Forestry, Fisheries and Wildlife Development, Norris, TN 37828

182. S. A. Spigarelli, Argonne National Laboratory, Argonne,
IL 60439
183. J. R. Stauffer, Gunter Hall, Frostburg State College,
Frostburg, MD 21532
184. R. E. Stevens, Director of Fishery Research, U.S. Fish and
Wildlife Service, Department of Interior, Washington,
DC 20240
185. R. Strange, University of Tennessee, Department of Forestry,
Wildlife and Fisheries, Knoxville, TN 37916
186. Robert C. Summerfelt, Oklahoma Cooperative Fishery Research
Unit, Oklahoma State University, Stillwater, OK 74074
187. J. C. Tash, Cooperative Fishery Research Unit, University of
Arizona, Tucson, AZ 85721
188. M. Tisa, Department of Forestry, Wildlife and Fisheries,
University of Tennessee, Knoxville, TN 37916
189. D. Tomljanovich, Tennessee Valley Authority, Fisheries,
Norris, TN 37828
190. C. Ungate, Engineering Laboratory, Tennessee Valley Authority,
Norris, TN 37828
191. R. D. Urban, Tennessee Valley Authority, Division of
Environmental Planning, Water Quality and Ecology Branch,
Muscle Shoals, AL 35660
192. R. D. Vancil, Nebraska Game and Parks Commission, P.O. Box
30370, Lincoln, NE 68503
193. M. Van den Avyle, Cooperative Fishery Research Unit, Tennessee
Technological University, Cookeville, TN 38501
194. C. Voigtlander, Tennessee Valley Authority, Division of
Forestry, Fisheries and Wildlife Development, Norris,
TN 37828
195. H. R. Waddle, 266 Robertsville Road, Oak Ridge, TN 37830
196. W. R. Waldrop, Tennessee Valley Authority, Division of Water
Management, Norris, TN 37828
197. H. V. Walls, Tennessee Eastman Co., P.O. Box 511, Kingsport,
TN 37660
198. R. H. Waring, Department of Forest Science, Oregon State
University, Corvallis, OR 97331
199. Robert L. Watters, Director, Terrestrial and Freshwater
Programs, Office of Health and Environmental Research,
Department of Energy, Washington, DC 20545
200. D. T. Westin, Box 21, Graduate School of Oceanography,
Narragansett Bay Campus, University of Rhode Island,
Kingston, RI 02881
201. David K. Whitehurst, District Fish Biologist, Box 11104,
Richmond, VA 23230
202. R. R. Whitney, Cooperative Fishery Research Unit, University
of Washington, Seattle, WA 98105
203. J. H. Wilson, Jr., Office of Technology Impacts, Department
of Energy, Washington, DC 20545
204. J. L. Wilson, Department of Forestry, Wildlife, and
Fisheries, University of Tennessee, Knoxville, TN 37916
205. Parley V. Winger, U.S. Fish and Wildlife Service, University
of Georgia, Athens, GA 30602

- 206. C. M. Wooley, U.S. Fish and Wildlife Service, Fishery Resources, 1612 June Ave., Panama City, FL 32405
- 207. R. S. Wydoski, Cooperative Fishery Research Unit, Utah State University, Logan, UT 84321
- 208. R. Young, EDB, Tennessee Valley Authority, Muscle Shoals, AL 35660
- 209-235. Technical Information Center, Oak Ridge, TN 37830