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GROWTH AND MOVEMENT OF SMALLMOUTH BUFFALO, *ICTIOBUS BUBALUS* (RAFINESQUE), IN WATTS BAR RESERVOIR, TENNESSEE

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Submitted as a thesis to the Faculty of the Graduate School of The University of Tennessee in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Zoology.

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ABSTRACT

The smallmouth buffalo, Ictiobus bubalus (Rafinesque), population of Watts Bar Reservoir, Tennessee, was investigated in order to describe its age distribution, growth rates, dispersion, and importance as an accumulator of radionuclides. Measurements and scale samples were taken from commercially-caught fish and fish caught in the ORNL tagging operations. Scale impressions were analyzed for age and growth phenomena. Dispersion of smallmouth buffalo was investigated by conventional tagging methods and by autoradiographic analyses of scales. Stable and radiochemical composition of scales was examined by spectrographic analysis, flame spectrophotometry, and radiometric surveys.

Watts Bar smallmouth buffalo in the commercial catch ranged from four to fifteen years of age. The largest number of fish in the catch was from year class six, the youngest year class which was completely vulnerable to commercial fishing gear. Annulus formation occurred prior to June. The total survival rate was found to be 49 per cent for year class six, 35 per cent for year class seven, 26 per cent for year class eight, and 19 per cent for year class nine.

The rate of change in weight as length increased was 100 g/cm for fish exceeding 31 cm in total length. Absolute growth was 422 mm at three years, 441 mm at six, 487 mm at seven, 522 mm at eight, and 609 mm at nine. The species characteristically exhibited the largest relative growth during the second year of life. Conditions for growth evidently had improved f the past six years as was indicated by an increase in total length attained at the end of succeeding years. Growth compensation was evident during the fourth and fifth years of life.

Calcium was the most abundant element in fish scales with at least twenty-three other elements present in varying quantities. Fish scales and bone were found to contain radionuclides of ruthenium, cesium, zirconium, zinc, and cobalt. Radiometric surveys of scales revealed the Watts Bar Reservoir smallmouth buffalo population was a relatively minor accumulator of radionuclides with only 0.08 per cent showing the presence of artificially produced radionuclides. Approximately 6 per cent of the Clinch River fish and 77 per cent of the White Oak Creek fish had accumulations.

Limited data on dispersion were determined from conventional tags. Much more dispersion and life history data were determined from autoradiographic analyses of scales. These dispersion data were applied only to individuals because the number was too small for generalizations for the population as a whole.

All normal scales containing radionuclide accumulations were found to produce identical autoradiographic patterns of concentric circles which were associated with growth of the fish in contaminated areas. This phenomenon was combined with conventional capture-recapture methods of population estimates in a proposed technique of population studies. A laboratory experiment showed that scales could be tagged with cesium-134, but this radionuclide was found to accumulate in much larger concentrations in the soft tissues than in the bony tissues.

Data on population characteristics of the smallmouth buffalo are biologically significant in that they increase our basic knowledge of this commercially important species. The dispersion study is especially important in that an entirely new technique of study was developed and found to be superior to conventional tagging methods.

ACKNOWLEDGMENTS

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CONTENTS

CHAPTER I

INTRODUCTION

In ecological investigations it is necessary to determine the interspecific and intraspecific relationships between organisms, their effects on the physical environment, and effects of the physical environment upon the organisms. The study of organisms in such an ecological investigation often follows the form of a population study designed to determine the characteristics of that population. A population is considered to be a group of organisms of the same species occupying a particular space and possessing characteristics of the group which are not characteristics of the individuals of the group. Some of these characteristics are: density, birth rate, death rate, age distribution, biotic potential, dispersion, and growth form (Odum, 1959).

The primary objective of this study was to determine the age distribution, growth rates, and dispersion characteristics of a selected fish population in the Clinch River. Because this investigation was a part of the continuing Clinch River Study (Morton, 1961), it included an investigation into the species' importance as an accumulator of radionuclides.

The smallmouth buffalo, Ictiobus bubalus (Rafinesque), was selected for this investigation of population characteristics for several reasons. An examination of the fish tagging records of the Radiation Ecology Section revealed that the species is abundant in the area throughout the year. The species is commercially important as indicated by the fact that over one million pounds are harvested annually from Tennessee Valley Authority impoundments. A preliminary radiometric survey of fish species from the Clinch River indicated that the smallmouth buffalo was one of the biotic accumulators of radionuclides released into the river as waste from the Oak Ridge National Laboratory.

The study of population characteristics was based on the examination of scales from the fish. It is a general principle that the scales register all the stages of growth of fish and that every factor influencing this growth is expressed on the sculptured, outer surface (Bertin, 1958). Periods of rapid growth, retarded growth, and even periods of spawning activity may be interpreted from the relative position of marks on the scales of most fish. Lea (1910) established that there is a constant relationship between the size of the fish and the size of its scales. Examination of the outer surface of the scale reveals the animal's current age. The knowledge of age is essential in the study of growth. In conventional growth studies the scales regularly are used to compute the length of the fish at the end of previous growing seasons, as indicated by the spacing of year marks (Ricker, 1958).

Emigration, immigration, and migration are movements of individuals which may affect several of the population characteristics. The investigation of these movements now is limited to capture-recapture study methods and conventional marking techniques. A major disadvantage exists in the conventional methods of marking fish. The attachment of metal or plastic tags to the animal's body has been shown to influence its behavior and inhibit growth (Ricker, 1942).

A preliminary autoradiographic examination of scales from several species of Clinch River fish revealed that the radionuclides had accumulated in patterns of concentric circles. This accumulation was assumed to be the result of growth of the animal in a contaminated area. If any of the nutrient materials used by the animal in forming new body tissues contain radioisotopes of essential elements, these isotopes will follow the same pathway as stable isotopes of the element and be incorporated into these tissues. When accumulation of radionuclides occurs in the scales it can be detected by autoradiography. A comparison of scale autoradiograms to the growth of the specimen should reveal when that individual was in a contaminated area.

In recent years radioisotopes have been applied effectively to the investigation of several phases of aquatic biology. Biological productivity and rates of biogeochemical cycling have been measured by radionuclide methods. They have been used in the investigation of fish diseases and nutrition. They also have been applied in tracing the movement of water and pollutants in water in hydrologic studies. Some application of radionuclides has been made to the marking of aquatic animals, but little success has been achieved. Most of these studies have been based on the use of radioactivity as a means of locating the radioactive individuals. One such study was conducted by Kondrat'ev (1962) in which he tagged commercial fish species by holding them in water containing a weak concentration of radionuclides for several hours. Then these fish were released and recaptured by commercial fishing methods. The catch of fish was passed through tanks equipped with radiometric counting devices and the number of radioactive fish was recorded. This method had some success in testing the efficiency of commercial fishing gear.

Pendleton (1956) pointed out the advantages of radionuclides for marking animals in ecological studies. The radionuclides are not detectable by the senses of the animals and they are easily applied with minimal handling to large groups of animals. Some techniques do not require that the organisms be captured, handled, or even seen by the investigator. The radionuclides are incorporated into the individual's body, thereby tending to prevent loss of the tag. Seymour (1958) discussed the tagging of fish with radionuclides, but concluded that present-day marking methods are much more practical. His objections to tagging fish with radionuclides were that tagged fish are difficult to detect because of the shielding effect of water, the high energy radiation necessary in radioactive tags might have a detrimental effect on the fish, the fish tagged with radionuclides might constitute a health hazard if consumed by humans, and the identification of individuals by such tags would be extremely complicated. However, Seymour appears to have considered using radionuclides primarily as a means of locating fish, as most previous investigators have done. Hooper, Podoliak, and Snieszko (1961) stated that future use of radionuclides in the marking of aquatic animals will be only in situations where there is complete control over the fish harvest or where the tagged fish can be handled without danger to the public.

CHAPTER II

REVIEW OF LITERATURE

A. Population Characteristics

1. Age distribution

Lotka (1925) concluded that a population tends to develop a stable age distribution. Movement of individuals from other populations or changes in environmental conditions may disrupt this balance. However, the population eventually regains its old stability or a new one after the disturbance. Allee, et al. (1949) discussed the relationships between age distribution and other characteristics of the population. There is a preponderance of young individuals in the population soon after spawning because of the high fecundity of fish. However, the survival rates for young fish usually are low because of the intense pressure of predation. Predation continues until the young fish reach a size where they no longer are suitable prey for larger fish. Survival rate is the factor determining the number of individuals entering a new age group.

2. Dispersion

Populations of stream fish in natural habitats cannot be assumed to be isolated units. In the absence of physical barriers movement of individuals occurs between adjacent populations. The movement of fishes may be random (Thompson, 1933), but more likely the movements have cause in population pressures, environmental changes, or migration behavior.

Funk (1955) presented evidence supporting a concept of stream fish populations being divided into sedentary and mobile groups. His data on fourteen species revealed that each species included a sedentary group which remained near the point of capture and release and a mobile group which ranged more or less widely. Carp seemed to adapt their movements to the physical conditions of their habitat. They usually were sedentary in stable habitats, but mobile in habitats subject to flooding. Some carp, the only rough fish species included in this work, ranged as far as 200 miles. Gerking (1953), Larimore (1952), Funk (1955), and others have concentrated on the investigation of game fish movements, home ranges, and homing behavior. Game fish are much less mobile than rough fish. Miller and Bryan (1948) after making a limited investigation of movements of fish in Tennessee Valley Authority impoundments, concluded that the fish populations of creek embayments studied were more or less independent of the main reservoir and few fish moved back and forth between them. Present knowledge of the movements of rough fish is limited because of the past emphasis placed on the study of game fish movements, but it is generally believed that rough fish do not maintain home ranges or exhibit homing behavior and that they range considerably farther than game and pan fish species.

3. Growth

Growth is defined as an increase in size. Rounsefell and Everhart (1953) described growth by two different approaches. Absolute growth is the average size of fish at each age. This size may be either length or weight measurements. The absolute growth rate curve is sigmoidal in shape and the inflection indicates the point at which the rate changes from a continually increasing rate to a decreasing rate of growth. Relative growth is defined as percentage growth in which the increase in size in each time interval is expressed as a percentage of the size attained at the beginning of the time interval. Relative growth is most rapid in younger fish and constantly declines. Total lengths were used in describing growth of smallmouth buffalo in this study because commercial fishermen removed the viscera before bringing the fish to the collection point.

B. Fish Scales in Population Studies

1. Methods

Carlander (1956) evaluated the methods currently used in studying age and growth. Recapture of tagged fish has been the method used in population studies by most investigators. Black (1957), Ricker (1958), Woodbury (1956), and many others have found that the presence of a tag on the fish's body inhibits growth and influences behavior. Hile (1941) analyzed the uses of length-frequency groupings for age determination and found that considerable inaccuracies existed because varying growth rates of individuals eliminate peaks of abundance at older ages. Most investigators agree that the interpretation of growth rings on scales, vertebrae, otoliths, opercular bones, spines, and fin rays is the best source of information on the age and growth of fish in natural habitats.

2. Scale formation and structure

Van Oosten (1957) summarized information on the formation and development of teleost scales. The scale has its origin in a mass of fibroblast cells in the dermal layer of the skin. This cell mass flattens out to form two distinct layers between which there appears a fibrous network. Surrounding osteoblast cells initiate the formation of the bony layer by secreting calcium salts into the osteoid tissue. The fibrillary plate next appears as a thin sheet between the bony scale and the lower layer of osteoblasts.

Growth of the formed scale is continued by addition to the margin of the bony surface layer and the deposition of thin fibrous layers below it. Since the surface layer grows by deposition of materials at the edge, it does not increase in thickness with age and the early surface sculpturing does not change except for wear. This fact makes it possible to determine the age of the fish from its scales. The thickest part of the scale is always in the center. Scales may be thought of as greatly flattened cones (Figure 1). The fibrillary plate is largely or entirely uncalcified and without vascular canals. The bony layer is composed of an organic framework impregnated with inorganic salts, mainly calcium phosphate and calcium carbonate. The surface sculpturing of scales has been described in detail by Creaser (1926).

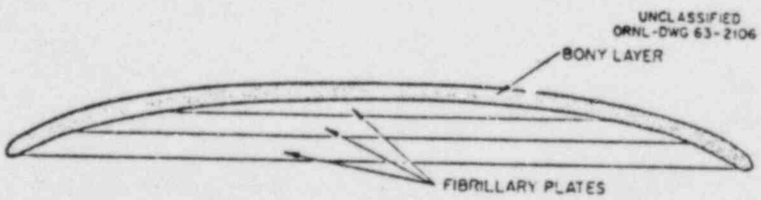

Fig. 1. Cross-Section Diagram of a Fish Scale.

C. Accumulation of Radionuclides by Fish

The advent of atomic energy installations has led to the contamination of some aquatic environments with low-level radioactive wastes. The distribution of these radionuclides in any aquatic environment will vary with the physical, chemical, and biological characteristics of that environment. Concentrations of radionuclides will vary between species and tissues and will fluctuate according to food habits, life cycles, and seasonal changes. A major quantity of the radionuclides within the biota will be held by organisms which make up the primary trophic levels in the early stages of contamination of aquatic habitats where the standing crop of producers exceeds that of the consumers. However, the radionuclides will move to other trophic levels later where they may be concentrated in large quantities (Davis and Foster, 1958).

Krumholz, Goldberg, and Boroughs (1957) summarized the factors which contribute to the accumulation of radionuclides in living organisms. The accumulation and loss of radionuclides depends on their physical half-lives and biological factors contributing to their incorporation in, retention by, and disappearance from the organisms. Water characteristics, such as salinity, per cent composition of the dissolved solids, pH, oxygen-carbon dioxide ratio, and the presence of complexing agents, also affect the accumulation of radionuclides.

The radionuclides of strontium, cesium, cobalt, and ruthenium are considered to be the most important waste products released into the Clinch River from a bioaccumulation point of view. Lack of investigation prohibits generalizations on the accumulation of cobalt by fish, but the other radionuclides have been investigated to some extent.

Boroughs, Chipman, and Rice (1957) traced an ingested dose of cesium-137 in small tuna, Thunnus spp., and found the radionuclide was taken up rapidly by the liver, heart, spleen, and kidneys, but was lost rapidly by these organs. Muscle, gonads, brain, and integument continued to accumulate cesium-137 faster than they lost it. Davis and Foster (1958) suggested that absorption was the primary method of cesium uptake, but experiments into this specific problem are inconclusive. Data on cesium-134 uptake by sunfish in this study support the idea that radiocesium enters the fish's body in considerable amounts through ingestion and accumulates in the soft tissues.

Jones (1960) discovered that bottom-feeding plaice, Pleuronectes platessa, accumulated nitrosyl ruthenium-106 in the liver and spleen eating organisms embedded in contaminated silt. The skin activity of these fish was low. When menhaden, Brevoortia spp., were fed ruthenium-106 there was only 0.05 per cent of the ingested dose remaining in the digestive tract after 128 hours. There was 0.25 per cent in the fish's body or on the skin surface and 0.01 per cent in or on the gills. It can be concluded that ruthenium-106 enters the fish's body by ingestion and accumulates in the active tissues, but only in small quantities.

The radionuclides of strontium have been studied extensively because of their long half-lives and tendency to concentrate in bony tissues. In one of the earliest studies on the absorption of radionuclides by fish, Prosser, et al. (1945) immersed goldfish, Carassius auratus (Linnaeus), in a solution containing strontium-89. They determined that the gills, skeleton, and integument of large goldfish were ten to twenty times more radioactive with strontium-89 than muscle tissue. The scales contained about 80 per cent of the total activity of the integument and the bony element of the gills contained more than the soft portions. Fat tissues were higher than integument in strontium-89 accumulation. Muscle and eggs were the lowest in strontium activity. Brain, heart, liver, testes, and swim bladder were relatively low in strontium activity. Of the total radioactivity of goldfish immersed in radiostrontium, two-thirds of the activity was in the integument, one-sixth in the skeleton including the fins, and one-tenth was in the gills including the bony element. Saurov (1957) found teleosts absorbed strontium-90 from an environmental solution with a higher accumulation in scales and bone than in muscle and internal organs. Bidwell and Foreman (1957) placed rudd, Scardinius erythrophthalmus (Linnaeus), in fresh water tagged with strontium-90 and after 272 days found a high accumulation in scales, a low accumulation in skin, and an intermediate accumulation in bone. Danil'chenko (1958) concluded that strontium-90 enters the vertebrate body and settles in skeletal structures, replacing calcium. Ophel (1962) observed that shiners, Notropis spp., living in Perch Lake, Ontario, which had contained strontium-90 for approximately five years, had a whole body concentration factor of 950 times that of the water. The flesh of perch in the same lake had an average concentration factor of five, while the bone of perch had an average concentration factor of 3,000 at the equilibrium which was reached in the fifth year. Martin and Goldberg (1962) found 95 per cent of the radiostrontium fed to Pacific mackerel, Scomber japonicus Houttuyn, was excreted in twenty-four hours. The remaining five per cent was fixed for at least 235 days with 80 per cent of this activity being in the calcareous tissues. Boroughs, Chipman, and Rice (1957) working with Tilapia observed that about 70 per cent of the radiostrontium accumulated in bone was readily exchangeable and that the remainder was firmly bound in a lattice or to an organic matrix with a slow turnover rate. It can be concluded that radiostrontium enters the fish's body primarily through absorption and accumulates in varying concentrations in all tissues. The highest accumulations occur in the bony tissues where the element has a slow turnover rate.

CHAPTER III

STUDY AREAS, SPECIES, AND METHODS OF STUDY

A. Study Areas

Data on fish in this study were collected from White Oak Creek, the Clinch River, and Watts Bar Reservoir. White Oak Creek, the major source of radioactive waste contamination (Morton, 1961), is within the backwaters of Watts Bar Reservoir and at full pool has an area in excess of five acres. White Oak Creek water is diluted an average of 450 times at the point where it enters the Clinch River, 20.8 river miles upstream from the confluence of the Clinch and Tennessee rivers. Clinch River water is diluted an average of 5.6 times as it enters the Tennessee River at TRM 567.7. Watts Bar Reservoir on the main stream of the Tennessee River is formed by Watts Bar Dam at TRM 529.9. This reservoir contains a surface area of 38,600 acres at full pool with a shoreline of 783 miles (Fig. 2).

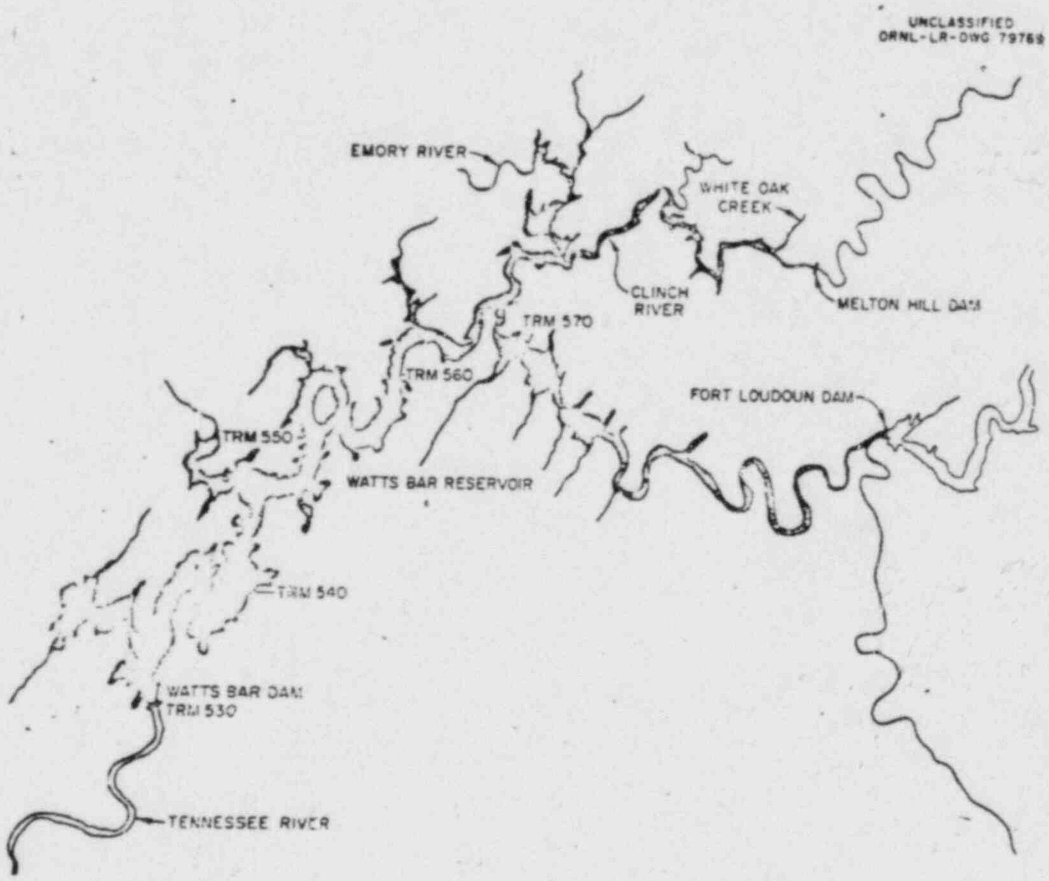

Fig. 2. Clinch River and Watts Bar Reservoir, Tennessee.

B. Species Description

The smallmouth buffalo, Ictiobus bubalus (Rafinesque) is a member of the Sucker Family, Catostomidae. The species is widely distributed from Lake Erie south to Mexico. It is common in the Mississippi, Missouri, Ohio, and Tennessee rivers and their larger tributaries.

The smallmouth buffalo reaches a size in excess of 30 inches and 25 pounds. Schoffman (1944) reported a specimen 30 inches long weighing 25 pounds 8 ounces from Reelfoot Lake, Tennessee. A 33.8 inch specimen weighing 23 pounds was taken from White Oak Creek in May 1962. Specimens of 15 pounds are relatively common in commercial catches on TVA reservoirs, but the average weight is near three pounds.

The smallmouth buffalo are bottom-feeders preferring muddy or silty bottoms. They eat both plant and animal foods. Aquatic insects, mollusks, other small aquatic animals, and algae are common in their diet. Local commercial fishermen occasionally find their stomachs packed with plant seeds. Weiss (1950) reported that in season this species may pack their stomachs with cotton from cottonwood trees or the seeds of other plants and trees. Since the introduction of carp which utilize the same foods and habitats, the two species have been in direct competition. However, both species are abundant in Watts Bar and this competition has not been observed to affect either species adversely.

Smallmouth buffalo evidently inhabit the deeper, swifter waters of the large rivers. No mass migrations, such as spawning runs, have been noted locally. They spawn in the early spring in sloughs and shallow weedy areas. An eight to ten pound female lays 300,000 to 400,000 eggs which are fertilized and scattered on the bottom and left without parental care (Weiss, 1950). There is undoubtedly a high mortality rate for the eggs and young fish. In spite of this, the smallmouth buffalo have flourished in the impoundments of the Tennessee Valley Authority system. They build up large populations. Yields of up to 700 pounds per acre have been reported from small lakes in Missouri.

CHAPTER IV

AGE DISTRIBUTION OF SMALLMOUTH BUFFALO

A. Specialized Methods

1. Annulus determinations

The scale method of age determination was proved to be valid for smallmouth buffalo by Schoffman (1944) and by Eschmeyer, Stroud, and Jones (1944). However, annulus formation in this species is not distinct and this fact leads to some difficulties in age determinations. Cutting over is a term applied to the presence of incomplete circuli between complete circuli. These incomplete circuli are the result of cessation of growth during spawning or adverse environmental conditions. Incomplete circuli may even be formed if the fish is injured. Known age buffalo from Wisconsin were examined and their scales were found to be similar to the Watts Bar fish. The annuli on the scales of the Wisconsin fish were not complete. This phenomenon can be considered to be a characteristic of the species.

Gross inspection of the buffalo scales gave a good idea of the different seasonal growth rates and was found to be useful in aging the fish. There was definite crowding of the circuli immediately inside the annuli toward the focus or center of the scale which corresponds very well to the reduced growth rate that would be expected during the winter.

Annulus formation seems to be followed by wider spaces between the circuli during the summer growth period which is due to the increased growth rate in the summer.

Several criteria were established for defining the true annuli on scales of the smallmouth buffalo. Usually there was some cutting over by the annulus in the lateral fields of the scale near the borders of the anterior and posterior fields. There definitely was some irregularity or pattern change in the posterior field along the annulus which was most obvious in gross inspection of the scale impression. In many scales there appeared to be crowding of the circuli prior to annulus formation and wider spacing of circuli after annulus formation. The change in spacing was most obvious in the anterior field. In many instances the scale was observed to have cracked along the annulus during pressing.

2. Tagboard strip manipulations

Two scales were examined from each fish on two different occasions giving four scales from each specimen in the calculations. In order to achieve the most consistent results in annuli determinations, tagboard strips were employed in this study. A tagboard strip is a strip of paper which is laid directly over the projected image of the scale impression. The strip is marked at the focus, margin, and each annulus of the scale on a radius through the center of the anterior field. The distance from the focus to each annulus and to the margin was measured in millimeters. A ratio was calculated between the distance from the focus to each annulus and the distance from the focus to the margin. A figure representing the percentage of the total distance from the margin to the focus was given to each annulus.

Usually four tagboard strips were made on scales from each fish. In some instances regenerated scales in the sample limited the readable scales to less than four. The tagboard strips from one individual were compared to each other. When the distance ratio to the same annulus corresponded closely on all four tagboard strips the average distance ratio was taken as the correct one. When obvious deviations existed between corresponding distance ratios on any of the four tagboard strips, the scales were reread to determine the correct location of the annulus.

When the tagboard strip examinations were completed the age of the individual was compared to the total length. If the length was out of proportion to the fish's apparent age, the scales were reexamined to determine if the correct age had been calculated. In most instances such fish were determined to have had exceptional growth, either fast or slow, and the calculated age was allowed to stand.

A preliminary age-frequency grouping was made after the completion of scale readings and annuli determinations. Fish in each age group were arranged according to total length. The median total length for each age group was determined. Individuals which deviated widely from the median were reexamined to verify their calculated age. Most of the deviants were found to be in the correct age group and to have had an extremely fast or slow growth rate which had placed them on the margin of the size range for their age group.

B. Analysis of Smallmouth Buffalo Age

After the final determination of the agė of each individual all the specimens were grouped into year classes. A year class designation indicates that the fish has lived through a cértain number of winters. Year class 1 had passed through one winter, but had no annulus. Year class 2 had passed through two winters and had one annulus. This method of year class designations continues through year class 15 which had passed through fifteen winters and had fourteen annuli.

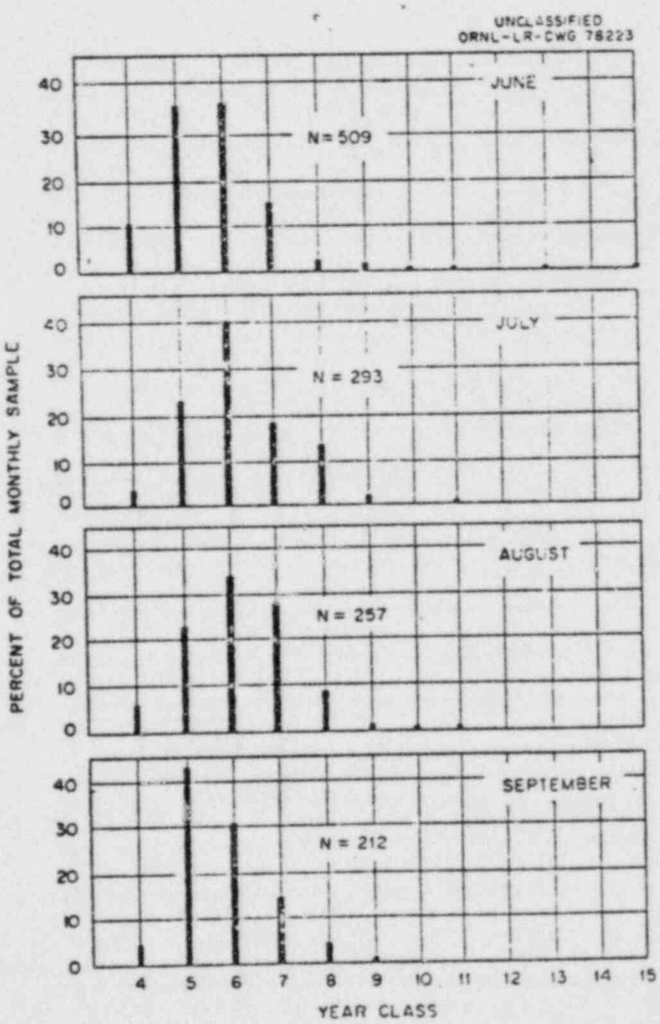

Fig. 3. Age-Frequency Distribution of Watts Bar Smallmouth Buffalo by Month of Collection.

Figure 3 represents the age-frequency distribution for the monthly collections of smallmouth buffalo from Watts Bar Reservoir for June, July, August, and September 1962. Figure 4, page 20, represents the age-frequency distribution for the four-month total. Figure 5, page 21, represents the length-frequency distribution of Clinch River smallmouth buffalo for 1960 and 1961, and the Watts Bar smallmouth buffalo for the summer of 1962.

The smallmouth buffalo of year class 6 were the most common in the commercial catch from Watts Bar during June, July, and August 1962 (Figure 3). However, year class 5 fish became most numerous in the September catch. This was due to recruitment into the vulnerable size during the late summer. The nets used by the commercial fishermen were of three inch mesh, and therefore, were selective for fish that had reached a size of approximately 400 mm in length. During June, July, and August, only the fish in the year class 6 and upwards had reached this minimum catchable size in large numbers. As the temperatures rose during the summer and growth rates increased, fish of year class 5 became large enough to be caught in large numbers. These data do not mean that either the fifth or sixth year class was dominant. The smallmouth buffalo in Watts Bar probably correspond to the theoretical age distribution curve for fish if the population is stable. The younger year classes contain larger numbers of individuals and become succeedingly smaller in each following year as the result of mortality. There is a smaller number of individuals in each succeeding year class unless a dominant year class is formed by exceptional survival for one year class allowing a large number of individuals to enter the next

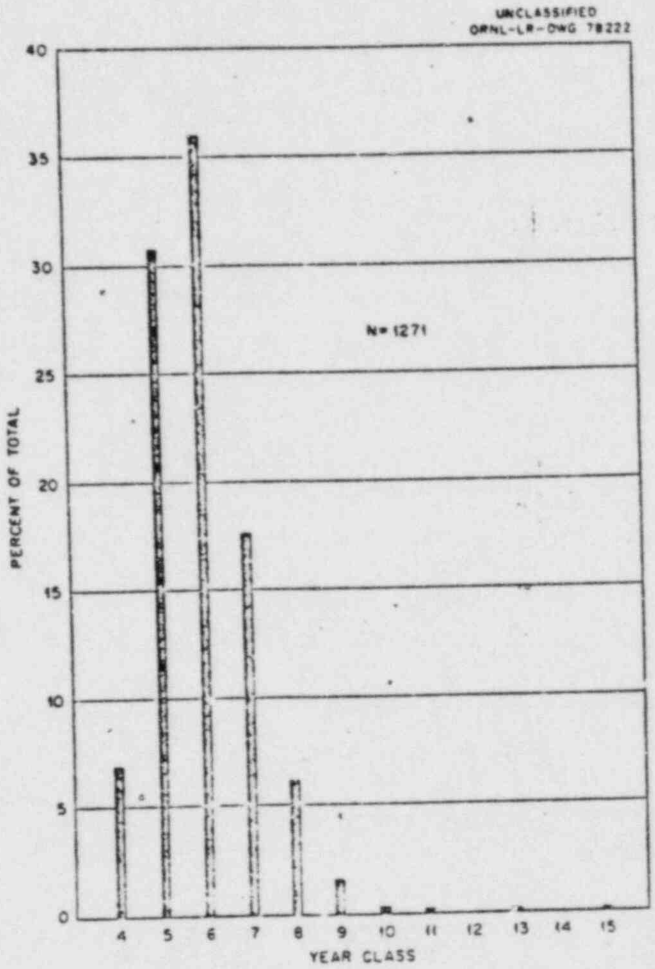

Fig. 4. Age-Frequency Distribution of Watts Bar Smallmouth Buffalo for Total Collection.

year class. No indications of such a dominant year class were found in the smallmouth buffalo population in Watts Bar Reservoir.

The length-frequency distribution graph of Clinch River and Watts Bar smallmouth buffalo (Figure 5, page 21) illustrates the effect of net selectivity. Commerical fishing gear allows only the larger individuals of year class 4 to be captured, although it is probable that more individuals of this year class are present than individuals in year class 5 or 6. The greater frequency of the smaller size fish in the

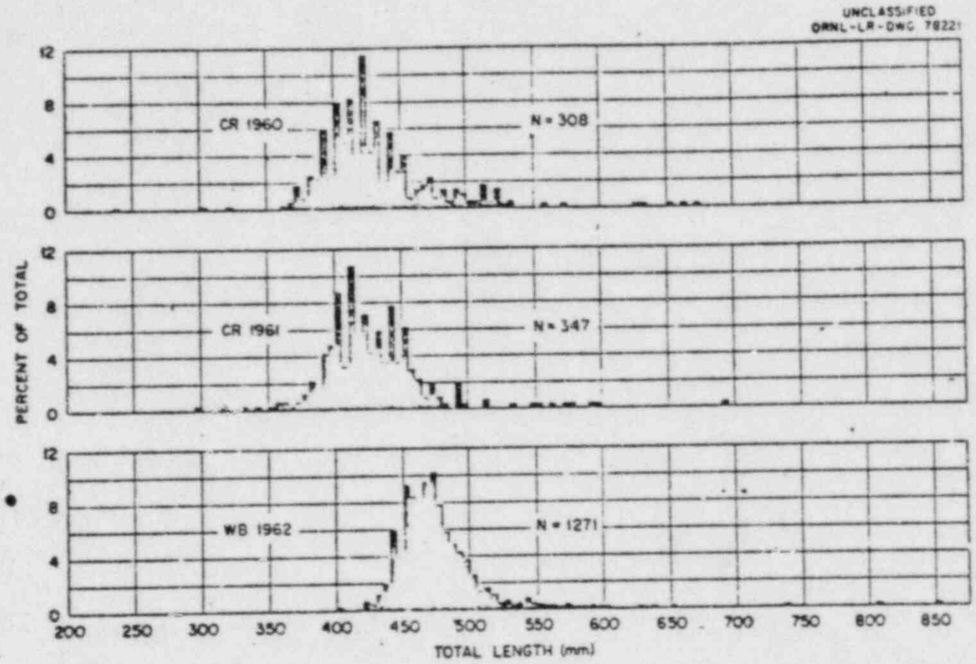

Fig. 5. Length-Frequency Distribution of Clinch River Smallmouth Buffalo for 1960 and 1961, and Watts Bar for 1962.

catches from the Clinch River in 1960 and 1961 resulted from the use of nets made of smaller mesh. A minimum mesh size of about one inch was used on the Clinch River, whereas the minimum mesh size on Watts Bar was three inches.

Assuming that the Watts Bar smallmouth buffalo numbers are representative from year class 6 through 10, the survival rates for the species in these year classes were calculated by the formula:

$$s = \frac{N_{t+1}}{N_t}$$

where N_t = the number of fish in any year class and N_{t+1} = the number of fish in the succeeding year class. Four hundred and ninety fish per thousand in year class 6 enter year class 7, 350 of year class 7 enter year class 8, 260 of year class 8 enter year class 9, and 190 of year class 9 enter year class 10. The number of individuals in the year classes older than ten was too low for calculation of survival rates.

Survival rates for Watts Bar smallmouth buffalo appear to be higher than those calculated from data on Wisconsin fish (Frey and Pedracine, 1938). The Wisconsin fish had 580 individuals per 1,000 surviving from year class 3 to 4, 130 from year class 4 to 5, 400 from year class 5 to 6, and 130 from year class 6 to 7. The Wisconsin data were characterized by the presence of dominant year classes.

Time of annulus formation affects the results of population studies where scale reading forms the basis for age determinations. Table I shows the calculated average total length at the last annulus for fish in each year class. These data are grouped according to month of collection. Calculated length increment since the last annulus was observed to increase steadily from June through September in all year classes except eight, where the June group had 3 mm more growth since the last annulus than the July collection of the same year class. This increase in length since the formation of the last annulus would indicate the annulus is formed sometime prior to June in Watts Bar smallmouth buffalo. Average total length at capture revealed an expected increase in total length between June - July and between August - September in most year classes. However, in all the year classes there was a noticeable decrease in the average total length between the July and August collections. These data indicate that the larger fish from all year classes are caught in June and July and that the smaller fish of the same year classes are caught in August and September. Presumably, fish caught in August should have an added month's growth over

TABLE I

CALCULATED AVERAGE TOTAL LENGTHS (BY MONTH)

Age	Month Col- lected	N	Average Total Length (mm) at Capture	Average Calculated Total Length (mm) at Last Annulus	Calculated Length Increase Since Last Annulus
4	Jun	53	451	424	27
	Jul	11	453	426	27
	Aug	17	441	406	35
	Sep	7	473	437	36
5	Jun	177	459	440	19
	Jul	67	470	449	21
	Aug	58	461	436	25
	Sep	90	469	439	30
6	Jun	180	470	454	16
	Jul	117	473	457	16
	Aug	86	469	450	19
	Sep	75	475	449	26
7	Jun	72	482	470	12
	Jul	53	488	474	14
	Aug	70	474	456	18
	Sep	30	477	456	21
8	Jun	12	536	521	15
	Jul	38	498	486	12
	Aug	21	490	473	17
	Sep	8	500	475	25
9	Jun	9	551	540	11
	Jul	6	549	537	12
	Aug	3	500	481	19
	Sep	2	478	459	19
10	Jun	3	650	643	7
	Aug	1	526	505	21
11	Jun	1	500	495	5
	Jul	1	736	714	22
	Aug	1	545	523	22
13	Jun	1	625	619	6
15	Jun	1	850	842	8

those caught in July. Since all the collections were taken from a region on the main stream of the Tennessee River, it is possible that smallmouth buffalo populations from different tributaries combine to form the Watts Bar mainstream population. If different growth rates existed in the various tributary populations, it would be possible that a segment of the Watts Bar population with a faster growth rate could move into the fishing area early in the summer and that a segment with a slower growth rate could arrive later. This possibility of a segmented population could not be tested from data in this study because all collections were made in the same area.

Recruitment is defined as the addition of new fish to the vulnerable population by growth of smaller size categories. Ricker (1958) described the modal age in the frequency distribution of the catch as lying quite close to the first year in which recruitment can be considered complete. Year class 6 was the modal age in the catch of Watts Bar smallmouth buffalo. The smallest sixth year class fish caught was 400 mm in length. Net selectivity allowed most fish less than 400 mm in length to pass through the 3 inch mesh. Data in this study indicate that recruitment is complete at age six and that fishing pressure is equal on all fish from year class 6 upward.

Recruitment was determined for year classes four through nine by back-calculation of the total length at previous annuli. Total length of 400 mm was considered the minimum size for fish caught in 3 inch mesh nets and the percentage of fish exceeding this minimum length at each age was determined (Table II). Increasing growth rates for Watts Bar smallmouth buffalo in their early years have resulted in younger fish being recruited into the fishery each year for the past five years.

TABLE II

PER CENT VULNERABLE AT EACH AGE

Age	Year Class 4	5	6	7	8	9
1	0	0	0	0	0	0
2	1	0	0	0	0	0
3	84	26	6	2	1	5
4	100	98	72	29	18	15
5	-	100	99	91	76	55
6	-	-	100	100	100	100

CHAPTER V

GROWTH OF SMALLMOUTH BUFFALO

A. Length-weight Relationship

In the tagging operations at Oak Ridge National Laboratory during 1960 and 1961, 655 smallmouth buffalo were taken from the Clinch River. These fish were measured to the nearest one-half centimeter and weighed to the nearest ten grams. In the normal course of operations all the fish-tagging data are recorded on IBM record cards. The length and weight data on the smallmouth buffalo were used in calculating a regression equation of weight as a function of length. This equation expressed the rate of change in fish weight as total length increased. Calculations were made by IBM 709 computer. The length-weight relationship of the 655 smallmouth buffalo from the Clinch River

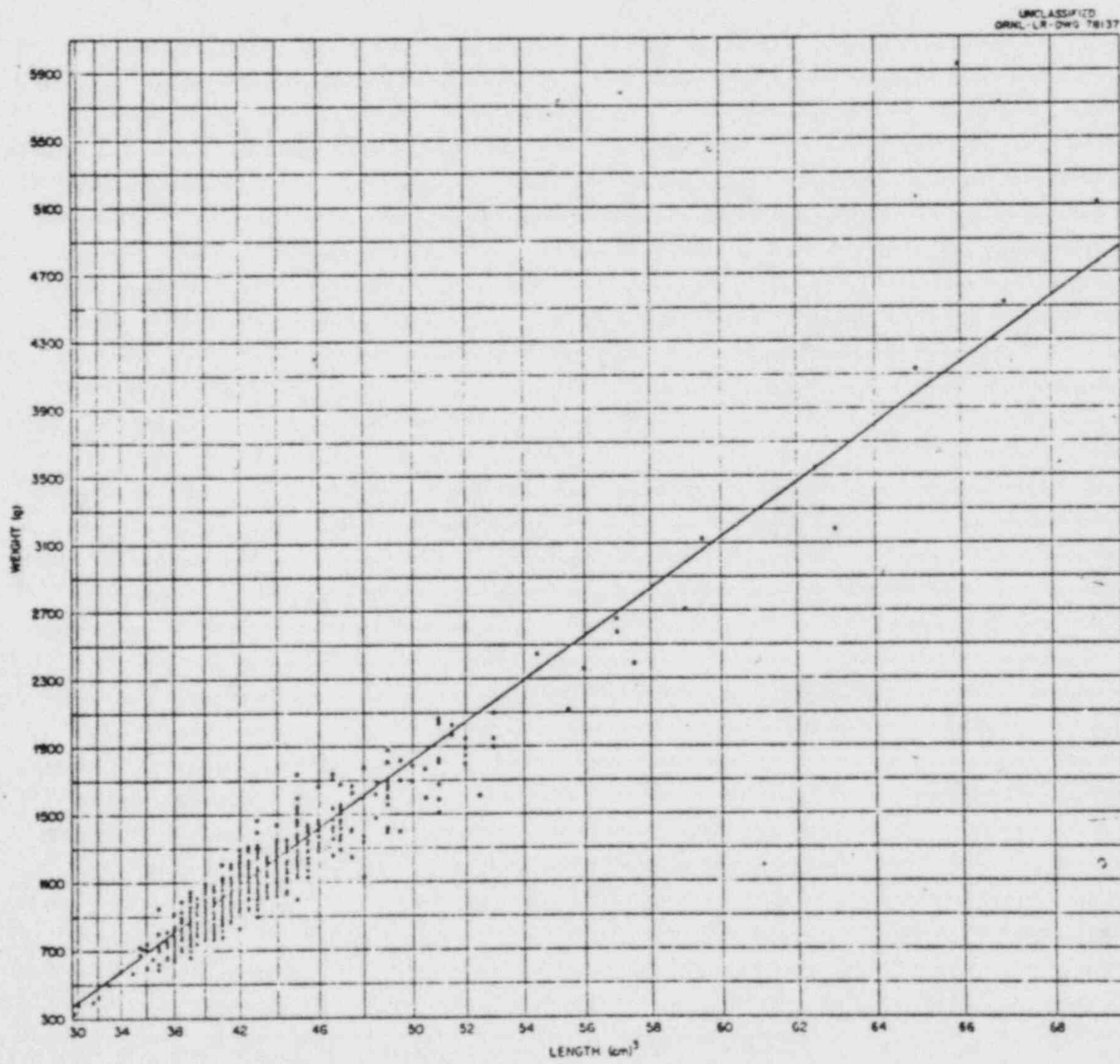

Fig. 6. Length-Weight Relationship of Clinch River Smallmouth Buffalo.

is illustrated by the scatter graph (Figure 6) with each point representing one individual. The calculated regression line is plotted on the graph.

Weight of a fish is considered to be a function of length (Hile, 1936). If the form and specific gravity of a fish were constant throughout its entire life the relationship between length and weight could be expressed as a constant. The length-weight relationship is expressed usually by the formula:

$$W = aL^n$$

where W = weight in grams, L = total length in millimeters, a is a constant, and n is an exponent. The calculated regression coefficient (a) is 0.9976 and the exponent (n) is 3. These data result in the formula for the rate of change in fish weight:

$$W = 0.9976\ L^3$$

The 95 per cent confidence interval on a is (0.9749 - 1.0204). Standard error of the regression coefficient is 0.0116. The length-weight regression line may be used as a nomogram for the conversion of measured total length to estimated weight for smallmouth buffalo within the length range covered by the nomogram.

B. Growth Analyses

Growth rate calculations were made on 1,271 smallmouth buffalo collected over a one week period each in June, July, August, and September 1962 from Watts Bar Reservoir. Total length of each fish to the nearest millimeter was used in conjunction with the distance ratio between focus-annulus and focus-margin of scales from the age determination study. The total length of each individual at each previous annulus was determined by use of the formula (Bertin, 1958):

$$L_1 = \frac{e_1}{e_m} \times L_t$$

where L_1 = total length of fish at the time the first annulus was formed, e_1 = distance from scale focus to the first annulus, e_m = distance from scale focus to margin, and L_t = total length of fish at capture. This formula is based on the fact that the size of the scales increases proportionally as the size of the fish increases. Annulus distance ratios and the individual's total length at time of capture were recorded on IBM record cards. Total length of each fish at each successive annulus was back-calculated, summed, and averaged for each year class by month of collection. All calculations were made by IBM 1420 Computer.

Absolute growth is the average size attained by the fish at each age. Length was the parameter selected for describing the growth of Watts Bar smallmouth buffalo because the fish were sampled at a local fish wholesale house after having been gutted on the lake by commercial fishermen. Absolute growth of the smallmouth buffalo has varied widely over the past fourteen years (Table III). The number of individuals in the older age groups (ten, eleven, thirteen, and fifteen) was too small for accurate generalizations on these year classes. The calculated total length at the end of the first year's growth has increased steadily from 98 mm for year class nine through 134 mm for year class four.

TABLE III

ABSOLUTE GROWTH OF SMALLMOUTH BUFFALO

Age	N	Average Total Length (mm) at Capture	Calculated Total Length Average/Range at Successive Annuli									
			1	2	3	4	5	6	7	8	9	10
4	88	451 391-520	134 82-246	303 206-400	422 368-484							
5	392	463 420-543	119 75-181	277 152-372	382 257-445	441 356-502						
6	458	471 400-595	110 71-175	253 147-344	348 232-465	412 312-534	453 380-559					
7	225	480 430-594	104 71-215	233 143-372	318 238-485	385 299-508	432 363-550	465 398-582				
8	79	502 451-600	103 61-179	219 146-318	306 245-450	372 311-522	422 356-540	459 397-576	487 424-594			
9	20	535 465-650	98 71-149	207 152-268	290 230-406	355 296-457	412 363-489	458 402-552	493 428-598	522 446-631		
10	4	619 526-8[illegible]	120 89-177	231 205-290	314 279-378	381 337-459	439 384-531	491 421-604	535 452-676	571 479-733	609 505-797	
11	3	594 500-736	91 65-125	165 140-191	238 210-280	328 270-420	397 330-508	444 370-559	476 400-596	505 430-633	538 460-670	577 495-714

The increase in calculated total length at the end of the first year's growth amounted to 5, 1, 6, 9, and 15 mm respectively for year class eight through four.

The relationships between absolute growth of the various year classes are apparent in Figure 7. The dashed lines connect the length for year classes nine through four at corresponding ages. The increasing slope of the dashed lines indicates that Watts Bar smallmouth buffalo have been increasing in total length in each successive year class. The increase in absolute growth for successive year classes probably was the result of improved food availability through removal of competing fish by commercial fishing.

Fishing pressure on the smallmouth buffalo has increased in Watts Bar Reservoir since 1958 when 15,687 pounds were caught through 1961 when 59,328 pounds were caught. The increase in fishing pressure would

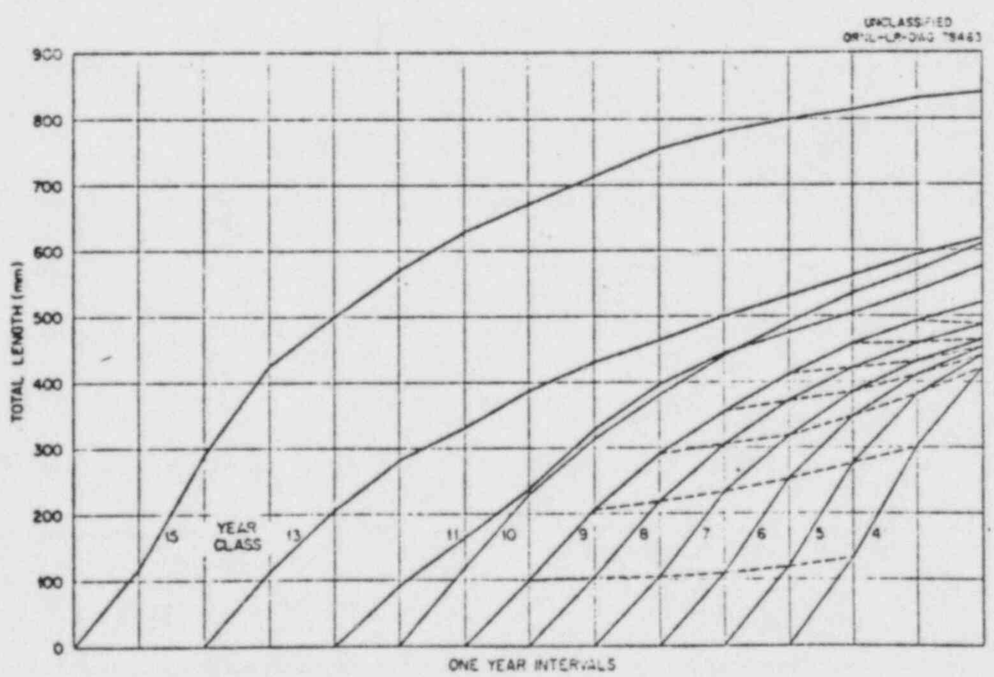

Fig. 7. Absolute Growth Rates of Watts Bar Smallmouth Buffalo.

result in decreased population density, in turn leading to improved food availability. However, smallmouth buffalo density data are not available at this time.

Absolute growth in weight was calculated from data on year classes five through nine. The average calculated total lengths for these year classes at annulus 4, 5, 6, 7, and 8 (Table III, page 29) were averaged. These average total lengths were converted to estimated weights by use of the length-weight regression nomogram (Figure 6, page 26). Watts Bar smallmouth buffalo had an average weight of 895 g at the time their fourth annulus was formed. The fish gained 275 g during their fifth year of life, 260 g during the sixth, 290 g during the seventh, and 355 g during the eighth. Insufficient numbers of individuals in the sample from other year classes prohibited calculation of weight increases in other years.

The average annual growth increment (Table IV) is largest for the second year of life in all year classes where adequate numbers exist in the sample. In year classes four through nine the second year's growth exceeded that of the first year by 35, 39, 33, 25, 13, and 11 mm respectively. In year classes ten, eleven, and thirteen the average annual growth increment for the second year of life was less than the first. The smaller increment for the second year of life in these three year classes is questionable because of small numbers of individuals in these year classes and the fact that annulus determinations of these older fish are subject to considerable inaccuracies. In year classes four through nine the third year's growth was less than that of the second year by 50, 53, 48, 44, 29, and 26 mm respectively.

TABLE IV

AVERAGE ANNUAL GROWTH INCREMENT (MM)

Year Class	Year 1	2	3	4	5	6	7	8	9	10	11	12	13	14
4	134	169	119											
5	119	158	105	59										
6	110	143	95	64										
7	104	129	85	67	47	33								
8	103	116	87	60	50	37	28							
9	98	109	83	65	57	46	35	29						
10	120	111	83	67	58	52	44	36	38					
11	91	74	73	90	69	47	32	29	33	39				
13	113	93	75	50	57	43	32	37	31	32	31	25		
15	119	170	36	77	68	59	43	42	43	25	17	17	17	9

The decrease in average annual growth increment continued through succeeding years after the second year's growth for all year classes examined. However, there were some fluctuations up and down, probably as a result of some favorable growth seasons. A graphic illustration of the annual growth increments (Figure 8) clearly shows the relationships between the amount of total length added each year by year classes nine through four. Apparently the habitat conditions for fish during their first three years of life have been improving in Watts Bar Reservoir since 1954, the year of spawning for year class nine. Each year class has been successively larger at the time it formed its first,

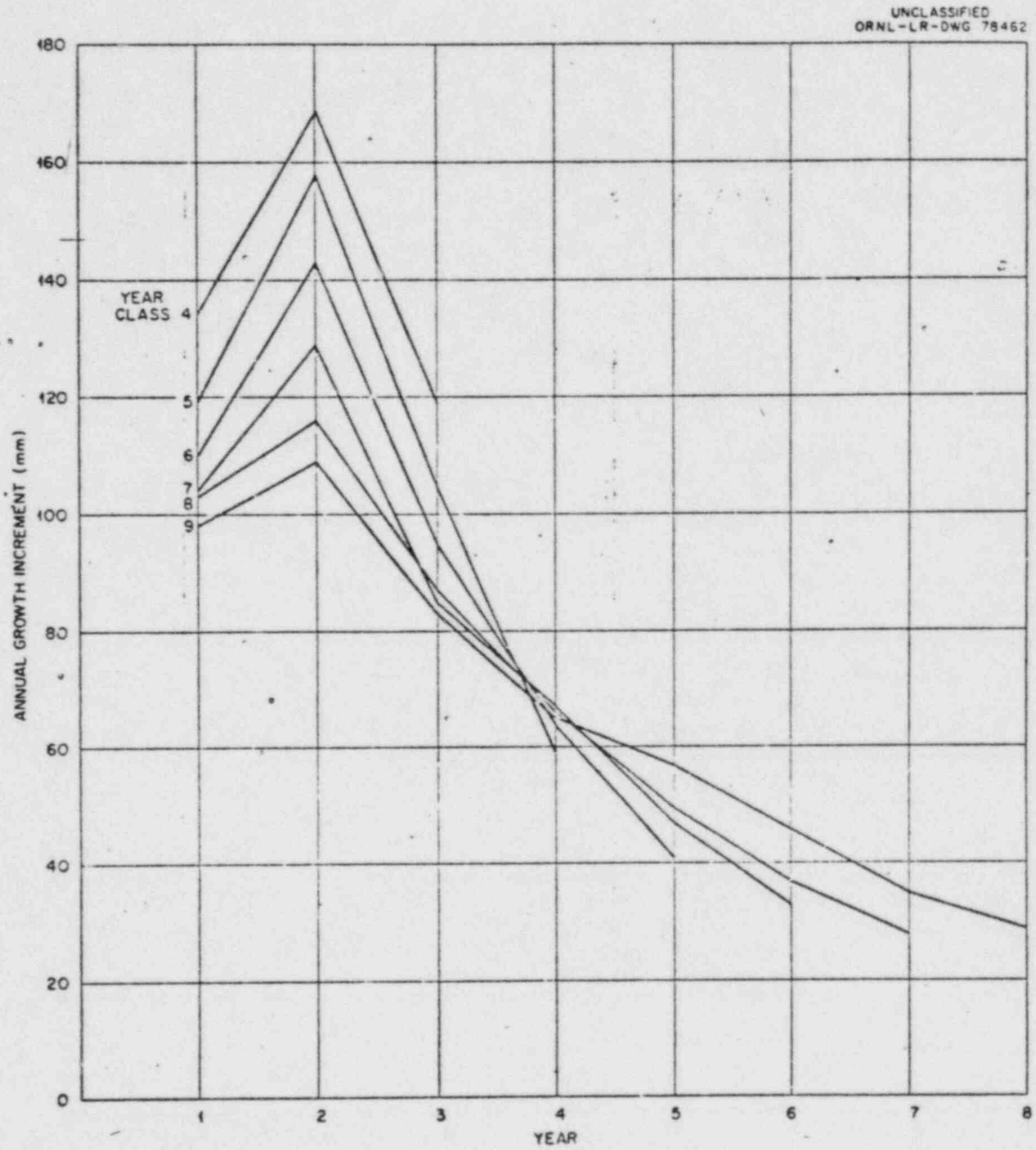

Fig. 8. Average Annual Growth Increments of Watts Bar Smallmouth Buffalo.

second, and third annuli. There was one unexplained exception where the difference was only 2 mm. Year class seven had a smaller growth increment during its third year of life then year class eight.

Absolute growth of Watts Bar smallmouth buffalo was compared to growth of the species in other areas (Table V, page 35). Calculated lengths at each age for year classes four through nine were averaged. These data were compared to back-calculated growth data on smallmouth buffalo from Grand Lake, Oklahoma (Thompson, 1950), Wister Reservoir, Oklahoma (Hall, 1951), Chickamauga Reservoir, Tennessee (Eschmeyer, Stroud, and Jones, 1944), and Reelfoot Lake, Tennessee (Schoffman, 1944). Smallmouth buffalo in Grand Lake, Oklahoma, were larger than those in Watts Bar at the end of the first year. The species was similar in size at the end of two years in both areas. However, Watts Bar smallmouth buffalo at three, four, and five years of age were larger than those in Grand Lake by 40, 53, and 60 mm respectively. Smallmouth buffalo in Wister Reservoir, Oklahoma, exceeded those in Watts Bar Reservoir at every age from one through six. This species is larger in Reelfoot Lake, Tennessee, than in Watts Bar at every age from one through seven. Smallmouth buffalo growth data from Grand Lake, Wister Reservoir, and Reelfoot Lake were only parts of pre-impoundment studies which included many fish species. The above-mentioned reports only described the growth and did not attempt to analyze it.

Smallmouth buffalo growth in Chickamauga Reservoir, a mainstream reservoir located immediately downstream from Watts Bar, should have been more similar to the growth of the species in Watts Bar than the growth of smallmouth buffalo in any of the other three areas. However, Chickamauga smallmouth buffalo were considerably smaller at ages one and two than Watts Bar fish. The Chickamauga fish were collected in 1944 and the Watts Bar fish were collected in 1962. It is possible that growth conditions have improved considerably in both reservoirs

TABLE V

TOTAL LENGTHS (MM) OF SMALLMOUTH BUFFALO

Age	Watts Bar, Tennessee 1962	Grand Lake, Oklahoma Thompson, 1950	Wister Res., Oklahoma Hall, 1951	Chickamauga Res., Tennessee Eschmeyer, Stroud, and Jones 1944	Reelfoot Lake, Tennessee Schoffman, 1944
1	111.4	154.9-218.4	127.0	96.5	284.5
2	248.7	215.9-256.5	342.9	162.6-182.9	388.6
3	344.7	264.2-304.8	408.9		439.4
4	393.0	302.3-340.4	487.7		467.4
5	429.8	337.8-370.8	520.7		543.6
6	460.7		571.5		594.4
7	490.0				647.7
8	522.0				
9					782.3
12					835.7

during the eighteen year time lapse between the two collections. No other possible explanations were found for the difference.

Relative growth is percentage growth in which the increase in size in each time interval is expressed as a percentage of the size attained at the beginning of that time interval. Relative growth was calculated by dividing the annual growth increment by the total length of the fish at the beginning of that year (Table VI).

Relative growth in most species is most rapid in the younger fish and constantly declines. If fish size at hatching were considered to be zero the percentage growth at the end of the first year would be infinite. Undoubtedly smallmouth buffalo at hatching have a measurable size, but lack of data on these small fish prohibited determination of the exact relative growth for year one. Walker and Frank (1952) reported fish in year class one had reached a total length of approximately 50 mm within one or two months after hatching, indicating a measurable size at the time of hatching. Watts Bar smallmouth buffalo were concluded to correspond to the theoretical relative growth curve with a high rate of relative growth during the first year and a constantly declining rate in succeeding years.

Per cent growth per year was averaged for the first eight years of life for Watts Bar smallmouth buffalo in year classes four through nine. When these data are compared to per cent growth of smallmouth buffalo from other areas (Thompson, 1950; Hall, 1951; Eschmeyer, Stroud, and Jones, 1944; and Schoffman, 1944) some striking dissimilarities are seen. Relative growth of Watts Bar buffalo averaged 125 per cent for the second year of life and was exceeded only by Wister Reservoir buffalo which had 170 per cent growth during the same year.

TABLE VI

PER CENT GROWTH PER YEAR

Year Class	Year 2	3	4	5	6	7	8	9	10	11	12	13	14
4	126.1	39.2											
5	132.7	37.9	15.4										
6	130.0	37.5	18.3	9.9									
7	124.0	36.4	21.0	12.2	7.6								
8	126.0	39.7	21.5	13.4	8.7	6.1							
9	111.2	40.0	22.4	16.0	11.1	7.6	5.8						
10	92.5	35.9	21.3	15.2	11.8	8.9	6.7	6.6					
11	81.3	44.2	37.8	21.0	11.8	7.2	6.0	6.5	7.2				
13	82.3	36.4	17.7	17.2	11.0	7.4	7.9	6.2	6.0	5.5	4.2		
15	142.8	47.0	18.1	13.5	10.3	6.8	6.2	6.0	3.3	2.1	2.1	2.0	1.0

Grand Lake, Reelfoot, and Chickamauga buffalo had 27, 36, and 82 per cent growth respectively during their second year. Watts Bar fish had 39 per cent growth during their third year which exceeded that of all the other areas. Grand Lake buffalo had 20 per cent, Wister 19 per cent, and Reelfoot 13 per cent during the third year. Respective relative growth rates for Watts Bar, Wister, Grand Lake, and Reelfoot during the fourth year were 20, 19, 13, and 6 per cent. During the fifth year they were 13, 7, 10, and 16 per cent. Wister and Reelfoot both had 10 per cent relative growth during the sixth year which exceeded the Watts Bar rate of 9 per cent. During the seventh year Watts Bar smallmouth buffalo had 7 per cent relative growth which was exceeded by Reelfoot's 9 per cent. During the eighth year Watts Bar fish had a rate of 6 per cent. Variations in relative growth rates for smallmouth buffalo from different areas in the third through eighth years of life indicate extrinsic factors, such as habitat changes or variations in food availability through changing population densities, are influencing the increase in size.

Instantaneous growth rate is the natural logarithm of the ratio of final size to initial size for a unit of time, usually one year. Instantaneous growth rates for Watts Bar smallmouth buffalo were computed from all the calculated average total lengths of all fish in each age group for each previous year. Annual instantaneous growth rates (Table VII) indicate the highest value for any year occurred in the 1-2 year interval in year class fifteen. The rates then steadily declined to a low in the eleventh year class. The data for year classes ten through fifteen cannot be considered valid because of the low

TABLE VII

ANNUAL INSTANTANEOUS GROWTH RATES

Year Class	Time Inverval (year)												
	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14
4	0.815	0.329											
5	0.846	0.322	0.140										
6	0.833	0.322	0.166	0.095									
7	0.807	0.308	0.191	0.113	0.077								
8	0.751	0.337	0.199	0.122	0.086	0.058							
9	0.747	0.337	0.199	0.148	0.104	0.077	0.058						
10	0.658	0.308	0.191	0.140	0.113	0.086	0.068	0.068					
11	0.593	0.365	0.322	0.191	0.113	0.068	0.058	0.068	0.068				
13	0.599	0.308	0.166	0.157	0.104	0.068	0.077	0.058	0.058	0.058	0.039		
15	0.888	0.385	0.166	0.131	0.095	0.068	0.058	0.058	0.030	0.020	0.020	0.020	0.010

number of individuals in the samples. However, there was a constant rise in the first year's annual instantaneous growth rate from year class nine through year class five, followed by a slight decline in year class four. The annual instantaneous rates of growth for these year classes in the second and succeeding years do not appear to have followed a particular pattern, but rather to have fluctuated from year to year with the variations in environmental conditions. Instantaneous growth rates also were calculated on a monthly basis, but the data were inconclusive because of the slight differences in rates.

Growth data on Watts Bar smallmouth buffalo were compared to the growth of buffalo in Wisconsin (Frey and Pedracine, 1938). Comparisons were complicated by the fact that the Wisconsin data included the largemouth buffalo, Ictiobus cyprinella (Valenciennes), in small numbers with about equal numbers of smallmouth buffalo and black buffalo, I. niger (Rafinesque). Wisconsin buffalo were found to have the most growth during their second year of life. The Watts Bar buffalo population also has the most growth during their second year. These data suggest that smallmouth buffalo characteristically have a higher absolute growth rate during their second year of life, which may be the result of a change in food habits after the first year of life.

Watts Bar buffalo averaged 5 mm less than the Wisconsin fish at the end of the first year, but exceeded the Wisconsin buffalo by 12 mm in the second year, 32 mm in the third, 18 mm in the fourth, and 4 mm in the fifth. Watts Bar buffalo were 8 mm shorter than the Wisconsin fish in year class six. Year class seven Watts Bar fish averaged 19 mm longer than Wisconsin buffalo. The Wisconsin collection was made up of large numbers of fish in year classes two through four, whereas, the Watts Bar collections were larger for year classes five through seven.

Large numbers of Wisconsin buffalo were found within a single age group which suggests a dominant year class. There also was evidence that the Wisconsin fish had cycles of abundance with good seasons coming every third year. Watts Bar data gave no indication of dominant year classes or a cyclic population.

Lee (1912) reported that estimated fish growth in earlier years of life, as determined from scales of the older fish, often was less than the observed growth. This observation, known as Rosa Lee's phenomenon, has been accepted as a true characteristic of some fish populations (Hile, 1936). A comparison was made of absolute growth in early years for year classes six through fifteen which were assumed to be equally vulnerable to the commercial fishing. There was a steady decrease in the calculated total lengths in early years from year class six through year class nine, but up and down fluctuations followed through year class fifteen. These fluctuations tend to preclude the presence of Lee's phenomenon in the Watts Bar smallmouth buffalo population. However, data on year classes ten through fifteen are questionable because of small numbers of fish of these ages in the sample Data on year classes six through nine only suggest the presence of Lee's phenomenon. In order to adequately test for the presence of this phenomenon samples of the same year class should be taken in several successive seasons to avoid possible bias introduced by differing growth rates in different years. Collections in this study were limited to one year.

The term growth compensation has been applied to a phenomenon in fish species where individuals that had grown rapidly in early life were approached in size in succeeding years by individuals which had a relatively slow growth rate in their early years. Growth compensation apparently is produced by a change in the relative rate of increase among the larger and smaller fish in any age group. Scott (1949) pointed out that growth compensation is associated with a decrease in the average yearly increment. Inspection of the average annual growth increments of Watts Bar smallmouth buffalo (Figure 8, page 33) revealed that there was a complete reversal in the relative position of the annual growth increments for year classes four through nine beginning during the fourth year of life and continuing through the fifth year. This reversal indicates that the large fish which had grown rapidly during their first three years of life start slowing down in their growth rate during their fourth year of life and that the small fish with a slow initial growth rate begin to grow at a relatively faster rate. Growth compensation does exist in the Watts Bar smallmouth buffalo population.

CHAPTER VI

STABLE AND RADIOCHEMICAL COMPOSITION OF FISH TISSUES

A. Stable Chemistry

A composite sample was made up of approximately four scales from each individual in the June collection of Watts Bar smallmouth buffalo. This sample was oven dried at 104° C.

An ash sample was sent to the Spectrochemical Laboratory of the Oak Ridge National Laboratory Analytical Chemistry Division for spectrographic analysis. The values reported (Table VIII) were visual estimates taken from a standard plate and using a common graphite matrix. These values are to be interpreted as approximations and are within the range of 1/2 to 2 times the actual concentrations.

One ash sample was put into solution by alternate addition of concentrated HCL, 30 per cent H_2O_2, concentrated HNO_3, and 0.1N HCL, with each step being preceded by complete evaporation. The sample finally was brought to twenty-five milliliter volume with distilled water. This sample was analyzed by flame spectrophotometry by the Oak Ridge National Laboratory Analytical Chemistry Division. Results of these stable chemical analyses are given in Table IX, page 45.

Smallmouth buffalo scales have a mineral residue content of 46.05 per cent by weight. Moisture content of the scales was not determined. Calcium was by far the most abundant element amounting to 0.142 mg/g fresh weight of the scale. There followed in decreasing abundance: sodium, potassium, manganese, zirconium, iron, aluminum, lead, silicon,

TABLE VIII

SPECTROGRAPHIC ANALYSIS FOR STABLE ISOTOPES IN FISH SCALES

Element	Ash Content (ppm)
Sodium	5000 - 10000
Potassium	500 - 1000
Manganese	200 - 300
Zirconium	Less than 200
Iron	50 - 100
Aluminum	20 - 100
Lead	Less than 100
Silicon	20 - 50
Cobalt	Less than 50
Chromium	Less than 50
Tin	Less than 50
Zinc	Less than 50
Molybdenum	Less than 50
Nickel	Less than 50
Rubidium	10 - 20
Strontium	10 - 20
Titanium	Less than 20
Vanadium	Less than 20
Boron	5 - 10
Copper	Trace - 10
Lithium	1 - 5
Silver	Traces

TABLE IX

FLAME SPECTROPHOTOMETRY ANALYSIS FOR STABLE ISOTOPES IN FISH SCALES

Element	Ash Content (ppm)
Strontium	266
Calcium	308,000
Potassium	1,720
Sodium	9,160
Cesium	1
Rubidium	1

cobalt, chromium, tin, zinc, molybdenum, nickel, strontium, rubidium, cesium, titanium, vanadium, boron, copper, lithium, and silver. A comparison of ash content of strontium (0.266 mg/g) to that of calcium (308 mg/g) shows a stable strontium-calcium ratio of 0.394×10^{-3} in fish scales.

Van Oosten (1957) summarized data on fish scale analyses and reported that fish scales were composed of 41 to 84 per cent organic protein and up to 59 per cent mineral residue in air dry matter. The moisture content of menhaden scales was 20.6 per cent, organic matter content 46.8 per cent, and mineral ash content 32.6 per cent. Chemical compounds and elements present were mainly $Ca_3(PO_4)$ and $CaCO_3$ with lesser amounts of $Mg_3(PO_4)_2$, CaF_2, Na_2CO_3, NaCl, Fe, S, As, CaO, MgO, P_2O_5, and CO_2.

Results of stable chemical analyses of smallmouth buffalo scales (Tables VIII, page 44, and IX, page 45) agree with Van Oosten on the importance of calcium and the presence of magnesium, sodium, and iron in fish scales. Van Oosten did not discuss the other elements found in this study.

B. Radiochemistry

Bones and scales of smallmouth buffalo from the Clinch River were analyzed by gamma spectrometry using the ORNL Low-level Radiochemical Laboratory. Bone samples were prepared by removing the flesh, cleaning in tap water, oven drying at 104° C for twenty-four hours, and pulverizing. Scale samples were prepared by scrubbing them in tap water to remove epidermal tissues and drying at 104° C for twenty-four hours. The samples were analyzed for gamma emitters; ruthenium-106, cesium-137, and cobalt-60 were found to be present (Table X).

TABLE X

RADIOCHEMICAL COMPOSITION OF SMALLMOUTH BUFFALO BONES AND SCALES

	x 10^{-7} μc/g		
Tissue	Ru^{106}	Cs^{137}	Co^{60}
Bone		135	
Bone		108	108
Scales	347		198

Of the four major radionuclide contaminants in the Clinch River, strontium-90, cesium-137, cobalt-60, and ruthenium-106, only strontium-90 can be considered a bone seeker. Nelson and Griffith (1962) in analyzing white crappie from the Clinch River found an average accumulation of strontium-90 of 120 μμc/g in bone. However, strontium-90 concentrations in bone were found to vary from 3.0 μμc/g to 297.0 μμc/g in white crappie bone. It can be assumed that strontium-90 was present in the bone and scales of smallmouth buffalo, but no analyses were made for this radionuclide.

Scales and bony tissues of fish analyzed in this study were found to contain radionuclides of ruthenium, cesium, and cobalt. These elements are not bone-seekers and it would not be expected that they should be found in large quantities in bony tissues. Analyses of other tissues probably would have revealed higher concentrations of these radionuclides, but this study was concerned only with those radionuclides accumulated in bony tissues except for strontium-90. Few of the fish taken in this study contained enough accumulated radionuclides in their scales and bones for accurate analysis.

C. Radiometric Surveys

Radiometric surveys were made of fish tissues to determine the quantity of activity from accumulated radionuclides. Scales were prepared by scrubbing them in tap water and drying at 104° C. Bones were scraped clean, scrubbed in tap water, and dried at 104° C for twenty-four hours. Gross gamma counts were made of the dried samples using a gamma spectrometer equipped with a 3 by 3 inch sodium-iodide crystal with a 1 by 1 inch well. Gross beta counts were made of the same samples using a counter equipped with a Geiger-muller tube. A comparison of the sensitivity of these two counting methods is made in Table XI.

Beta surveys revealed the presence of accumulated radionuclides in tissues which showed no gamma activity. The high sensitivity of beta counting results from the fact that Co^{60}, S^{90}-Y^{90}, Zr^{95}-Nb^{95}, Ru^{106}-Rh^{106}, Cs^{137}, and Ce^{144}-Pr^{144} decay primarily by negative beta particle emission. Of the radionuclides found in fish scales from the Clinch River, only Zn^{65} with 98.5 per cent decay by orbital electron capture and 1.5 per cent decay by positive beta particle emission does not decay primarily by negative beta particle emission.

The primary purpose of the radiometric surveys was to determine from which fish the scales would be autoradiographed. Most of the autoradiographic exposure of No-screen X-ray film is produced by beta particles, therefore, gross beta counting was selected as the best method of screening the scales. Radiometric surveys were made with a Model D47 Gas Flow Counter manufactured by Nuclear-Chicago Company. The counter was equipped with a "Micromil" window and automatic sample changer. Results of this counting were grouped by capture location and month of capture. Frequency distribution of the counting results of all the Clinch River smallmouth buffalo appear in Figure 9. Figures 10 through 13, pages 50 through 51, show the frequency distribution of beta counts of scale samples from the Watts Bar smallmouth buffalo for the months of June through September respectively.

TABLE XI

COMPARISON OF BETA AND GAMMA SURVEYS OF FISH TISSUES

Species	Capture Location	Gross Beta cpm		Gross Gamma cpm	
		Scales	Bone	Scales	Bone
Carpsucker	White Oak Creek	45-111	0	63	0
"	"	40	184	0	191
"	"	28	117	105	0
"	"	39-114	111	0	0
"	"	23- 38	66	0	0
White Bass	Watts Bar	2	-	44	-
Gizzard Shad	CRM 19.0	0	0	0	0
Sunfish Hybrid	"	0	0	0	0
"	White Oak Lake	6- 13	7	0	0
Flat Bullhead	"	0	14	0	0
"	"	-	41	-	0
"	"	-	32	-	210
Warmouth	"	-	50	-	0
Bluegill	"	9	10	0	0
"	"	4	4	0	21
"	"	8	10	0	0
White Crappie	White Oak Creek	0	16	0	0
"	"	0	6	0	0
"	"	0	27	0	0
"	"	0	2	0	0
"	"	0	6	0	0
"	"	0	0	0	0
Black Crappie	White Oak Lake	0	8	0	0
Smallmouth Buffalo	White Oak Creek	0	6-10	0	0
"	"	43	200	55	0
"	"	95	208	0	0
"	"	75	132	0	0
Yellow Bullhead	Watts Bar	0	-	31	-
"	White Oak Creek	-	55	-	0
Channel Catfish	"	-	21	-	0
Golden Redhorse	"	-	380	-	0
"	"	4	5	0	0
"	"	2	6	0	0
Goldfish	"	2	6	0	0
Carp	White Oak Lake	21- 37	58	-	595
"	CRM 20.0	4- 5	0	6	0
	"	5	0	0	0
Largemouth Bass	White Oak Creek	0	0	0	0

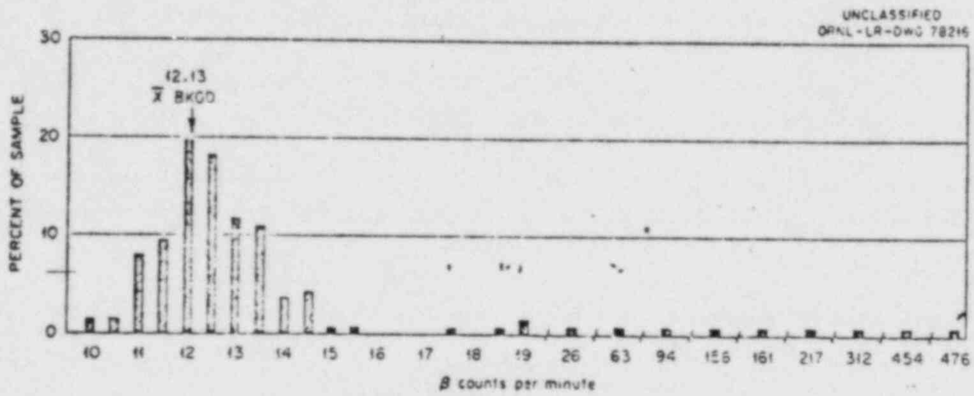

Fig. 9. Frequency Distribution of Gross Beta Counts of Scales from 146 Clinch River Smallmouth Buffalo.

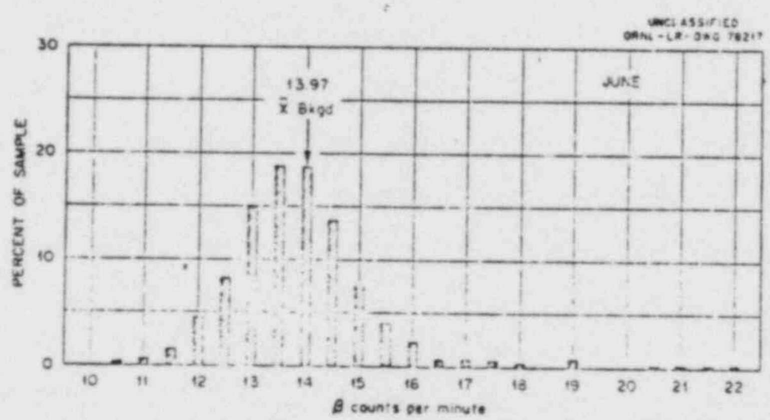

Fig. 10. Frequency Distribution of Gross Beta Counts of Scales from 509 Watts Bar Smallmouth Buffalo Caught in June 1962.

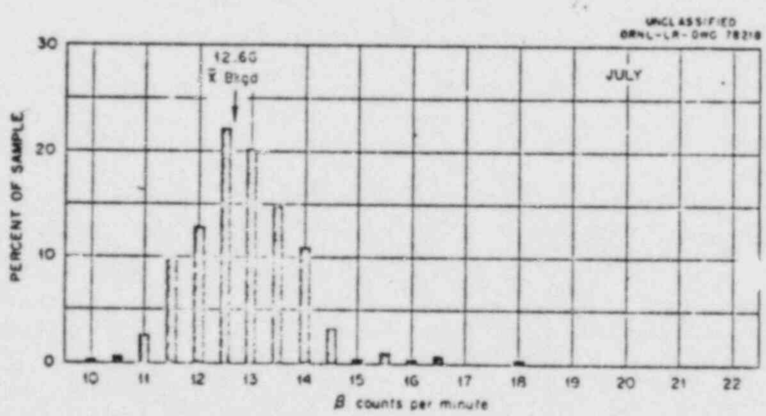

Fig. 11. Frequency Distribution of Gross Beta Counts of Scales from 293 Watts Bar Smallmouth Buffalo Caught in July 1962.

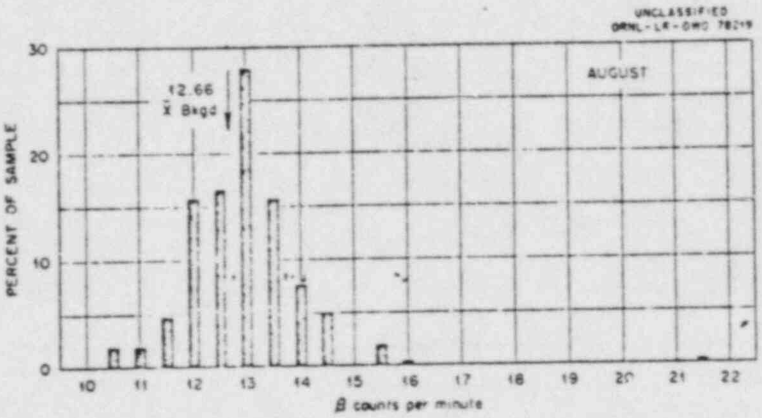

Fig. 12. Frequency Distribution of Gross Beta Counts of Scales from 257 Watts Bar Smallmouth Buffalo Caught in August 1962.

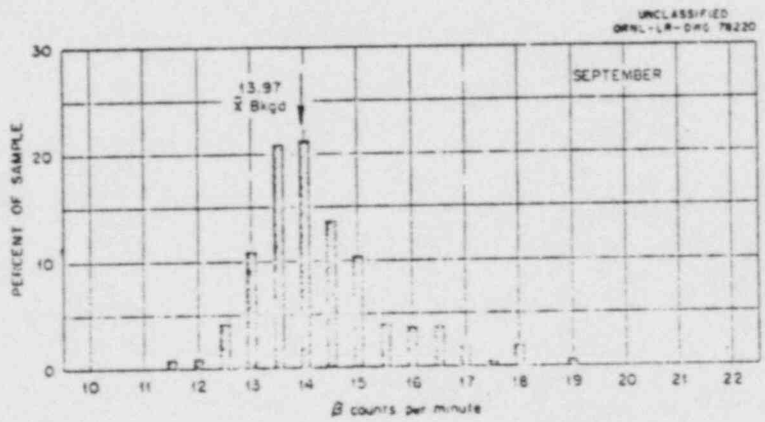

Fig. 13. Frequency Distribution of Gross Beta Counts of Scales from 212 Watts Bar Smallmouth Buffalo Caught in September 1962.

Thirty-two scale samples and three background counts were in each counting group. A preset count of one hundred was reached for each sample and background. The background varied from day to day by as much as two counts per minute. Counting data were converted to counts per minute. The highest background measurement in each counting group was used as the background for that particular group. When the counts per minute for any single scale exceeded the highest background for that group the sample was selected for autoradiography. A total of 1,271 smallmouth buffalo scales from Watts Bar were surveyed and 342 of these individuals were selected for scale autoradiography. All of the 146 Clinch River smallmouth buffalo were scale autoradiographed.

A comparison was made of the number of individuals in each monthly sample of smallmouth buffalo from Watts Bar Reservoir which exceeded the average background for that counting group. In the June group from Watts Bar 49.9 per cent of the fish exceeded the average background. The percentage increased in the July group to 51.8. In August the percentage again increased to 59.2. The September group was the highest with 61.4 per cent of the samples exceeding the average background for the group. This may mean that the radionuclide content of smallmouth buffalo scales in Watts Bar Reservoir increased during the summer of 1962, but a thorough investigation is needed to test this supposition. Smallmouth buffalo from the Clinch River would be expected to have a higher percentage exceeding the average background because the group is much closer to the source of contamination. Of all the smallmouth buffalo taken from the Clinch River in 1961 and 1962, 60.4 per cent of the samples exceeded the average background for the group.

Comparison of the counting results was questioned because of operational difficulties encountered during counting the samples. The "Micromil" window of the gas flow counter was damaged and had to be replaced with an aluminum foil window (1 mg/cm^2). This changed the efficiency of the counter and caused a noncorrectable variation in background readings. With the "Micromil" window the average background was 12.66 ± 3.245 cpm at the 95 per cent level of significance. However, with the aluminum foil window the average background was 13.97 ± 0.965 cpm at the same level of significance. When the scale counts are at such a low level that few exceed background, the confidence interval becomes critical and must be very exact for the comparisons to have meaning.

D. Scale Autoradiography

1. Scale cleaning and mounting

Several different methods were tested for cleaning the scales to remove epidermal tissues. Scales were placed in a solution of pepsin and HCL at various concentrations to digest the epidermis. This method proved to be unsatisfactory because there was some breakdown of the bony structures when the solution was highly acid. Solutions of low acidity had no apparent advantage over tap water in removing the epidermis. Scales were soaked in tap water for several hours and then scrubbed by hand. This method was effective, but too time consuming.

The most efficient method of cleaning scales was found to be placing them in tap water and allowing the epidermal tissues to decay at room temperature. During this process the scales were placed on a shaker which provided continuous, slow agitation. Usually less than two weeks were required for the epidermis to disintegrate. The scales then were rinsed several times in tap water. Then they were placed between sheets of blotting paper and weighted and allowed to dry at room temperatures for about two to three weeks. This method was adequate for removing the epidermis and flattening the scales. However, some radioactivity was lost into the water during soaking. Origin of the radioactivity was not determined. It is probable that most came from the radionuclides within the epidermis, rather than from the bony parts of the scales.

Dried, flattened scales were mounted on glass microscope slides for autoradiographic exposure. The inner or fibrillary plate surface was fixed to the glass. Fish scales have the shape of flattened cones and have a tendency to bend or buckle away from the slide when the cement dries. Several different types of cement were tested in fixing the scales to the slides. The most successful method of mounting the scales involved the use of subbed slides. Dipping the slide into a subbing solution coats the surface of the slide with a substance which is more easily adhered to than clean glass. Slides were subbed in a solution of five grams of gelatin, one-half gram of chrome alum ($Cr_2(SO_4)_3$) and 1,000 cc of distilled water. Slides were dried for twenty-four hours after subbing before scales were mounted on them. Scales were held on the slides by a small drop of Eastman 910 cement and pressed flat for several minutes, then allowed to air dry at room temperature. This method generally was successful, but in several instances the scales buckled away from the slide during drying. The slides were labeled and mounted on 8 by 10 inch sheets of carb ard for exposure.

2. Exposure and development

Scales of sufficient activity were exposed in 10 by 12 inch cassettes and weighted to prevent the slides from shifting position on the film. The outer sculptured surface of the scale was placed toward the film. At first a layer of Saran Wrap was placed between the scale and the film to prevent any chemical reactions from moisture diffusing out of the scale. Saran Wrap effectively prevented any moisture from reaching the surface of the film from the scale. However, sufficient drying eliminated the need for the protective layer between the scale and film.

Several different types of autoradiographic film were tested to find the fastest and clearest method. NTB-2 and NTB-3 liquid emulsions were painted directly on the outer surface of mounted scales. Liquid emulsions were highly unsatisfactory because the scales bent and buckled away from the slide under the shrinking influence of the drying emulsion. Buckling occurred during development and fixing also. This caused some difficulty in the preparation of permanent slides. Distortion caused by the scale buckling rendered the autoradiograms unreadable.

Stripping film was placed directly on the sculptured surface of the scales which were mounted on glass slides. Type AR .10 and AR .50 stripping films were tested. The AR .10 was unsatisfactory because of its low sensitivity which required a lengthy exposure period at the low activity exhibited by most fish scales. Type AR .50 stripping film which is approximately ten times more sensitive than AR .10 proved to be partially satisfactory and was used for preliminary analyses and for the laboratory tagging experiment. Both types of stripping film caused considerable buckling of the scales during drying and development and were not suitable for permanent records.

No-screen X-ray film was the best material for scale autoradiography. However, this film is not particularly sensitive. A total exposure of about 2,000,000 counts over background was needed to produce a readable pattern or image. Exposure times for the fish scales ranged from ten days to nine months. Autoradiograms exposed for a long period of time were expected to show evidence of some exposure from naturally occurring radionuclides. Robeck, Henderson, and Palange (1954) reported that the natural radioactivity in fresh water is extremely low and that the radioactivity in aquatic organisms is at or below 2×10^{-2} dpm/g. There were no obvious differences in the number or distribution of exposed photographic grains in the background areas between scales and the number or distribution of exposed grains in those areas of scales where there were no accumulations of radionuclides.

Development and fixing methods were the same for all films used. They were developed for five to ten minutes in Kodak D-19 Developer at 20° C. As soon as the image started to appear on the film the development was stopped by placing the film in tap water at 20° C for about thirty seconds. Leaving the film too long in the developer resulted in over-development causing the background areas of the film to become darkened. Film was cleared and fixed immediately in DuPont X-ray Fixer and Hardener at 20° C for at least ten minutes. Film was then washed for at least fifteen minutes in running tap water and dried in a dust-free drier with circulating air at room temperature. Photographic negatives were made of the scale autoradiograms and these negatives were used in producing prints for permanent records.

Prosser, et al. (1945) autoradiographed scales of goldfish which had been immersed in a pond water solution of strontium-89 at 0.6 μc/ml for six hours. Examination of these scales revealed concentric rings and greater activity in the thick area at the base of the scale than in the thinner areas. It was concluded that the concentric bands did not correspond to growth rings, but rather to areas of different thickness.

Micrometer measurements were made of the thickness of smallmouth buffalo scales in this study. All scales were found to increase in thickness from the margin to the focus. Many autoradiographed scales showed the greatest ratioactivity was in the thin marginal areas. In comparing results of this study to those of Prosser, et al., it is significant to note that fish in this study had lived in contaminated areas and actually incorporated radionuclides into structural material in the scales, whereas, fish in the other study were simply immersed in the tagged solution for a few hours where it was impossible for growth to occur. The presence of any radionuclides in the goldfish scales must have been due to imperfect cleaning methods prior to autoradiography.

The first step taken when fish scales containing radionuclide accumulations were found to produce autoradiographic patterns of concentric circles was to determine if all the scales from an individual would produce the same pattern. One smallmouth buffalo was taken from White Oak Creek with scales which counted over 440 beta counts over background. All the scales, more than one thousand, were removed from one side of this fish and labeled on the inner surface with india ink. These scales were cleaned, pressed, mounted in order, and autoradiographed with No-screen X-ray film.

Subsequent development of the film showed that all the normal scales of the fish had the same pattern of concentric circles (Figure 14). Some regenerated scales produced an exposure over the entire regenerated portion of the scale with the concentric circle pattern being resumed at the point where normal growth resumed. Some of the regenerated scales produced no exposure at all. It was concluded that scales

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Fig. 14. Autoradiogram of Scales from a Single Smallmouth Buffalo from White Oak Creek.

which grew while the fish was in a contaminated area accumulated radionuclides in the region of scale growth. Scales which were regenerated while the animal was in a contaminated area contained accumulated radionuclides in the regenerated portion of the scale. However, scales which were regenerated while the animal was in a noncontaminated area exhibited no accumulated radionuclides in the regenerated portion. These data tend to deny the translocation of radionuclides from one portion of the scale to another.

Autoradiographic examination of fish scales was established as a valid method of determining the distribution of accumulated radionuclides in the bony surface layer of the scale. There are several problems yet to be solved in the perfection of this technique. Most important is the availability of a film sensitive enough for the low activity in the scale to produce an exposure within two or three weeks. Films currently in use require up to 2,000,000 counts over background irradiation to produce an adequate image. On this basis, the most active scales would produce a readable image on No-screen X-ray film in three to seven days. However, this high degree of activity was unusual and the most active scales from the Watts Bar collection exhibited only 21.5 beta cpm, which required over two months of exposure time to produce an acceptable image. Scales counting less than 20 beta cpm produced no readable images because the time required for exposure was so long that natural background irradiation and chemical reactions produced fogging of the film and eliminated the scale image.

E. Cesium-134 in Scale Tagging

In the early autoradiographic examinations of scales from fish caught in contaminated areas the patterns of concentric circles led to the idea that radionuclides are accumulated in scale structures as growth occurs. If these rings could be identified with residence in a contaminated area it would be possible by back calculation to trace the movements of fish in relation to contaminated and noncontaminated areas. A laboratory experiment was designed to test the feasibility of tagging fish scales with radionuclides and using the accumulations to identify the fish.

Bluegill, *Lepomis macrochirus* Rafinesque, and warmouth, *Chaenobryttus coronarius* (Bartram), were selected for the tagging attempt because of their small size and ease of feeding and maintaining in aquaria. Fish were maintained individually in ten gallon aquaria which were submerged in a water bath for temperature control. Aeration was provided to each aquarium. Periodic weights, measurements, and whole body gamma counts of the fish were taken. Three scales were taken from each fish at the start of the experiment and periodically during the course of the experiment. Mounted scales were autoradiographed with Kodak AR .50 stripping film. The fish were fed earthworms. Worms were washed in tap water prior to tagging. They were tagged by placing them in 25 ml of a solution of cesium-134 for three to eight hours at a concentration of approximately 1.1×10^6 dpm.

Fish were divided into three groups. Experimental fish from noncontaminated areas were fed only tagged food during the experiment. Reciprocal fish from contaminated areas were fed only noncontaminated food. Control fish from noncontaminated areas received noncontaminated food.

The tagging experiment was only partially successful. There were two reasons for lack of success. Growth was evident in only one of the fish, therefore, the others did not deposit new scale material. Cesium-134 is not a bone-seeker and only a small percentage of the accumulated radionuclide was deposited in the scales of the fish that did grow.

Analyses of autoradiograms of scales from the warmouth which grew showed that fish scales can be marked with an accumulation of radionuclides for use in identifying the animal (Figure 15). The margin of the scale appears in the left side of the picture. A narrow line of exposed photographic grains was evident extending from the top to the

Fig. 15. Autoradiogram of the Posterior Margin of a Scale from a Warmouth Tagged with Cesium-134.

bottom of the picture along the margin of the scale in the area where growth has taken place. This line of exposed grains indicated the presence of accumulated cesium-134. Widely scattered exposed photographic grains were observed over the entire surface of the autoradiogram.

These were caused by background irradiation. There were no radionuclide accumulations in scales of the experimental fish which were fed tagged food, but did not grow. The lack of accumulation in these scales indicates that radionuclides are accumulated only in those portions of the scales which actually are grown in the contaminated area.

Experimental fish which had been fed only tagged food were dissected upon completion of the experiment. Tissues were separated and oven dried for twenty-four hours at 104° C. Samples were counted in 25 by 150 mm glass tubes in a gamma spectrometer equipped with a 3 by 3 inch sodium-iodide well detector. The counter was calibrated with cesium-137. All samples and backgrounds were counted for five minutes each in the 0.555 to 0.844 Mev portion of the gamma spectrum where cesium-134 exhibits characteristic photopeaks. Results of the radio chemical analysis of these tissues are shown in Table XII.

Distribution of cesium-134 in the fish's body was compared to the work of Boroughs, Chipman, and Rice (1957) who found that an ingested dose of radiocesium in small tuna accumulated rapidly in the liver, heart, spleen, and kidneys, but was lost rapidly from these organs. Muscle, gonads, and skin continued to accumulate cesium-137 faster than they lost it. The largest accumulations of cesium-134 in this experiment were in the testes, muscle, and liver and spleen. Generally the gills, gastrointestinal tract, and eyes were intermediate. Bone, skin and scales, and fins had the lowest accumulation of cesium-134 of any tissue tested.

TABLE XII

CESIUM-134 ACCUMULATION IN FISH TISSUES

Tissue	Cesium-134 Accumulation ($\times 10^{-2}$ μc/g dry weight)
Bluegill	
Gills (including bony element)	3.20 ± 0.06
Muscle	8.58 ± 0.04
Testes	8.75 ± 0.42
Bone	1.11 ± 0.02
Gastrointestinal tract (cleaned)	1.84 ± 0.04
Skin and scales	1.21 ± 0.01
Liver and spleen	4.17 ± 0.08
Warmouth	
Gills (including bony element)	1.56 ± 0.02
Muscle	3.75 ± 0.02
Testes	8.71 ± 0.42
Bone	0.65 ± 0.03
Gastrointestinal tract (cleaned)	3.21 ± 0.05
Skin and scales	1.24 ± 0.02
Liver and spleen	4.08 ± 0.08
Fins	0.70 ± 0.02
Eyes	2.14 ± 0.05

CHAPTER VII

DISPERSION OF SMALLMOUTH BUFFALO

A. Conventional Tagging

There are several methods of marking living fish for future recognition. Fish may be marked by mutilation, such as fin-clipping, branding, or tattooing. The most common marking method is the attachment of tags. In the tagging operations of the Radiation Ecology Section, Oak Ridge National Laboratory, Atkins type plastic tags were used. These tags were numbered and labeled for return through the TVA Fish and Game Section. The tags were attached by monofilament polyethylene line inserted through the muscles ventral to the posterior portion of the fish's dorsal fin. These tags were used in the tagging operations of 1960 and 1961.

In 1960, 347 smallmouth buffalo were tagged. There were ten tag returns from this group. Five of these returns were from commercial fishermen and five were in Radiation Ecology Section hoop nets. A total of 309 smallmouth buffalo were tagged in 1961. There were three returns from this group: two in Radiation Ecology Section hoop nets and one from commerical fishermen. Table XIII shows data on smallmouth buffalo movements as revealed by examination of tag return records. Tag returns represent 2.8 per cent of the fish tagged in 1960 and 1 per cent of those tagged in 1961.

A comparison was made of the length and weight changes between capture and recapture of rough fish species tagged during 1960 and 1961.

TABLE XIII

SMALLMOUTH BUFFALO MOVEMENT AFTER TAGGING

Tagging Date	Tagging Location	Time Lapse (Days)	Distance Moved (Miles)	Direction Moved
7-6-60	CRM 19.5	129	15.1	Downstream
7-9-60	CRM 20.8	154	16.4	"
7-13-60	CRM 21.8	287	1.0	"
7-15-60	CRM 21.8	306	2.4	"
8-10-60	CRM 21.8	365+	450.0+	"
8-15-60	CRM 21.8	259	0.7	"
8-26-60	CRM 18.5	298	4.9	"
9-7-60	CRM 17.5	109	13.1	"
9-14-60	CRM 17.5	275	2.9	Upstream
8-11-60	CRM 17.5	577	35.5	Downstream[a]
4-17-61	CRM 19.4	50	0	
5-19-61	CRM 20.8	38	0	
6-16-61	CRM 20.6	199	43.0	Downstream

[a]This individual moved 17.5 miles down the Clinch River and 18 miles upstream in the Tennessee River.

This comparison was made in an attempt to determine if tagging exerted a detrimental influence on the growth of individuals. Adequate data for this comparison were available on eleven fish (Table XIV).

TABLE XIV

LENGTH AND WEIGHT CHANGES BETWEEN TAGGING AND RECAPTURE

Species	Tagging		Recapture		Time Lapse (Days)
	Length (mm)	Weight (g)	Length (mm)	Weight (g)	
Smallmouth Buffalo	520	1890	500	1700	287
"	400	850	385	710	306
"	395	980	385	850	259
"	440	1280	430	1210	275
"	420	1040	415	1050	50
River Carpsucker	530	1930	530	2000	286
"	505	1560	490	1600	263
"	490	1410	470	1300	279
"	500	2090	500	1700	159
Carp	395	790	390	800	305
Golden Redhorse	605	2120	585	2000	403

Tag returns from the 1960 and 1961 tagging operations revealed great variations in movements of smallmouth buffalo between tagging and recapture. From a total of thirteen tag returns the fish were determined to have moved distances ranging from 0 to over 450 miles during a time lapse between tagging and recapture which ranged from 38 to 577 days. The speed of movement ranged from 0.01 to 0.22 river miles per day for the eleven fish which moved. One fish had moved 2.9 river miles upstream. One had moved 17.5 miles down the Clinch River and 18 miles upstream in the Tennessee River. The remainder of fish which moved went downstream. It is possible that capture, handling, and attachment of the tag reduced the vigor of the animal giving the fish a greater tendency to move downstream with the current rather than exerting the energy necessary to move upstream against the current. Commercial fishing operations occur in the areas downstream from the tagging area. Sampling upstream might have revealed that some of the individuals moved upstream after tagging.

The study of plants and animals is designed primarily to obtain information about their operation under natural conditions and studies of physiology or behavior of organisms held under abnormal ecological conditions may be misleading (Woodbury, 1956). When a tag is attached to a fish's body abnormal conditions are created which decidedly affect the animal's physiology and behavior. Ricker (1942) concluded that trapping, handling, removing the fins, and even the presence of a tag resulted in little or no mortality; but that the tag, presumably by interfering with feeding, vitiated estimates of populations made from recoveries of line-caught fish. Rousefell and Everhart (1953) reported that the chief drawback of the mark-recapture method of population estimates lies in the assumptions that the tagged fish do not suffer any increased mortality and that the recaptured fish are observed and recorded. Black (1957) demonstrated that some physiological difficulties were imposed on fish in the process of capturing and marking it. DeRoche (1963) presented data indicating that monel metal jaw tags on adult lake trout produced a reduction in growth rate which continued with increasing effect throughout the life of a tagged fish. Ricker (1958) reversed his opinion that marking imposes no increased mortality on fish and reported a frequent effect of marking is extra mortality among marked fish, either as a direct result of the mark or tag, or indirectly from the exertion and handling incidental to marking operations. In either event recoveries will be too few to be representative; hence population estimates made from them will be too great and rates of exploitation will be too small.

Conventional tagging methods normally are used to determine the movement of fishes between the time of tagging and recapture. However, many instances of abnormal behavior of tagged fish have been reported. Ricker (1958) reported that tagged sunfish usually swim to the bottom and burrow into vegetation immediately after being released. This behavior might make them more apt to remain in the same area and be recaptured than untouched fish. Marking may cause less feeding or less moving and reduce the chance of being caught. Tagging of some fish resulted in increased or more erratic movement for some time.

Results of the ORNL Radiation Ecology Section tagging operations of 1960 and 1961 indicate that the presence of tags on smallmouth buffalo has a detrimental effect on the animal. Only five smallmouth buffalo tag returns were accompanied by accurate length and weight measurements. These fish had experienced length losses of from 5 to 20 mm. Four of the fish had had weight losses of from 70 to 190 g and the other had gained 10 g. The time lapse between tagging and recapture ranged from 50 to 306 days. Of a total of eleven rough fish tag returns accompanied by accurate length and weight measurements nine fish lost length and two had no length change between tagging and recapture. Seven of the eleven fish lost weight and four gained weight during the time lapse. There were many observations of open wounds where the monofilament line passed through the dorsal muscles of the tagged fish. Such wounds undoubtedly would be a drain on the vitality of the animal.

B. Autoradiogram Analyses

Autoradiograms were made of scale samples from 146 Clinch River smallmouth buffalo. Ten of these samples (7 per cent) contained sufficient radioactivity to produce readable autoradiograms. Scale samples from 342 Watts Bar smallmouth buffalo were autoradiographed. Only one of the samples (0.3 per cent) produced a readable image. The autoradiograms were compared to impressions of the same scales in order to determine movements of the fish in and out of contaminated areas.

Smallmouth buffalo 1 (Figure 16) hatched in the spring of 1955 in a noncontaminated area. It lived until the spring of 1959, four complete seasons, in the noncontaminated area. This fish formed its fourth annulus in the spring of 1959 at a total length of 422 mm. It entered the contaminated area at the start of its fifth growing season immediately after formation of its fourth annulus. The fish was captured at CRM 21.7, 0.9 mile upstream from the mouth of White Oak Creek, on April 1, 1960. It had remained in the contaminated area since the spring of 1959 and had added 18 mm in length during that time. The fish was 440 mm long and weighed 1,222 g at capture. Scales from this specimen averaged 13.4 beta counts per minute exceeding background at capture.

Smallmouth buffalo 2 (Figure 17, page 70) hatched in the spring of 1956 in a noncontaminated area. It lived until the spring of 1960, four complete seasons, in the noncontaminated area. The fourth annulus

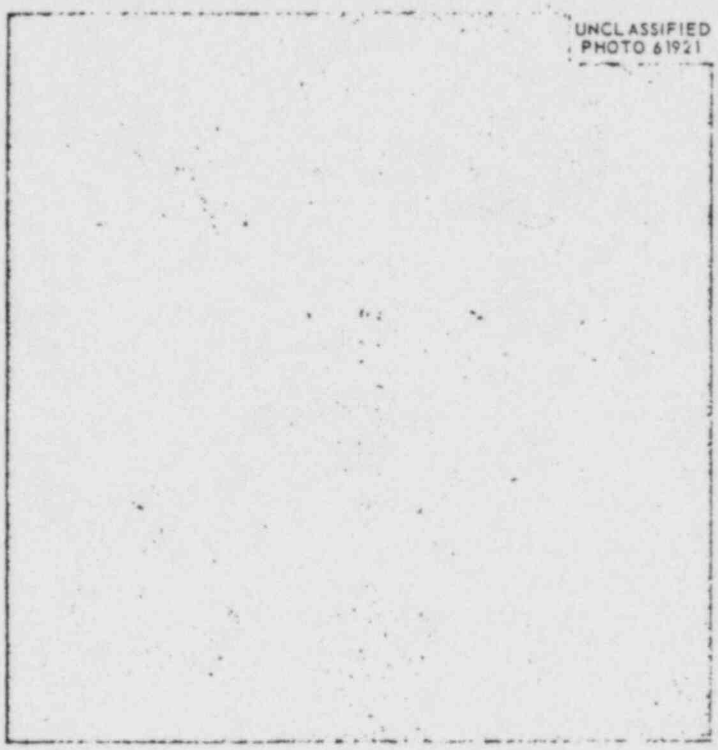

Fig. 16. Autoradiogram of Scales from Smallmouth Buffalo 1.

Fig. 17. Autoradiogram of Scales from Smallmouth Buffalo 2.

was formed in the spring of 1960 when the fish had a length of 365 mm. At this time the animal moved into a contaminated area and remained through its fifth growing season. The fifth annulus was formed in the spring of 1961 when the fish was 418 mm long. It remained in the contaminated area until capture in White Oak Creek on November 6, 1961. It was 440 mm long and weighed 1,345 g at capture and scale samples averaged 144 beta cpm over background. This specimen had been in a contaminated area for over one year and had added 75 mm length during this time.

Smallmouth buffalo 3 (Figure 18) hatched in the spring of 1956 in a noncontaminated area. It lived five completed years in the noncontaminated area until the spring of 1961. Just prior to annulus formation in the early spring it entered a contaminated area at a length of 412 mm.

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Fig. 18. Autoradiogram of Scales from Smallmouth Buffalo 3.

This fish remained in the contaminated area from the spring of 1961 until its capture in White Oak Creek on November 13, 1961. It was 420 mm long and weighed 1,465 g at capture and its scales averaged 300 beta cpm per scale over background.

Smallmouth buffalo 4 (Figure 19) hatched in the spring of 1956 in a noncontaminated area. It lived five completed years in the noncontaminated area until the summer of 1961, at which time it moved into a contaminated area at a length of 414 mm. It remained in the contaminated area until its capture on January 23, 1962, in White Oak Creek. At capture this fish was 440 mm long and weighed 1,045 g. Its scales averaged 2 beta cpm per scale over background.

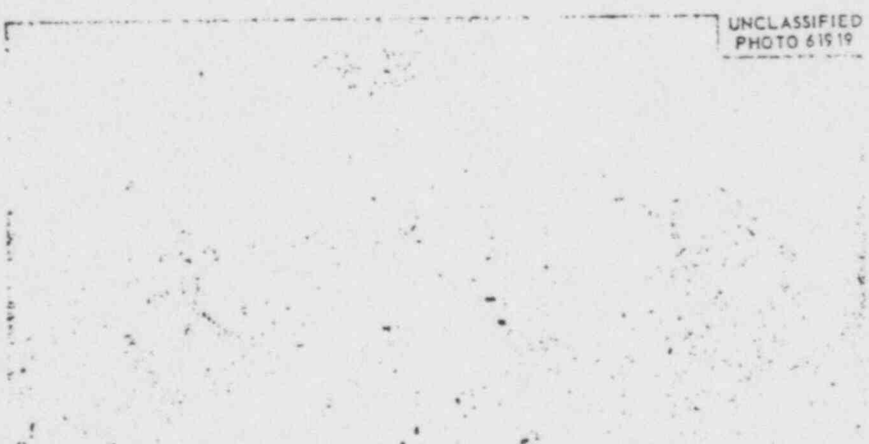

Fig. 19. Autoradiogram of Scales from Smallmouth Buffalo 4.

Smallmouth buffalo 5 (Figure 20) hatched in the spring of 1957 in a noncontaminated area. It lived three complete years in the noncontaminated area until the summer of 1960, at which time it moved into a contaminated area at a length of 304 mm. This fish remained in the contaminated area through formation of its fourth annulus, summer of 1961, and until its capture on November 13, 1961, in White Oak Creek. It was 400 mm long and weighed 975 g at capture. Scale samples averaged 205 beta cpm per scale over background.

Smallmouth buffalo 6 (Figure 21) hatched in the spring of 1957 in a noncontaminated area. In the summer of 1961, after four complete growing seasons, this fish moved into the contaminated area at a length

Fig. 20. Autoradiogram of Scales from Smallmouth Buffalo 5.

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Fig. 21. Autoradiogram of Scales from Smallmouth Buffalo 6.

of 361 mm. It remained in the contaminated area until capture on May 10, 1962, in White Oak Creek. At capture it was 410 mm long and weighed 953 g. Scales averaged 8 beta cpm per scale over background.

Smallmouth buffalo 7 (Figure 22) hatched in the spring of 1956 in a noncontaminated area. It remained in the noncontaminated area for over three years. This fish moved into the contaminated area in the winter of 1959, during its fourth growing season, at a length of 359 mm. It remained in the contaminated area during formation of its fourth annulus, spring of 1960, and through formation of its fifth annulus, spring of 1961. It was captured on May 10, 1962, in White Oak Creek at a length of 520 mm and weight of 1,969 g. Scale samples averaged 82 beta cpm per scale over background.

Fig. 22. Autoradiogram of Scales from Smallmouth Buffalo 7.

Smallmouth buffalo (Figure 23) hatched in the spring of 1957 in a noncontaminated area. It entered a contaminated area immediately after formation of its second annulus, probably the spring of 1959. This fish was 271 mm long at formation of the second annulus. It remained in the contaminated area until some time during the winter of 1959-1960 when it left the contaminated area at a length of 304 mm. The animal was in a noncontaminated area until its capture on June 29, 1962, just prior to the formation of its fifth annulus. This fish was captured at CRM 16.0 at a length of 460 mm and weight of 1,410 g. Scales averaged 6 beta cpm per scale over background at capture.

Smallmouth buffalo 9 (Figure 24) hatched in the spring of 1957 in a noncontaminated area. This fish remained in the noncontaminated

Fig. 23. Autoradiogram of Scales from Smallmouth Buffalo 8.

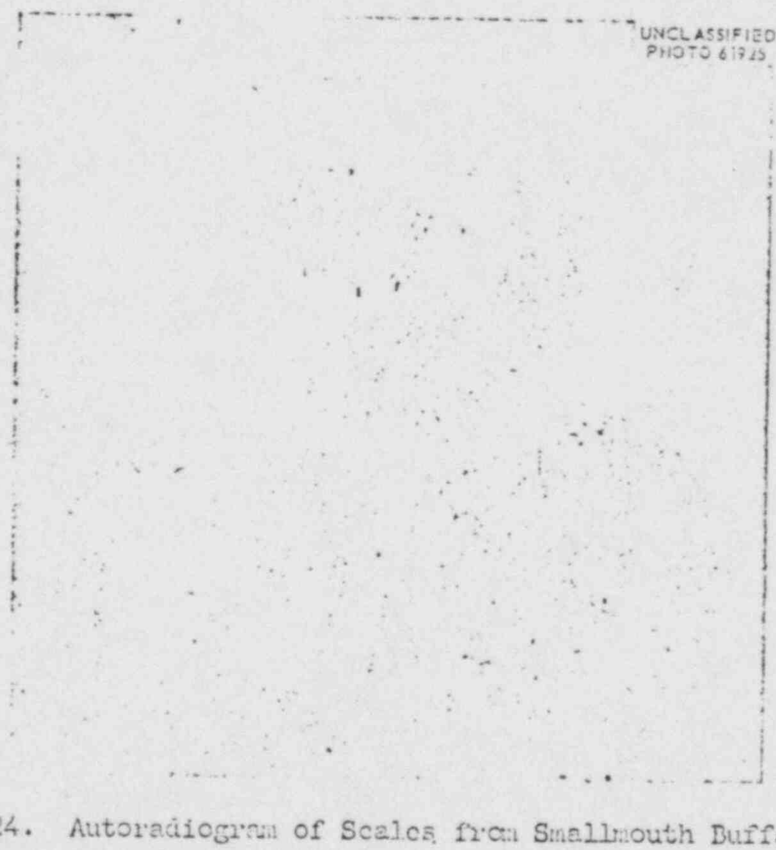

Fig. 24. Autoradiogram of Scales from Smallmouth Buffalo 9.

area for over two years. During the winter of 1959-1960 it entered a contaminated area at a length of 294 mm. This animal remained in the contaminated area through the formation of its third annulus and until the formation of its fourth annulus. It left the contaminated area in the spring of 1961 at a length of 368 mm. This fish was caught on August 4, 1962, at approximately mile 542 in the Tennessee River. At capture it was 460 mm long and scales averaged 21.5 beta cpm per scale over background.

Smallmouth buffalo 10 (Figure 25) hatched in the spring of 1956 in a contaminated area. It remained in the contaminated area for two full growing seasons until it left in the summer of 1958. This individual moved into a noncontaminated area and remained through the summer of 1959. In the fall of 1959 it returned to the area of contamination and

Fig. 25. Autoradiogram of Scales from Smallmouth Buffalo 10.

remained for over one year, until the summer of 1961. It again left the contaminated area and remained away until its capture on December 19, 1961, at the mouth of White Oak Creek. Apparently this animal had just returned to the area of contamination at the time of its capture.

Smallmouth buffalo 11 (Figure 26) hatched in a contaminated area in the spring of 1957. It remained two full growing seasons until the summer of 1959, at which ~~time~~ time it entered a noncontaminated area. This fish was 201 mm long at the time it left the area of contamination. It remained in the noncontaminated area for two complete growing seasons until the summer of 1961, at which time it returned to the contaminated area at a length of 326 mm. It was caught on December 28, 1961, in White Oak Creek at a length of 340 mm.

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Fig. 26. Autoradiogram of Scales from Smallmouth Buffalo 11.

In defining the contaminated area only the immediate vicinity of White Oak Creek can be considered. Of the eleven smallmouth buffalo with readable autoradiograms eight were captured in White Oak Creek, one at CRM 21.7, one at CRM 16.0, and one at TRM 542, approximately forty-seven miles below the mouth of White Oak Creek. A high concentration of radionuclides is assumed to be necessary in order for an animal to accumulate sufficient quantities in the scales for autoradiogram exposure and these high concentrations are present only in White Oak Creek. One hundred and forty-six smallmouth buffalo from the Clinch River were subjected to scale autoradiography. Only ten of these fish had scales containing sufficient activity for autoradiogram exposure indicating the contaminated area is rather small. If surface area is considered as a measurement of available fish habitat, White Oak Creek (estimated surface area of five acres) comprises less than 0.02 per cent of Watts Bar Reservoir (38,660 acres) at full pool. If smallmouth buffalo were equally dispersed over the entire area of Watts Bar Reservoir approximately 0.02 per cent of the animals could be expected to enter White Oak Creek or reside there if the species were not wide ranging. One individual out of 1,271 captured from the Watts Bar area (0.08 per cent) showed autoradiographic evidence of residence in White Oak Creek. Small numbers in the sample prevent conclusions as to the percentage of the smallmouth buffalo population in Watts Bar which actually enters White Oak Creek.

Movements of individuals which were determined by autoradiographic analyses in this study can be considered accurate. However, generalizations made concerning the smallmouth buffalo population as a whole are questionable because of the small number of autoradiographed individuals involved. Age of the individual seemed to have some influence on movement. None of the fish apparently left the area of hatching before it was two years old. The area of hatching here is defined as being either a noncontaminated or a contaminated area. The two fish hatched in a contaminated area left at the end of their second year of life. One of these (Figure 26, page 78) returned to the contaminated area at the start of its fifth year of life. The other (Figure 25, page 77) returned to the contaminated area during the fall of its fourth year of life. All the fish hatched in noncontaminated areas moved into the contaminated area no earlier than two years and no later than five years after hatching. This may mean that smallmouth buffalo are relatively sedentary for two years after hatching, then move upstream into the tributary areas, possibly maturing sexually and entering the upstream areas to spawn. Age of sexual maturity is not known for this species.

Total length of the individuals at the time of movement into or out of a contaminated area was examined. There was no apparent correlation between size and movement. Total length at the time of such movement varied from 271 to 422 mm.

In the eleven fish examined autoradiographically there were sixteen instances where movement occurred between noncontaminated and contaminated areas. Twelve of these moves coincided with resumption of growth at the time of annulus formation. This fact would indicate that the majority of the moves occurred during the late winter or early spring. There have been no recorded mass movements or migrations of this species in Watts Bar, the Clinch River, or anywhere else.

A large number of regenerated scales were observed in the smallmouth buffalo scale samples. Autoradiograms revealed that when scales were regenerated while the fish was in a contaminated area there was an even distribution of accumulated radionuclides over the entire regenerated portion of the scale. Figure 19, page 72) indicates the rapidity with which scales are regenerated. Autoradiograms of the three normal scales indicate that this individual was in the contaminated area from annulus formation in the spring of 1961 until its capture on January 23, 1962. During this period of time the regenerated scale was formed.

Two regenerated scales shown in Figure 16, page 70) were formed prior to the individual's entry into the contaminated area. These scales had resumed the normal growth pattern of circuli formation by the time the fish started to accumulate radionuclides, therefore, there was an accumulation only in those parts of the scale which were formed while the animal was actually in the area of contamination.

The classic concept of scale growth advanced by Creaser (1926) and Van Oosten (1957) is that growth is not equal around the entire margin of the scale at the same time, but that detached portions may be forming at the same time. These portions usually unite to form a continuous circulus. The lateral fields of the scale are limited in size by the proximity of the adjacent scales in vertical rows and the anterior field is limited by the density of the lower layers of dermis into which the scale penetrates. The position of cutting-over of the circuli which usually is in the posterior region of the lateral scale fields indicates growth commences in the anterior field and progresses around the margin of the lateral fields, thus giving the ridges the appearance of extending from the anterior field laterally around both sides of the scale in a posterior direction.

Analyses of the autoradiograms revealed that growth of scales of year class four smallmouth buffalo and older begins in the lateral fields (Figure 16). Growth next occurs in the posterior field (Figures 19, 21, and 22) and finally, occurs around the entire margin of the scale (Figures 17, 18, 20, 23, 24, 25, and 26). These data indicate that smallmouth buffalo scales commence growth in the lateral fields, followed by growth in the posterior and anterior fields respectively. This information on the progress of scale growth is in contrast to the classic concept and may give an indication of the reason for incomplete annulus formation in the cycloid scales of some fish species.

Examination of preliminary autoradiograms of scales from several different species of fish revealed that accumulated radionuclides were evenly distributed throughout the fibrillary plate layer of the scale. This distribution was evident when scales were exposed with the lower surface of the scale next to the film. These same scales when exposed with the bony layer next to the film showed the characteristic concentric circle pattern of other scales from the same fish. One scale in Figure 23, shows a spot of exposure in the center. The "hot spot" resulted when the bony surface layer of the scale was broken allowing the underlying fibrillary plate's accumulated radionuclides to expose the film. These data suggest that the bony layer of the scale acts as a shield which prevents beta particles emitting from the radionuclides accumulated in the fibrillary plate from passing through to expose the film.

CHAPTER VIII

DISCUSSION

An analysis of the Watts Bar smallmouth buffalo population can be made by applying data obtained in this study to a catch curve calculated from the 1962 Watts Bar Collection (Figure 27). The catch

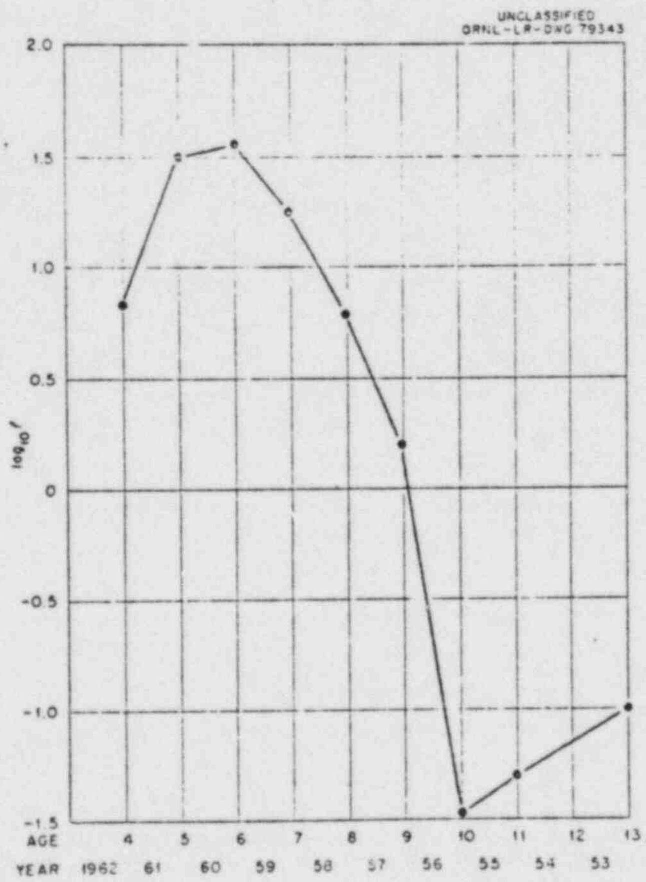

Fig. 27. Catch Curve of Watts Bar Smallmouth Buffalo for 1962.

curve is based on the log frequency of the number of individuals in each year class in the catch plotted against age. The ascending left limb of the curve represents the age groups which are incompletely vulnerable. The descending right limb represents those year classes which were completely vulnerable. Small numbers of individuals in year classes ten and older invalidate any assumptions made in that portion of the curve.

The rate of commercial fishing on Watts Bar Reservoir has changed considerably over the past five years. Fishing was negligible during 1957 because there were no organized commercial fishing operations on Watts Bar and sport fishermen rarely take this species. Comerical fishing commenced on Watts Bar on a limited scale in 1958, when 15,687 pounds (dressed weight) of smallmouth buffalo were removed from the lake. This catch represented a catch per unit effort of 7.34 pounds/yard of net/year. In 1958 the nets used were made of 4 and 5 inch mesh which selected for larger fish than the 3 inch nets used later. Fishing pressure increased considerably in 1959, when 54,035 pounds of smallmouth buffalo were taken from the lake. This represents an increase of 345 per cent of the 1958 catch. Catch per unit effort was 12.01 lbs/yd/year. In 1960, 63,705 pounds of smallmouth buffalo were removed from Watts Bar. This was 118 per cent of the 1959 catch and represented a catch per unit effort of 14.16 lbs/yd/year. In 1961, 59,328 pounds were caught. This was 93 per cent of the 1960 catch and represented a catch per unit effort of 13.18 lbs/yd/year. During these years the fishing mortality was relatively constant and the smallmouth buffalo population apparently did not suffer depletion as was indicated by the catch per unit effort.

There was a heavy influx of commercial fishermen in 1962, when 161,303 pounds of smallmouth buffalo were taken from Watts Bar. This was 272 per cent of the 1961 catch. A catch per unit effort could not be determined for 1962 because of irregular fishing and varying numbers of fishermen working the lake. However, the catch during the first three months of 1963 has been considerably less than in previous years and the smallmouth buffalo population in Watts Bar apparently has been somewhat depleted by the heavy fishing pressure of 1962. If this depletion proves to be true it will become more apparent in later catches and population studies in Watts Bar.

A catch curve with a convex right limb can be produced by any one of three conditions within a population (Ricker, 1958). Continued recruitment at later years can produce a convex curve. However, data from this study indicate that recruitment is completed by age six and that there is no continuation in later years. Table II (page 25) indicates there is a definite trend toward younger fish being recruited, but an adequate examination of recruitment trends can be made only by continued samples over a period of years.

A steady increase in rate of fishing with age can produce a convex catch curve. The rate of fishing in Watts Bar could not be accurately determined from available data, but it can be assumed that the population is sampled representatively since recruitment appears to occur abruptly. There are no indications that fishing pressure increases with age for the Watts Bar smallmouth buffalo.

An increase in the rate of natural mortality with age of the fish can produce a convex catch curve. Since recruitment appears to be abrupt and the older fish are not subjected to increased fishing pressure, it can be assumed that an increase in the rate of natural mortality as the fish become older is responsible for the convexity of the Watts Bar smallmouth buffalo catch curve.

No matter when year classes t and t-1 are sampled, the ratio of their abundance is a measure of the survival rate which existed during the first year that the younger year class became vulnerable to fishing. Therefore, survival rates pertain to past years. The slope of the catch curve in any given part will represent the survival rate at the time the fish in question were being recruited into the fishery.

Data from the age distribution of Watts Bar smallmouth buffalo (Table 1, page 23) give some indication that a segmented population may exist in that reservoir. The higher percentages of scales exceeding background counts in August and September might suggest the movement of an increasing number of Clinch River smallmouth buffalo into the fishing area. However, additional investigation would be necessary to establish the Clinch River fish as a segment of the Watts Bar population.

Broad generalizations on the relative importance of the smallmouth buffalo as an accumulator of radionuclides would be speculative if based on the available data. Major radionuclides in White Oak Creek are accumulated by the species in quantities which generally have varied with the degree of exposure by residence in White Oak Creek. The body burdens should vary with the concentration in the environment of both stable and radioisotopes of the particular element, essentiality of the element, and the physical and chemical state of the element.

Smallmouth buffalo undoubtedly take up radionuclides both by ingestion and absorption, depending on the element.

When the population is considered as a whole, the smallmouth buffalo is a relatively minor accumulator of radionuclides. Only 0.08 per cent of the Watts Bar smallmouth buffalo definitely showed an accumulation by scale analyses. Approximately 6 per cent of the Clinch River smallmouth buffalo definitely showed an accumulation. Approximately 77 per cent of the White Oak Creek smallmouth buffalo contained large accumulations of radionuclides in their scales. These data emphasize the importance of distance from the source of contamination as a factor in the accumulation of radionuclides within a specific population. The small percentage of Clinch River fish showing accumulated radionuclides probably is due to the limited size of White Oak Creek, the only area where the concentration of radionuclides is great enough for accumulation to occur in measurable quantities. This limitation of habitat means that only a small percentage of the total population can remain in the contaminated area for any length of time.

A comparison was made of the total length of smallmouth buffalo which had resided in contaminated areas to the total length range of Watts Bar smallmouth buffalo. Watts Bar fish in year class five ranged from 420 mm to 540 mm in total length. Year class six fish ranged from 400 mm to 570 mm. Evidently, net selectivity prevented the capture of the smaller year class five fish. There were five (5) fish of year class five from the contaminated areas with total lengths of 340, 400, 410, 440, and 460 mm. All these fish would fall well within the range for their year class with the possible exception of the fish measuring

340 mm. This smaller fish was one of those which had hatched in the contaminated area, left the area for two years, and returned to the contaminated area approximately six months prior to capture. There were five (5) year class six fish from the contaminated areas with total lengths of 420, 440, 440, 460, and 520 mm. All these fish fell well within the total length range for their year class. These data tend to suggest that growth of the smallmouth buffalo is not affected by periodic residence in an area contaminated with radionuclide wastes.

The fact that fish have definite patterns of radionuclide accumulation in their scales results in the possibility of a new technique for studying populations. Identification of resident and transient individuals in a population has long been a problem. Capture-recapture methods of population estimates have no provision for separating these population segments into their relative numbers. When capture-recapture estimates are made there is always the possibility that transient individuals are caught and tagged. When these are released they resume their movements and may leave the area. This loss of tagged individuals from a study area can result in bias causing the population to be overestimated.

When individuals reside in a contaminated area they have definite patterns of radionuclide accumulation in their scales. All the members of any particular year class would exhibit the same pattern. These patterns can be used as identifying marks.

Autoradiographic examination of radionuclide accumulation patterns in fish scales can be used in conjunction with capture-recapture estimates of population estimates. This application would follow a definite series of steps: (1) The selection of an area of study would be limited to an area where an adequate concentration of radionuclides existed for the resident individuals to accumulate them in the scales. (2) The area should be effectively blocked off with nets to prevent the escape of tagged individuals during the capture-recapture phase of the study. (3) A conventional capture-recapture estimate should be made of the total number of fish within the area. This method is based on the assumption that the ratio of the number of fish captured and marked during the first collection to the total number of fish in the area is the same as the ratio of marked recaptures to the total catch during the second collection. (4) Scale samples would be taken from all individuals in both collections. The scales would be radiometrically surveyed and those with sufficient activity would be autoradiographed. Autoradiographs would be analyzed to identify the resident individuals in the sample. Then, only the numbers of resident individuals from the capture-recapture operation would be considered in estimating the size of the resident population. The number of transient individuals within the area at the time of study also could be estimated from the numbers of nonresident fish.

Tagging of fish with radionuclides is a definite possibility at the present time. Large numbers of fish could be tagged in holding ponds with little effort and later released into natural habitats for population studies. Systematic use of scale autoradiography could be used in identifying these tagged individuals. Scales were observed to regenerate rapidly and to accumulate large quantities of radionuclides during regeneration in contaminated areas. Removal of a key scale or small group of scales from all individuals to be tagged, then holding the fish in a pond with a sufficient concentration of bone-seeking radionuclides, would result in a group of fish tagged in a consistent manner. Tagged fish could be identified later by removal of the key scales from all recaptured individuals and either radiometrically surveying or autoradiographing them.

In radionuclide tagging, selection of the radionuclide is of primary importance. Effective half-life (T_{eff}) of the radionuclide must be considered. The T_{eff} of an element is the time required for the radioactive element fixed in tissue of the animal's body to be diminished 50 per cent as a result of the combined action of radioactive decay and biological elimination:

$$T_{eff} = \frac{(T_r)(T_b)}{T_r + T_b}$$

where T_r = physical half-life, and T_b = biological half-life. Strontium-90 appears to be an excellent radionuclide for tagging purposes because of its affinity for bone and its physical half-life of 27.7 years. However, in the selection of a radionuclide for tagging the health hazards must be carefully analyzed and the application must be kept under strict control.

Any population study is biologically significant in that it increases our knowledge of the organism and the characteristics of the population. The age distribution and growth of smallmouth buffalo in Watts Bar has been described. This information is basic and may be used in conjunction with later studies of a similar nature in determining the history of this commercially important species in Watts Bar as a management tool for the regulation of this fishery.

The dispersal study is especially significant, in that an entirely new technique of study was developed and compared to a conventional tagging study. Even though the numbers of individuals involved in the study were small, considerably more data were derived from the autoradiographic analyses of scales than from the tagging returns because conventional tagging and recovery can only locate fish at single points in time while autoradiographic records of scales provide a continuously recorded history. When large numbers of fish with sufficient radionuclide accumulations in their scales are available for autoradiography, the natural dispersion of these fish without the detrimental effects of conventional tags may be determined.

CHAPTER IX

SUMMARY AND CONCLUSIONS

The smallmouth buffalo, Ictiobus bubalus (Rafinesque), population of Watts Bar Reservoir, Tennessee, was investigated in order to describe its age distribution, growth rates, dispersion, and importance as an accumulator of radionuclides. Measurements and scale samples were taken from commercially-caught fish and fish caught in the ORNL tagging operations. Scale impressions were analyzed for age and growth phenomena. Dispersion of smallmouth buffalo was investigated by conventional tagging methods and by autoradiographic analyses of scales. Stable and radiochemical composition of scales was determined by spectrographic analysis, flame spectrophotometry, radiometric surveys, and gamma spectrometry.

Watts Bar smallmouth buffalo were found to correspond to the theoretical distribution for stable fish populations where large numbers are present in the younger year classes and succeeding year classes become less numerous as a result of mortality. The largest number of fish in the commerical catch was in year class six, the youngest year class which was completely vulnerable to the commercial fishing gear. No indications were found that a dominant year class existed in the Watts Bar population.

Survival rates were calculated to be 49 per cent for year class six, 35 per cent for year class seven, 26 per cent for year class eight, and 19 per cent for year class nine. Annulus formation was concluded to be prior to June for Watts Bar smallmouth buffalo. There were some indications that the Watts Bar population is made up of segments which have different growth rates associated with tributary habitat differences. Recruitment was found to be complete at age six and commercial fishing pressure was equal on all fish from year class six upward.

The calculated length-weight relationship of Clinch River smallmouth buffalo revealed that the fish had isometric growth which is characterized by an unchanging body form and specific gravity. The fish were found to increase 100 g in weight for every 1 cm increase in length for fish in excess of 31 cm total length.

Absolute growth of Watts Bar smallmouth buffalo averaged 422 cm at the end of the third growth year, 441 mm for the fourth, 453 mm for the fifth, 465 mm for the sixth, 487 mm for the seventh, 522 mm for the eighth, and 609 mm for the ninth. Absolute growth rates were found to have increased with each succeeding year for year classes nine through four probably as a result of increased food availability accompanying increased fishing pressure. Calculated annual total length increments indicated this species characteristically had the largest increment during the second year of life. This fact was confirmed by data from other study areas and may be the result of a change in food habits after the first year of life. Growth compensation was evident during the fourth and fifth years of life.

Smallmouth buffalo scales were found to have a mineral residue content of 46.05 per cent by weight. Calcium was the most abundant element amounting to 0.142 mg/g fresh weight with at least twenty-three other elements present in lesser quantities. The strontium-calcium ratio was found to be 0.394×10^{-3} in scales. Smallmouth buffalo scales were found to contain radionuclides of ruthenium, cesium, zirconium, zinc, and cobalt.

The Watts Bar smallmouth buffalo population was concluded to be of minor importance as an accumulator of radionuclides. Only 0.08 per cent of the Watts Bar population in radiometric surveys showed accumulations of artificially produced radionuclides Samples from areas closer to the source of contamination showed greater concentrations. Approximately 6 per cent of the Clinch River smallmouth buffalo had measurable accumulations of radionuclides and White Oak Creek fish had 77 per cent.

Autoradiographic examinations of smallmouth buffalo scales revealed that radionuclides were accumulated in patterns of concentric circles. These patterns were found to be consistent in all the norma scales from any individual and were associated with growth in a contaminated area. A new technique was proposed by which scale autoradiography could be used in conjunction with a conventional capture-recapture population estimate to divide a fish population within a contaminated area into the sedentary and mobile segments if such existed.

Scale autoradiography and conventional tagging methods were used to study the movements of Watts Bar smallmouth buffalo. Conventional methods revealed these fish traveled 0 to 450 miles during time lapses ranging from 38 to 577 days. Evidence was presented that the presence of a tag on the animal's body is detrimental, resulting in a loss of length and/or weight. This fact supported the opinions of many investigators that tagged animals suffer physiological and behavioral difficulties imposed by the presence of the tag.

Autoradiographic examinations of smallmouth buffalo scales revealed considerably more information on movements than conventional tagging methods. The movements of individuals between noncontaminated areas and White Oak Creek, the only area of considerable contamination, were determined, as well as the age and size of the fish at the time it entered or left White Oak Creek. Smallmouth buffalo were concluded to be relatively sedentary for two years after hatching, then to have moved upstream into the tributary areas. The majority of the moves occurred during the late winter or early spring, but no mass movements or migrations were recorded on Watts Bar. Growth was not affected by residence in contaminated areas.

Laboratory experiments showed that fish scales could be tagged with cesium-134 for autoradiographic identification of the tagged individual. However, much larger concentrations of the cesium-134 occurred in the soft tissues than in the scales and bony tissues leading to the conclusion that this radionuclide was not suitable as a scale tag. Selection of a suitable radionuclide for scale tagging and methods of application were discussed.

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ANNIVERSARY OF PEOPLE IN PARTNERSHIP

January 17, 1974

Dr. Frank Valiulis
Environmental Systems Department
Westinghouse
P. O. Box 355
Pittsburgh, Pennsylvania 15230

Dear Frank:

Enclosed are some on-site fish data. We also have Watts Bar and Melton Hill rotenone data if you need them, although they are not worked up as yet. Hope you can use this.

Sincerely,

Jack

John A. Holbrook, Biologist
Fisheries and Waterfowl Resources
Division of Forestry, Fisheries,
and Wildlife Development

Enclosure

Ben D. Jaco, Supervisor, Fisheries Resources Management Section, FOR B, Norris
Tommy L. Sheddan, Biologist, Fisheries and Waterfowl Resources Branch, FOR LAB, Norris
January 11, 1974

✓ TVA FISH POPULATION MONITORING - LMFBR DEMONSTRATION PROJECT

Objective

The objective of this study was to obtain data on the fish population between Clinch River Mile 15 and 18. This area, approximately five miles below Melton Hill Dam, Roane County, Tennessee, will eventually be the site for a Liquid Metal Fast Breeder Reactor Demonstration Project.

Background

The LMFBR site is not a typical lake habitat, but is actually a river with flow governed by the operation of TVA's Melton Hill Dam. No known fisheries data had been gathered on these specific three miles (CRM 15-18) of coolwater river. Oak Ridge National Laboratories compiled some data during a fish-tagging project in 1961 (Morton, 1961) between Clinch River Mile 0 and 23.0. Cooperative fish population inventories of Watts Bar were done by TVA and the Tennessee Game and Fish Commission in 1964 and 1973 (TVA, 1964 and 1973).

Procedure

Three stations (Table 1) with diverse characteristics were sampled in February, in April-May, and again in August 1973 (Table 2). At each station on each date the sample included both daylight and nighttime electrofishing by boat and two gill nets set overnight. One gill net was 1½" square mesh x 8' x 100', size 139 nylon thread, the other 3" square mesh x 8' x 150' size 139 nylon thread. Nets were tied to the river bank and set perpendicular and anchored on the bottom. One gill net was set approximately 100 yards upstream from the electrofishing site and the other about 200 yards.

Electrofishing was from an 18 foot aluminum johnboat manuevered by a 6 h.p. outboard engine. Electric power was furnished by a 230 volt alternating current generator through a silicone rectifier which converted to pulsating direct current. Output voltage was maintained at 1.5 amps. Current was dispersed through the water from a floating aluminum grid--the positive electrodes--suspended from a 14-foot fiberglass boom. Negative electrodes, one on each side of the positive, consisted of 14-foot fiberglass booms through which is mounted a vertical row of whip antennas, 12 inches apart, projecting into the water in a "comb like" configuration. One negative boom is mounted straight ahead and the other at 45° to the right.

Electrofishing was generally within 10 feet of the bank. When possible, fish were counted and identified without removing them from the water. Fish under 4 inches were classified as minnows or identified to species. Netted fish were measured (total length), weighed, and returned to the water.

Summary

Electrofishing produced 75 percent of the total sample of 1,628 fish. Gill netting produced the remainder. Forage fish numbers dominated the samples with 74.4 percent. About half of these were adult gizzard shad and half were 4-inch long threadfin. Rough fish accounted for 18.7 percent and game fish 6.9 percent (Table 3).

Comparison with other samples is not valid since different habitats were sampled and sampling methods were not consistent. The 1964 and 1973 population inventories were done in a lake shoreline habitat using 5-percent emulsifiable rotenone.

Percentages of game, rough, and forage from 1973 samples are shown in Table 4. Lengths and weights are available for each netted fish taken in 1973. Station 3 was the most productive one, both by electrofishing and netting.

The April-May sample data was most productive for netted fish. It also produced the greatest number of game fish. February electrofishing produced the largest number of fish, predominantly shad.

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TVA FISH POPULATION MONITORING - LMFBR DEMONSTRATION PROJECT

Fish Inventory Data, Watts Bar Reservoir. 1973. TVA, Fish and Wildlife Branch. 13 pp.

TLS:DW
Attachments: Tables 1 - 4

TABLE 1

PERCENTAGE OF GAME, ROUGH, AND FORAGE
FISH FROM CLINCH RIVER SAMPLES

Date	Method	Comments	% Of Numbers		
			Game	Rough	Forage
1961	Hoop nets	Between miles 0-23	39.6	49.4	11.0
1964	Rotenone	In Watts Bar Res.	34.9	8.2	56.9
1973	Gill nets & electro-fishing	Between miles 15-18	6.9	18.7	74.4
1973	Rotenone	In Watts Bar Res.	22.2	5.2	7[illegible].6

TABLE 2

FISH POPULATION MONITORING STATIONS
LMFBR DEMONSTRATION PROJECT

Station 1	Right bank.* From CRM 15.7 downstream to white mark. Shallow bank.
Station 2	Left bank.* From CRM 16.5 (approx.) at barbed wire fench upstream to east bank of Caney Creek. Steep bank.
Station 3	Right bank.* From CRM 17.9 downstream to rock ledge with painted white square. Medium depth bank.

*Left and right banks facing downstream.

TABLE 3

Numbers and Percentages of Fish Sampled at LMFBR Demonstration Project Site
1973

	Game	Rough	Forage
February	8	25	88
	7	19	330
	10	21	396
	25	65	814
	2.8%	7.2%	90%
April-May	12	68	51
	16	55	13
	54	83	11
	82	206	75
	22.6%	56.7%	20.7%
August	0	19	118
	4	6	118
	1	9	86
	5	34	322
	1.4%	9.4%	89.2%

Results of All Three Samples

Game	Rough	Forage
6.9%	18.7%	74.4%

TABLE 4

STATION 1

	February 1-2, 1973			April 30; May 1-9, 1973			August 9-10, 1973		
	Gill Net Data		Electro-Fishing	Gill Net Data		Electro-Fishing	Gill Net Data		Electro-Fishing
	No.	Wt. (Gms)	No.	No.	Wt. (Gms)	No.	No.	Wt. (Gms)	No.
Walleye	1	2,525							
Sauger	6	4,425		7	4,525				
White bass	1	650		2	600	3			
Carp			17	10	19,720	2			
Quillback	3	3,050		3	3,875				
River carpsucker				1	1,550				1
Golden redhorse	1	350	1	2	800				1
Black redhorse	1	600							
Silver redhorse				1	2,050				
Smallmouth buffalo			1	21	35,550	1			
Black buffalo				2	7,320				
Gizzard shad	5	910	76	5	800	43	1	186	57
Skipjack herring	1	650		24	14,910		3	1,138	12
Drum				1	150		1	164	1
Channel catfish									
Minnows			7			3			60

TABLE 4

STATION 2

	February 1-2, 1973			April 30; May 1-9, 1973			August 9-10, 1973		
	Gill Net Data		Electro-Fishing	Gill Net Data		Electro-Fishing	Gill Net Data		Electro-Fishing
	No.	Wt. (Gms)	No.	No.	Wt. (Gms)	No.	No.	Wt. (Gms)	No.
Sauger	4	3,700		10	8,125		1	1,025	
White bass	1	375		5	1,675	1			
Bluegill			2						3
Carp	1	2,800	9	5	7,700		2	3,600	
Quillback	2	2,450		7	7,725				
River carpsucker	4	7,850		2	3,300				
Golden redhorse				1	500				
Silver redhorse				1	2,200				
Smallmouth buffalo	1	1,350		27	42,925				
Black buffalo							1	1,850	
Gizzard shad	4	525	70	1	200	9			83
Mooneye	1	250							
Skipjack herring	1	1,125		9	5,800		1	458	
Drum							1	138	
Longnose gar						3			
Channel catfish							1	340	
Emerald shiner						3			
Minnows			256						35

TABLE 4

STATION 3

	February 1-2, 1973			April 30; May 1-9, 1973			August 9-10, 1973		
	Gill Net Data		Electro-Fishing	Gill Net Data		Electro-Fishing	Gill Net Data		Electro-Fishing
	No.	Wt. (Gms)	No.	No.	Wt. (Gms)	No.	No.	Wt. (Gms)	No.
Walleye	1	3,200							
Sauger	6	3,575	1	16	No. Wt.				
White bass	2	750		38	13,130				
Largemouth bass									1
Carp	1	3,150	9	2	2,340		1	193	
Quillback				4	4,620				
River carpsucker				1	1,690				
Golden redhorse	1	425	2	1	300				1
Black redhorse	1	775							
Silver redhorse				4	7,430		1	1,360	
Smallmouth buffalo	5	8,625		43	65,610				
Hogsucker	1	350							
Gizzard shad	5	875	95	2	370	7			84
Skipjack herring	1	600		28	17,120		4	1,575	2
Minnows			296			2			2

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POPULATION DATA - FIELD FORM

Species ______________ Location Upper Watts Bar for LM 73

Date Feb 2 1973 Time __________ Depth __________

Temperatures: Air __________ Water __________

1"		2"		3"		4"		5"		6"	
No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.

Lower Station (1) 3" Net

Species	Length	(mm)	Wt.
Walleye	23.3"	(592mm)	2525
Gillback	17.9"	(452mm)	1300 g
"	16.8"	(426mm)	1150 g

7"	8"	9"	10"	11"	12"

1½" Net

Species	Length	(mm)	Wt.
Sauger	19.3"	(487mm)	1450 g
"	18.5"	(470mm)	[illegible] g
"	15.[illegible]"	(384mm)	550 g
"	16.[illegible]"	(3[illegible]mm)	[illegible] g
"	16.[illegible]	(41[illegible]mm)	[illegible] g
"	16.3	(414mm)	475 g
Gr. Redhorse	13.9"	(353mm)	350 g
"	15.3"	(389mm)	650 g
White Bass	14.1"	(358mm)	650 g

13"	14"	15"	18"

19"	20"	21"	22"	23"	24"

Species	Length	(mm)	Wt.
[illegible]	14.6"	(371mm)	[illegible] g
[illegible] Redhorse	1[illegible].[illegible]	(406mm)	650
[illegible]	12.[illegible]	(305mm)	250 g
"	[illegible]	(2[illegible]mm)	150 g
"	[illegible]	(2[illegible]mm)	1[illegible]0 g
"	[illegible].4	(289mm)	200 g
"	[illegible].4	([illegible])	1[illegible]0 g

FISH POPULATION DATA - FIELD FORM

Species ______________ Location Upper Wells Bar

Date Feb 2 1973 Time ______________ Depth ______________

3") Middle Station (#2) Temperatures: Air ________ Water ________

Species	Length	(mm)	Wt.
S.M. B[illegible] 3	18.1"	(460 mm)	1350 g.
[illegible] Sork	19.0	(482 mm)	1350 g.
"	17.5"	(445 mm)	1100 g.
River Carpsucker	[illegible]	(552 mm)	2575 g.
"	2[illegible].4	(518 mm)	1850 g.
"	[illegible]	(536 mm)	2150 g.
"	[illegible]	(472 mm)	1[illegible] g.
Sauger	18.8"	(477 mm)	1150 g.
"	19.4	(493 mm)	1300 g.
"	16.8"	(426 mm)	640 g.
"	15.9	(401 mm)	600 g.
White Bass	12.3"	(313 mm)	325 g.
Carp	23.3	(592 mm)	2800 g.
[illegible]	[illegible]	(462 mm)	[illegible]
[illegible]	11.2	(284 mm)	[illegible]50 g.
Gizzard Shad	9.[illegible]	(252 mm)	160 g.
"	10.5	(267 mm)	150 g.
"	10.9	(277 mm)	150
"	10.3	(262 mm)	135

FISH POPULATION DATA - FIELD FORM

Net 3"

Species ____________ Location ~~Upper Watts Bar~~

Date Feb 2, 1975 Time ____________ Depth ____________

Upper Station (x3) Temperatures: Air ________ Water ________

1"		2"		3"		4"		5"		6"	
No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
	Walleye				24.2"		(614 mm)	3200 g			
	S.M. Buffalo				18.4"		(467 mm)	550 g			
	"				21.2"		(538 mm)	2350 g			
	"				22.7"		(577 mm)	3075 g			
	"				19.5"		(496 mm)	1550 g			
	"				17.3"		([illegible] mm)	1100 g			
7"		8"		9"		10"		11"		12"	
	[illegible]				12.1		(308 mm)	350 g			
	"				12.4		(315 mm)	400 g			
	Sauger				[illegible]		(442 mm)	925 g			
	"				14.5		(359 mm)	425 g			
	"				[illegible]		(371 mm)	400 g			
	"				[illegible]		([illegible] mm)	[illegible]			
	"				15.7		([illegible] mm)	[illegible]			
13"	"	14"		15"	15.0		(388 mm)	[illegible]		18"	
	Carp				23.5		(597 mm)	3150 g			
	[illegible]				17.2		(437 mm)	775 g			
	[illegible]				[illegible]		(318 mm)	485 g			
	[illegible]				12.5		(313 mm)	350 g			
	[illegible]				15.1		(384 mm)	600 g			
	G. Shad				11.9		([illegible] mm)	[illegible]			
	"				11.6		(294 mm)	175 g			
19"	"	20"		21"	11.4		(289 mm)	200 g		24"	
	"				11.[illegible]		([illegible] mm)	150 g			
	"				10.5		(267 mm)	150 g			

P. 1 of 3

Station 1
Lower St.
3" Net.

	Lm FBR	5-1-75
	Lt. mm	wt. grs.
Sm. Buf.	454	1300
	514	2200
	455	1300
	553	2250
	556	1170
	[illegible]	2050
	[illegible]	1400
	[illegible]	1500
Black Buf.	[illegible]	6000
Small Buf.	[illegible]	2500
Black Buf.	[illegible]	2400
[illegible]	[illegible]	1320
	[illegible]	2190
	[illegible]	[illegible]
	[illegible]	1550
	455	1100
	447	1210
	464	1250
	561	2250
	431	1050
	[illegible]	[illegible]
	513	1750
	45-	1240
Carp	476	1500
	533	1900
	470	1540
	531	1900
	540	2000
	471	1400
	514	1950
	615	3450
	504	[illegible]

P. 2 of 3

[illegible]	L? F [illegible] Lt. [illegible]	5-1-[illegible] Wt. 9
Corp	500	[illegible]
Silver K. Hose	607	2050
Sty. Jack	440	1370
O.D. [illegible]	[illegible]	1250
	455	1125
	[illegible]	1500
[illegible]	[illegible]	1550
—	—	—
[illegible]	[illegible]	Wt. 9
[illegible]	[illegible]	260
	[illegible]	[illegible]
	[illegible]	550
	[illegible]	[illegible]
	[illegible]	725
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]
	400	[illegible]
	[illegible]	450
	[illegible]	575
	[illegible]	600
	[illegible]	525
	395	500
	[illegible]	550
	[illegible]	530
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]

[illegible]	[illegible]	5-1-73
	[illegible]	wt. 2
[illegible]	[illegible]	[illegible]
	305	250
	275	175
[illegible]	[illegible]	500
[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]
[illegible]	[illegible]	650
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]
		[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

P.1 of 3

STA 2

[illegible] 31.	LMFER	5-1-72
[illegible]	Lt. [illegible]	Wt. 9
Carp	478	1225
Carp	360	600
[illegible] Jack	411	650
	360	500
	451	900
	473	775
	[illegible]	250
	[illegible]	400
	[illegible]	700
	[illegible]	400
	[illegible]	450
	[illegible]	300
[illegible]	[illegible]	800
[illegible] Bass	[illegible]	450
	[illegible]	[illegible]
	[illegible]	200
	375	500
	[illegible]	800
[illegible]	415	500
[illegible] Bass	[illegible]	1700
Sauger	[illegible]	650
	[illegible]	1050
	[illegible]	600
	414	700
	415	600
	407	750
	425	950
	460	525
	415	600

P.2 of 3

[illegible] 3" Net	LIMFRR	5-1-73
	Lt. [illegible]	Wt. g
Sm. [illegible]	420	1450
	[illegible]	2450
	490	1525
	[illegible]	1500
	[illegible]	1800
	415	1250
	[illegible]	[illegible]
	[illegible]	1550
	520	2150
	[illegible]	1975
	[illegible]	1200
	[illegible]	2050
	[illegible]	1350
	[illegible]	[illegible]
	[illegible]	1950
	[illegible]	2125
	[illegible]	1650
	[illegible]	1800
	525	[illegible]
	[illegible]	1375
	[illegible]	1300
	[illegible]	1400
	419	1600
	423	1450
	441	1250
	[illegible]	1400
	513	1500
G.B. [illegible]	[illegible]	[illegible]
[illegible]	[illegible]	1350
[illegible]	[illegible]	[illegible]
	465	1225
	435	[illegible]

5-1-73

[illegible] 3" Net	LMF Bl. Lt. [illegible]	Wt. g
B. Carpsucker	537	1950
3" [illegible] Sucker	451	1200
↓	[illegible]	1300
Silver Red Horse	6[illegible]	3200
Carp	5[illegible]	2675
	[illegible]	1400
↓	[illegible]	1700

P1 of 5

STA 3
Upper St.
3" N-1

LIMFBR

5-1-73

	Li %	wt. g
Sub. Lot	414	1160
	525	1950
	[illegible]	1150
	[illegible]	1600
	472	1540
	[illegible]	1410
	43	[illegible]
	[illegible]	1030
	[illegible]	1110
	[illegible]	[illegible]
	[illegible]	1240
	[illegible]	1310
	[illegible]	1940
	[illegible]	[illegible]
	[illegible]	1570
	[illegible]	1540
	403	1400
	420	1590
	[illegible]	1530
	411	1300
	401	1510
	452	1170
	4?4	1240
	500	1540
	[illegible]	1490
	[illegible]	[illegible]
	[illegible]	1350
	5??	2190
	[illegible]	1310
	4??	1310
	5?	[illegible]
	[illegible]	[illegible]

P. 2 of 5

[illegible] B	LWIFER 24 hr	5-1-73 at 9
[illegible]	460	1210
	[illegible]	2930
	[illegible]	1240
	[illegible]	1400
	[illegible]	1270
	[illegible]	3810
	[illegible]	1350
	[illegible]	1350
	[illegible]	2150
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
	471	[illegible]
	[illegible]	1250
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	1680

P 3 of 5

[illegible]	[illegible] VBR	5-1-73
[illegible]	[illegible]	wt. g
[illegible]	482	820
✓	472	1590
G. Shaft	[illegible]	170
✓	277	200
[illegible]	310	200
[illegible]	[illegible]	1400
[illegible]	280	450
✓	420	1000
	[illegible]	740
✓	[illegible]	1500
[illegible]	240	500
	[illegible]	700
	[illegible]	500
	[illegible]	410
	430	760
	[illegible] (circled)	880
	310	520
	416	680
	387	620
	[illegible]	910
	[illegible]	650
	[illegible]	650
	[illegible]	720
	341	540
	[illegible]	450
	[illegible]	440
	[illegible]	650
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	570
	412	610
		[illegible]
	[illegible]	[illegible]

P. 4 5

[illegible]	Lufra Lt %	5-1-73 Vol. ?
	367	450
	383	870
	423	800
	340	590
	[illegible]	570
	376	510
[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]
	322	410
	[illegible]	480
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	260
	[illegible]	210
	[illegible]	360
	[illegible]	240
	[illegible]	350
	[illegible]	330
	304	340
	[illegible]	300
	[illegible]	640
	335	400
	[illegible]	470
	320	420
	295	230
	327	540
	309	290
	311	360
	[illegible]	400
	387	410
	303	300
	[illegible]	[illegible]
	372	[illegible]

Psy 5

Upper St. [illegible]	Ln FRR	51-73
[illegible]	[illegible]	wt. g
[illegible]	207	260
	[illegible]	260
	[illegible]	[illegible]
	[illegible]	[illegible]
	317	[illegible]
	[illegible]	[illegible]
	[illegible]	370
	[illegible]	212
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	242

[illegible] Plumb at [illegible]

LMFBR 8-10-73

St. #1 Gill Netting (Upper station)

No fish in 5" mesh net.

$1\frac{1}{2}$" mesh net

SP.	Wt. g	Lt. mm	NO.
Drum	184	259	1
G. Shad	186	301	1
Sky Jack	1137	327-406	5

LIMFER 8-10-73

Station #2 mid station.

3" mesh net

	Wt. g	Lt. m/m	NO
Carp	1700	500	1
"	1900	549	1
Blk. Buffalo	1850	527	1

1½" mesh net.

SP.	Wt. g.	Lt. m/m	NO
Skip Jack	458	400	1
C. Cat	3[illegible]0	351	1
Drum	138	250	1
Sanger	1025	492	1

There was the remains of a skip jack in the 1½" net that had been dined on by a turtle.

LmFBR 8-10-73

Station # 3 (Lower st.)
No fish in 3" mesh net
1½" mesh

Sp	wt g	Lt m/m	NO.
Skip Jack	1575	331-401	4
Silver R. Horse	2260	510	1
Carp	193	245	1

Section 2.7.1
Reference 4R
Section 2.7.2, ref. 105

W A Bimbom

TENNESSEE WILDLIFE RESOURCES COMMISSION
PROCLAMATION
ENDANGERED OR THREATENED SPECIES

Pursuant to the authority granted by Tennessee Code Annotated, Sections 51-905 and 51-907, the Tennessee Wildlife Resources Commission does hereby declare the following species to be endangered or threatened species subject to the regulations as herein provided. Said regulations shall become effective sixty days from this date.

SECTION I. ENDANGERED OR THREATENED SPECIES

MOLLUSCS

ENDANGERED

Birdwing pearly mussel	*Conradilla caelata*
Dromedary pearly mussel	*Dromus dromas*
Yellow-blossom pearly mussel	*Epioblasma (-Dysnomia) florentina florentina*
Green-blossom pearly mussel	*Epioblasma (-Dysnomia) torulosa gubernaculum*
Tuberculed-blossom pearly mussel	*Epioblasma (-Dysnomia) torulosa torulosa*
Turgid-blossom pearly mussel	*Epioblasma (-Dysnomia) turgidula*
Tan riffle shell pearly mussel	*Epioblasma (-Dysnomia) walkeri*
Fine-rayed pigtoe pearly mussel	*Fusconaia cuneolus*
Shiny pigtoe pearly mussel	*Fusconaia edgariana*
Pink mucket pearly mussel	*Lampsilis orbiculata orbiculata*
White warty-back pearly mussel	*Plethobasis cicatricosus*
Orange-footed pimpleback	*Plethobasis cooperianus*
Rough pigtoe pearly mussel	*Pleurobema plenum*
Cumberland monkeyface pearly mussel	*Quadrula intermedia*
Appalachian monkeyface pearly mussel	*Quadrula sparsa*
Pale lilliput pearly mussel	*Toxolasma (-Carunculina) cylindrella*
Painted snake coiled forest snail	*Anguispira picta*

FISH

ENDANGERED

Lake Sturgeon	*Acipenser fulvescens*
Ohio River Muskellunge (in Morgan, Cumberland, Fentress & Scott Counties)	*Esox masquinongy ohioensis*
Barren's Topminnow	*Fundulus sp. (cf. F. albolineatus)*
Spotfin Chub	*Hybopsis monacha*
Yellowfin Madtom	*Noturus flavipinnis*
Snail Darter	*Percina tanasi*

Proc. No. 75-15*

**Section I amended by Proc. No. 77-4 dated May 13, 1977, Proc. No. 78-14 dated Sept. 22, 1978; and, Proc. No. 78-20 dated Dec. 8, 1978.*

SECTION I. (Continued)

FISH (Continued)

THREATENED

Silverjaw Minnow	*Ericymba bucatta*
Slender Chub	*Hybopsis cahni*
Blue Sucker	*Cycleptus elongatus*
Pigmy madtom	*Noturus sp. (cf. N. hilderbrandi)*
Frecklebelly Madtom	*N. munitus*
Slackwater Darter	*Etheostoma boschungi*
Coldwater Darter	*E. ditrema*
Trispot Darter	*E. trisella*
Duskytail Darter	*E. (Catonotus) sp.*
Coppercheek Darter	*E. sp. (cf. E. maculatum)*
Longhead Darter	*Percina macrocephala*
Amber Darter	*P. (Imostoma) sp.*
Reticulate Longperch	*P. sp. (cf. P. caprodes)*

AMPHIBIANS

THREATENED

Tennessee Cave Salamander	*Gyrinophilus palleucus*

REPTILES

THREATENED

Northern Pine Snake	*Pituophis m. melanoleucus*
Western Pigmy Rattlesnake	*Sistrurus miliarius streckeri*

BIRDS

ENDANGERED

Mississippi Kite	*Ictinea mississippiensis*
Golden Eagle	*Aquila chrysaetos*
Bald Eagle	*Haliaeetus leucocephalus*
Osprey	*Pandion haliaetus*
Peregrine falcon	*Falco peregrinus*
Red-cockaded Woodpecker	*Picoides borealis*
Raven	*Corvus corax*
Bachman's Sparrow	*Aimophila aestivalis bachmanii*

THREATENED

Sharp-shinned Hawk	*Accipiter striatus*
Cooper's Hawk	*A. cooperi*
Marsh Hawk	*Circus cyaneus hudsonius*
Bewick's Wren	*Thyromanes bewickii*
Grasshopper Sparrow	*Ammodramus savannarum*
Black-Crowned Night Heron	*Nycticorax nycticorax*

*Section I amended by Proc. No. 77-4 dated May 13, 1977, Proc. No. 78-14 dated Sept. 22, 1978; and, Proc. No. 78-20 dated Dec. 8. 1978.

SECTION I. (Continued)

MAMMALS

ENDANGERED

Eastern Cougar	*Felix concolor cougar*
Indiana Myotis	*Myotis sodalis*
Gray Myotis	*Myotis grisescens*

THREATENED

River Otter	*Lutra canadensis*

SECTION II. REGULATIONS

Except as provided for in Tennessee Code Annotated, Section 51-906 (d) and (e), it shall be unlawful for any person to take, harass, or destroy wildlife listed as threatened or endangered or otherwise to violate terms of Section 51-905 (c) or to destroy knowingly the habitat of such species without due consideration of alternatives for the welfare of the species listed in (1) of this proclamation, or (2) the United States list of Endangered fauna.

Date: June 12, 1975

Proc. No. 75-15*

Section I amended by Proc. No. 77-4 dated May 13, 1977, Proc. No. 78-14 dated September 22, 1978; and, Proc. No. 78-20 dated Dec. 8, 1978.

Sec. 2.7, ref. 106 REFERENCE 2-43

TENNESSEE VALLEY AUTHORITY

NORRIS, TENNESSEE 37828

RECEIVED 10/31/80 ENERGY IMPACT ASSOCIATES, INC. WATER RESOURCES

October 28, 1980

Dr. Donald Wagner
Energy Impact Associates
P.O. Box 1899
Pittsburgh, PA 15230

Dear Dr. Wagner:

Enclosed is the photocopy of the field data sheet you requested to document the capture of a blue sucker during Kingston Steam Plant 316a studies. Any information you need should be on the field sheet. If I may be of further assistance, please contact me at (615) 632-6450.

Sincerely,

George E. Peck

George E. Peck
Biologist, Eastern Area Field Operations
Division of Water Resources

Enclosure

195
Category Aquatic Ecology
C-200
Resource File

... gar

O'ER-4004

River and Mile	Station or Cove	Project Title	SM	DT	Gear Type
Kingston [illegible]	Intermediate	316a			[illegible]

Net Information

Net Number		1B	2B	3B	4B	5B	6B	7	8	9	10
Date Net Set 04/08/75	Time	1130	1110	1055	1045	1035	1005			✓	
Date Net Pulled 04/09/75	Time	1135	1125	1110	1140	1030	0950		1½" gill net		
Depth at shallow end of net (M)		1.0	1.0	3.0	1.0	1.0	1.0				
Depth at deep end of net (M)		3.5	3.0	4.0	3.5	1.5	10.0				

If net interference, check appropiate net number and explain in comment section on back of form

Common Name	Code	Number of fish caught									
[illegible] Temp		11.0	11.0	12.5	13.5	11.5	13.0				
gar											
skipjack herring	106003	2	2	4	3	3	5				
gizzard shad	106007	1	1	1	8		3				
threadfin shad	106008	1		1							
carp	111012				1	1	1				
[illegible]											
BLUE SUCKER							1				
		Net set about Clinch River Mile 0.3									
river carpsucker	112001										
quillback	112002										
highfin carpsucker	112004										
hogsucker											
smallmouth buffalo	112030										
bigmouth buffalo	112031										
GOLDEN redhorse		1									
blue catfish	113002						3				
channel catfish	113009						2				
flathead catfish	113022										
YELLOW bullhead						1					
white bass	122002						1				
striped bass	122004										
						1					
bluegill	123017										
largemouth bass	123027										
white crappie	123029								Golden [illegible] with [illegible]		
sauger	124097				1		4				
walleye	124098										
	125001										

EPHONE CONFERENCE MEMORANDUM C260-134-80 Sec. 2.7.2, reference 107

Associates

DATE October 15, 1980

INCOMING [X] OUTGOING C.O. G.O.

MR. Fred Heitman OF THE Lake Eufalla Fishery Management Unit
918/689-5954

MR. OF THE REFERENCE 2-44

TO: G. A. Valiulis

L. L. Simmons

W. A. Beimborn

JECT: Blue sucker in Watts Bar Reservoir TIME 1:00 P.M.

COST

C-260 CHARGE

AIL OF CONFERENCE

Fred confirmed that he had collected a blue sucker in Watts Bar Reservoir. The fish was discarded, but he has photographs of it. I asked about the location of the catch. Fred was not sure, but said it was on the Tennessee River arm downstream of Fort Loudon Dam, not on the Clinch River. He will check his notes and call back later this week with more precise information.

PT. Resource Analysis D. J. Wagner D. J. Wagner (SIGNATURE) EXT. NO. 175

LEPHONE CONFERENCE MEMORANDUM C260-136-80

DATE 10/15/80

✓ INCOMING ☐ OUTGOING C.O. C.O.

MR. Fred Heitman OF THE Lake Eufalla Fishery Management Unit
918/689-5959

MR. OF THE

IES TO: G. A. Valiulis
L. L. Simmons
W. A. Beimborn

JECT: Blue sucker TIME

COST

E C260 CHARGE

TAIL OF CONFERENCE

Fred was calling back with more details of his blue sucker collection.

The fish was collected on April 23, 1977 at Tennessee River Mile 591.9. This is at a lighted navigation marker just upstream of the boat ramp at Loudon, Tenn. He thinks the bottom is in transition from rock to mud there.

A 3 1/4" trammel net was set overnight (1415 to 0555 hrs). The fish was 805 mm long and weighed 5 lb. 4 oz.

He referred to p. 19 and p. 79 of his thesis (being sent by Mike Van Den Avyle). Fred also said this work was presented at the Southeastern Conference in 1978 - he's sending a reprint.

DEPT. Resource Analysis D. J. Wagner (SIGNATURE) EXT. NO. 175

REFERENCE 2-45

Philip W. Smith

THE FISHES OF ILLINOIS

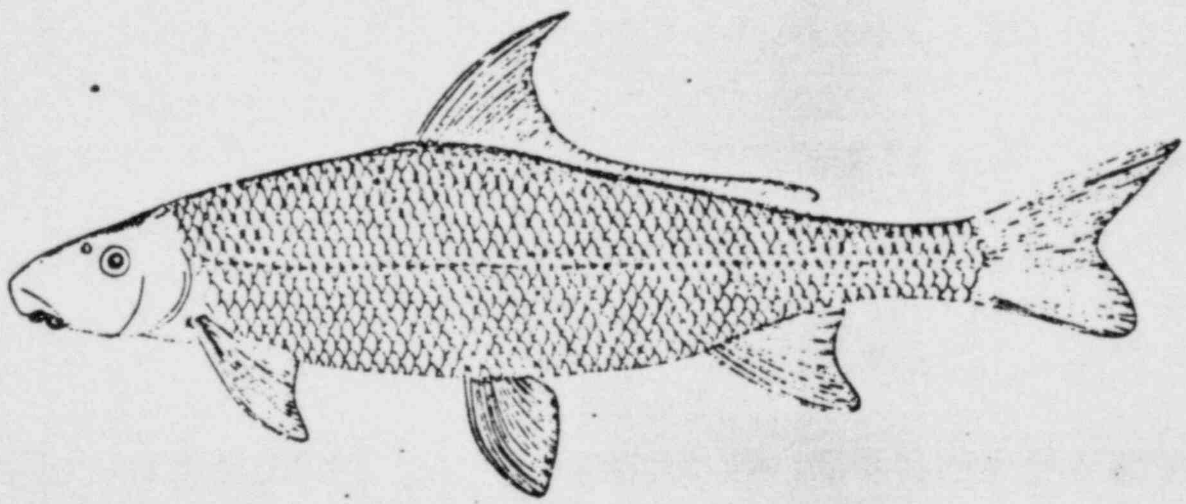
Published for the Illinois State Natural History Survey by the
UNIVERSITY OF ILLINOIS PRESS
Urbana Chicago London

6. Scales small and closely crowded, more than 55 in lateral line; ground color dusky; lips entirely papillose .... *Catostomus*
   Scales large, not closely crowded, fewer than 50 in lateral line; ground color silvery or bronzy; lips plicate or both plicate and papillose .... *Moxostoma*
7. Body terete; dorsal fin slightly falcate; body with many distinct longitudinal rows of small brown dots, each dot being a spot at the scale base; lateral-line scales, 43 or more .... *Minytrema*
   Body slab-sided; dorsal fin convex; body pattern not consisting of longitudinal rows of small brown dots; lateral-line scales, fewer than 43 .... *Erimyzon*

Cycleptus Rafinesque

This bizarre genus contains only one species, which is restricted to rivers of the central and southern United States.

Blue sucker
Cycleptus elongatus (Lesueur)



Catostomus elongatus Lesueur 1817*b*:103 (type-locality: Ohio River).
Cycleptus elongatus: Nelson 1876:50 (recorded from Illinois); Jordan 1878:64; Forbes 1884:81; Large 1903:12; Forbes & Richardson 1908:65–66; O'Donnell 1935:478; Smith 1965:8.

Diagnosis.—The blue sucker is an elongate and terete fish unique in the Catostomidae because of its small head (the length contained five or more times in the standard length) and long caudal peduncle (greatly exceeding length of adpressed anal fin). It has a blue-black or dark gray dorsum, darkly pigmented fins, a somewhat paler venter, 50 or more lateral-line scales, and a long and extremely falcate dorsal fin; the lower lobe of its caudal fin is black. So bizarre are the proportions that neither adult nor young can be confused with any other sucker. The species attains a length of about 890 mm (35 inches).

Variation.—No studies of geographic variation have been published and no subspecies have been described. The scientific name of this fish has been remarkably stable.

Ecology.—The blue sucker is a large-river species most often found in deep riffles and fast chutes over rocky or gravelly bottom in March and April, when the species is probably spawning. It is a strongly migratory fish that occasionally ascends

Distribution of the blue sucker in Illinois.

tributary streams for considerable distances and then is not recognized by the small-river fishermen who catch them. Many such discoveries are reported to authorities, but the specimens rarely reach a museum collection. Almost nothing is known about the feeding and reproductive habits of the species, and no one publication summarizing the available information can be cited.

Distribution.—The blue sucker has been declining in abundance for many years; its decimation has been attributed to the construction of dams on navigable rivers, the deterioration of water quality, excessive catches of adults in spawning runs, and the gradually decreasing depths of river channels through sand and silt choking. The blue sucker still occurs in the Mississippi River at least as far north as Rock Island County but is generally uncommon. It is probably more common in the less turbid Wabash and Ohio rivers than available records indicate but, according to long-time commercial fishermen, much less common now than formerly. How generally it occurs is difficult to assess because of its habit of occasionally ascending great distances into medium-sized rivers.

Ictiobus Rafinesque

This genus, restricted to Mexico, Central America, and the Mississippi River valley of the central United States, contains five currently recognized species, three of which occur in Illinois. Juveniles are similar to each other and to the young of the quillback and are difficult to distinguish.

KEY TO SPECIES

1. Mouth large, terminal, and extremely oblique; tip of upper lip about on level with lower margin of eye; lips faintly striate .... *cyprinellus*

   Mouth small, somewhat subterminal, and not extremely oblique; tip of upper lip well below level of lower margin of eye; lips thicker and more striate 2
2. Mouth small, almost horizontal, decidedly inferior; body deep and slab-sided in the adult, its greatest depth contained less than three times in standard length; back in front of dorsal fin highly arched, thin, and keeled; eye large, its diameter contained fewer than two times in snout length; parietal and occipital region not appreciably swollen .... *bubalus*

   Mouth large, slightly oblique, almost terminal; body thick, not deep and not slab-sided in the adult; back in front of dorsal fin not highly arched, thin, and keeled; eye small, its diameter contained two or more times in snout length; parietal-occipital region swollen .... *niger*

REFERENCE 2-46

The Fishes of Missouri

by

William L. Pflieger

Mark Sullivan • Editor

Lynne Taylor • Artist

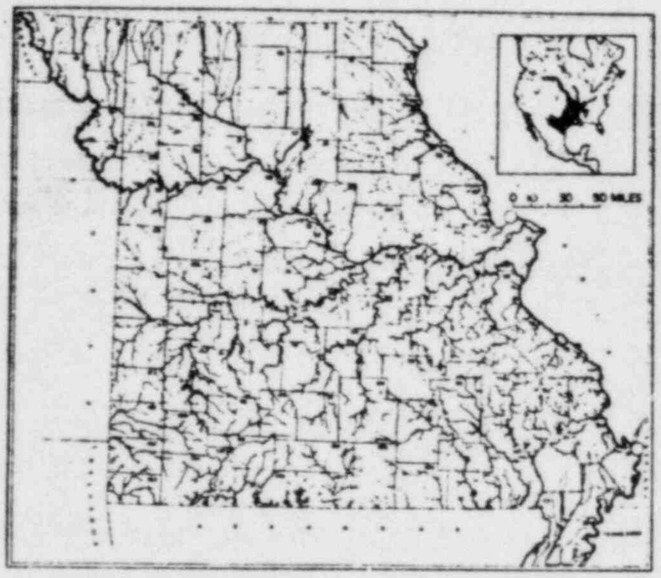
Published by

Missouri Department of Conservation

1975

Blue Sucker

Cycleptus elongatus (Lesueur)



Other local names: Missouri sucker, Slender-headed sucker, Blackhorse, Gourdseed sucker, Schooner

DESCRIPTION

Illustration: Page 179, 2a.

Characters: A slender, dark-colored sucker with a small head and a long, sickle-shaped dorsal fin. Eyes small and closer to rear margin of gill cover than to tip of snout. Mouth small, horizontal, and distinctly overhung by snout. Lips covered by numerous wart-like papillae. Lateral line complete, containing 55 to 58 scales. Body depth going about 4 to 5 times into standard length. Dorsal fin with 28 to 33 rays.

Life colors: Back and sides blue-black or dark olive with brassy reflections; belly white. Fins dusky or black. Breeding males are very dark and have small tubercles over most of head, body, and fins.

Size: According to commercial fishermen, blue suckers weighing up to 20 pounds were formerly common in the Missouri River. Most specimens taken in recent years were 16 to 24 inches long and weighed 1½ to 3 pounds.

Scientific name: *Cycleptus*, reported by its author to mean "small round mouth"; *elongatus*, "elongate."

DISTRIBUTION AND HABITAT

The blue sucker is rare but widespread in the Missouri and Mississippi rivers and the lower sections of their larger tributaries. It seems to have declined in abundance since 1900.

This sucker inhabits the deep, swift channels of large rivers over a bottom of sand, gravel, or rock. It is tolerant of high turbidity if there is sufficient current to prevent deposition of silt. Construction of dams, with the attendant decrease in current velocity that permits siltation, has been unfavorable to the blue sucker.

HABITS AND LIFE HISTORY

The habits of this distinctive sucker are not well known. The streamlined body and sickle-shaped fins are adaptions for maintaining a position in swift currents. The blue sucker probably feeds on insect larvae and other small invertebrates taken from the bottom. It is a highly mobile fish. Formerly there were important spring runs and lesser fall runs of the blue sucker in the upper Mississippi River.[22] Adults in breeding condition have been taken in Current River as early as February and March, but spawning is said to occur in May and June at this latitude.[24] A larval blue sucker was collected from the Missouri River, Boone County, in mid-June. In Lake Texoma, Oklahoma, two-year-old fish were about 15 inches standard length.[114]

IMPORTANCE

The blue sucker is said to be the best food fish of all the suckers and was formerly of some commercial importance along the Missouri and Mississippi rivers. It is still taken in small numbers by commercial fishermen, most often by drifting trammel nets with the current.

Bigmouth Buffalo

Ictiobus cyprinellus (Valenciennes)

Other local names: Gourdhead, Redmouth buffalo, Common buffalo

DESCRIPTION

Illustration: Page 180, 4a.

Characters: A dark-colored sucker with a deep, rather thick body and a long, sickle-shaped dorsal fin. Eyes small and closer to tip of snout than to rear margin of gill cover. Lower fins with much dusky pigment. Subopercle (bone at lower back margin of gill cover) broadest at middle, its outer margin gently rounded. Lateral line complete, containing 32 to 40 scales. Dorsal fin with 23 to 32 rays.

Similar to smallmouth and black buffaloes but with a large, oblique mouth, and thinner, less strongly grooved (striate) lips. Front of upper lip about on a level with lower margin of eye. Length of upper jaw much greater than diameter of eye.

Section 2.7.2; reference 112

TRIP REPORT C260-56-80 REFERENCE 2-47

Trip to: Clinch River, Tenn. Date: 8/19-20/80

Subject: Aquatic Reconnaissance and Data Acquisition

Contract or Negotiation Name and Number: C-260, Tasks 2, 3 and 4

Persons Present and Company:

D. J. Wagner	Vince Fayne, CRBR Program Office
G. A. Valiulis	Donley Hill, TVA
L. L. Simmons	Edward Scott, TVA
D. W. Myers	Thomas Swor, TVA
Ken Yates, CRBR Program Office	

Distribut :

W. . Beimborn	D. W. Myers
G. A. Valiulis	A. Huggins
L. L. Simmons	

SUMMARY:

Tuesday, 8/19

0900-1400: DJW, GAV, LLS and Ken Yates met Don Hill and Ed Scott of TVA at launch area on Clinch River. Ran a series of bathymetric profiles near locations of intake, discharge and barge unloading facility - results appear generally similar to 1974-75. Obtained ponar grab samples of bottom, which were described qualitatively in a field book, at Stations 0.3, 0.5 and 0.7 on Transects 1-5, plus Station 0.1 at unloading area. Noted several species of macrophytes growing in limited but dense stands in shallow water.

1400-1600: DJW and DWM discussed Tasks 2 and 3 with Vince Fayne. Vince supplied Tenn. Laws and attendant regulations on air and water pollution, regulations on hazardous wastes and solid wastes. Also a file memo he wrote 4/8/80, which will be updated by the end of this month. Finally, he supplied a copy of his working draft of Table 12.0-1. It was made clear that we would also be working on an update of Table 12.0-1, not a permit compliance plan.

In discussion, Vince noted the following concerns:

Air - new federal requirements for State regulations - FR, Aug. 7

Water - new Tenn. water quality criteria; new Army Corps regulations; revised Steam Electric Effluent Guidelines due to be proposed at any time

Authorized Signature: D. J. Wagner Donald J. Wagner Date: August 22, 1980

Solid/Hazardous Wastes - a sanitary landfill is a potentiality
- check the nature of the   te lagoon - contents may require ev tion according to hazardous waste rule.

Vince also noted that the water quality criteria are i luded in Section 14 as an appendix, but air quality criteria are n .

LLS, GAV, DWM returned to Pittsburgh.

Wednesday, 8/20

DJW met with TVA personnel at Norris, obtained the following information:

1. Water quality reports and data from Melton Hill Dam prepared by Eric Mulkey

2. Confirmation of unusually great macrophyte growth this summer. Causes uncertain but may be due to prolonged dry, hot spell, with warmer water temperatures and less turbidity than usual - Leon Bates; Muscle Shoals lab (under Joe Cooney, /383-4631). Annual report will be sent for 1979, and for 1980 when available (early 1981). The problem is general in eastern Tenn. this year. Noted that Najas minor and Potamogeton pucillus are common near site.

3. Ed Scott (Fielc erations, 615 4-9800, X 215 pplied:

   Watts Bar roten ng survey dat 1949 to presen

   Report on evide of sauger sp ing near propc dis- charge (RM15-17 This report pared the sect of the river from R.M. -17 with the a of the lock ls at Melton Hill Dam

   The area near t submerged isl d produced the eatest number of ripe sh, but the si ificance of thi area relative to other laces in the C nch River or Wa s Bar Reservoir is obs ure due to the imited data coll cted. The report does sugg st that the ta lwater of Melton Hill Dam is not used for spawning.

   Another reference of much interest is: Fletcher, J. W., 1977. Assessment of adult and larval fish populations of the Lower Clinch River below Melton Hill Dam. M.S. Thesis, Tennessee Technological University, Cookesville, Tennessee. 99 pp. Ed Scott will be sending a copy.

4. Tom Swor (Fisheries and Aquatic Ecology):

Will forward a report on 1975-77 monitoring program. Also referred to: McLean, et. al., report on threadfin shad and cold stress (NUREG/CR-1044, ORNL/NUREG/TM-340).

For Corbicula problem and chlorination information, contact:

Edward A. Kopatz, Jr., Office of Power, Div. of Fossil and Hydro Power, Ext. 2465 in Chattanooga, or

L. B. [illegible]edy, Plant Sup[illegible]intendent at Kingston, 615/376-6135.

returned to [illegible]sburgh.

REFERENCE 2-48

EPHONE CONFERENCE MEMORANDUM C260-50-80

Section 2.7.2, reference 113

DATE August 18, 1980

INCOMING [X] OUTGOING C.O. ______ G.O. ______

MR. Dr. Jim Loar OF THE ORNL, Environmental Sciences Division 615/574-7323

MR. ______ OF THE ______

IES TO: G. A. Valiulis

W. A. Beimborn

L. L. Simmons

JECT: Oak Ridge Aquatic Data TIME 1600

COST ______

E C-260/2,4 CHARGE ______

AIL OF CONFERENCE

Talked to Jim re: aquatic info. on Clinch River and vicinity. Studies he knows of are:

1. 1973: TVA did some limited adult fish sampling, from R.M. 10 to Melton dam

2. '74-'75: CRBR surveys

3. '75-'76: surveys v. similar in scope to item 2, but extended from R.M. 12 to 15, plus Grassy Creek and Bear Creek. Info. was used to prepare an ER for Exxon Nuclear, Inc., he thinks mainly by people at Tennessee Tech. Contact: Dr. Parley Winger at T.T.

4. April '77-March '78: 3 sites on Clinch River and 3 on Poplar Creek - ORNL

5. Feb-Sept. '78: Ichthyoplankton sampling at 6 sites in river, 3 in creek, on a weekly basis - ORNL

Items 4 and 5 were combined, plus a review of earlier studies on biology, hydrology and water quality, in a report Jim prepared that is currently being reviewed internally. He expects it will be published this fall. He didn't want to sent the data minus the interpretation/conclusions. Will send me a copy of the report as soon as he can, sometime this fall.

These studies formed the basis of an EA for "K-25", which is mothballed at the printers.

6. March '79-May '80: another study, like 4-5, but more frequent collections, from R.M. 19-22, plus Whiteoak Creek. In preparation, to review in Sept. This will form the basis for an EIS that DOE will prepare on ORNL.

EPT. Resource Analysis D. J. Wagner (SIGNATURE) D J Wagner EXT. NO. 175

TVA data is, to his knowledge older: 316a, b on Bull Run power plant (Melton Hill Res.) and on Kingston Steam Plant (Watts Bar Res.); both are early-mid '70's.

TVA (Bob Wallus at Norris) is apparently doing some work on sauger spawning Habits, but Jim is not too familiar with it.

There is also a major study on threadfin shad recoveries in Watts Bar after cold kills. This is related to TVA's Kingston plant, but is overseen by Rich McLean (ORNL: 615/574-7383). It covered the period 1976-79. Also McGee (?) looked at the effect of threadfin populations on sauger.

Sediment sampling (cores) done in 1977-78, mainly to examine radionuclides. Talk to Tom Oates, ORNL, at 615/574-6669.

Re: changes near site since 1975:

Tenn. Wildlife Resources Agency now stocks striped bass (see also Chuck Coutant at ORNL)

In this study (report on items 4 & 5, above), he noted an apparent increase in yellow bass.

Otherwise, there was too much variation between sampling techniques, etc., to say much.

Jim recommends looking at patterns of operation at Watts Bar and Melton Hill dams, plus available water quality data. He suspects that if these are not very different, neither will biota.

See also, ORNL publications (from Information section)

Annual Monitoring Reports
Environmental Sciences Division Annual Progress Reports
Health-Physics Divisions, last several Annual Progress Reports

I thanked Jim profusely for this wealth of information, said I hoped to talk to him again in the future.

Sec. 2.7, ref 114

STATISTICAL ANALYSIS SYSTEM
TOTAL NUMBERS AND WEIGHT (KG) PER HECTARE IN WATTS BAR RESERVIOR, BY SIZE CLASS

106

YEAR	NUMBER OF SAMPLES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
1949	1	46529.23	55.01	60.00	10.74	95.38	14.14	46684.62	79.89
1950	1	5456.79	12.63	174.07	20.75	500.00	63.47	6130.86	96.85
1951	1	2646.91	13.57	176.54	9.62	3145.68	56.69	5969.14	79.88
1953	1	2659.26	14.89	211.11	8.98	395.06	75.43	3265.43	99.31
1957	2	13042.22	77.08	696.50	19.28	414.34	116.53	14153.06	212.89
1958	1	9983.58	59.07	270.90	11.84	396.27	103.96	10650.75	174.88
1959	1	4500.75	17.46	211.94	12.46	355.97	105.07	5068.66	134.99
1960	3	23626.78	32.01	304.12	16.27	414.73	161.23	24345.62	209.51
1964	20	5199.76	11.75	398.64	19.53	508.68	174.23	6107.08	205.51
1973	10	13236.87	29.72	854.46	30.18	1237.82	286.64	15329.16	346.54
1975	6	1873.22	5.05	574.21	23.64	1112.00	317.50	3559.43	346.19
1976	8	3222.65	10.15	809.62	23.29	843.27	224.89	4875.54	258.33
1977	8	8849.50	22.01	445.67	14.93	877.27	189.75	10172.44	226.69
1978	2	2509.91	5.53	621.08	14.23	339.53	42.60	3470.52	62.36
1979	2	1999.34	14.22	469.18	16.38	910.28	176.89	3378.80	207.49
1980	4	10881.87	17.23	906.65	44.06	4828.26	449.88	16616.79	511.17
ALL YEARS	71	7964.33	19.03	552.42	21.68	1010.73	210.52	9527.49	251.23

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 1 SAMPLES IN WATTS BAR RESERVIOR, 1949

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
GAME								
WHITE BASS	4.62	0.03	–	–	–	–	4.62	0.03
BLUEGILL	33.85	0.16	10.77	0.35	1.54	0.15	46.15	0.66
LONGEAR SUNFISH	9.23	0.07	1.54	0.06	–	–	10.77	0.13
LARGEMOUTH BASS	15.38	0.07	12.31	0.66	3.08	0.63	30.77	1.36
WHITE CRAPPIE	18.46	0.03	3.08	0.16	–	–	21.54	0.19
BLACK CRAPPIE	–	–	–	–	1.54	0.16	1.54	0.16
GROUP TOTAL	81.54	0.37	27.69	1.22	6.15	0.94	115.38	2.53
ROUGH								
LONGNOSE GAR	1.54	0.08	–	–	–	–	1.54	0.08
SKIPJACK HERRING	–	–	1.54	0.19	–	–	1.54	0.19
CARP	–	–	4.62	1.45	3.08	1.82	7.69	3.27
UNIDENTIFIED BUFFALO	–	–	21.54	7.68	3.08	1.57	24.62	9.25
UNIDENTIFIED REDHORSE	1.54	0.03	–	–	–	–	1.54	0.03
CHANNEL CATFISH	–	–	4.62	0.20	–	–	4.62	0.20
FRESHWATER DRUM	7.69	0.06	–	–	–	–	7.69	0.06
GROUP TOTAL	10.77	0.18	32.31	9.51	6.15	3.39	49.23	13.08
FORAGE								
GIZZARD SHAD	46255.38	54.15	–	–	83.08	9.82	46338.46	63.97
BLUNTNOSE MINNOW	1.54	T	–	–	–	–	1.54	T
LOGPERCH	1.54	T	–	–	–	–	1.54	T
MIXED & UNID MINNOWS	178.46	0.31	–	–	–	–	178.46	0.31
GROUP TOTAL	46436.92	54.46	0.00	0.00	83.08	9.82	46520.00	64.28
FINAL TOTAL	46529.23	55.01	60.00	10.74	95.38	14.14	46684.62	79.89

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 1 SAMPLES IN WATTS BAR RESERVIOR, 1950

SPECIES	YOUNG OF YEAR		INTERMEDIATE		HARVESTABLE		TOTAL	
	NUMBER	WEIGHT	NUMBER	WEIGHT	NUMBER	WEIGHT	NUMBER	WEIGHT
				GAME				
WHITE BASS	23.46	0.30	1.23	0.08	1.23	0.18	25.93	0.57
BLUEGILL	-	-	58.02	1.53	18.52	1.38	76.54	2.91
LONGEAR SUNFISH	246.91	0.54	-	-	-	-	246.91	0.54
SPOTTED BASS	29.63	0.21	13.58	0.38	2.47	0.34	45.68	0.93
LARGEMOUTH BASS	64.20	0.45	37.04	1.63	3.70	1.03	104.94	3.11
WHITE CRAPPIE	33.33	0.06	3.70	0.12	2.47	0.31	39.51	0.49
BLACK CRAPPIE	6.17	0.03	-	-	-	-	6.17	0.03
SAUGER	-	-	-	-	2.47	0.86	2.47	0.86
GROUP TOTAL	403.70	1.60	113.58	3.73	30.86	4.12	548.15	9.45
				ROUGH				
SKIPJACK HERRING	1.23	0.02	7.41	0.44	-	-	8.64	0.46
CARP	-	-	3.70	1.37	8.64	4.93	12.35	6.30
SMALLMOUTH BUFFALO	-	-	37.04	14.27	11.11	6.16	48.15	20.43
SPOTTED SUCKER	-	-	1.23	0.22	-	-	1.23	0.22
UNIDENTIFIED REDHORSE	2.47	0.15	1.23	0.11	2.47	0.83	6.17	1.08
CHANNEL CATFISH	-	-	-	-	1.23	0.70	1.23	0.70
FLATHEAD CATFISH	1.23	0.02	-	-	-	-	1.23	0.02
FRESHWATER DRUM	-	-	9.88	0.60	3.70	0.53	13.58	1.13
GROUP TOTAL	4.94	0.19	60.49	17.01	27.16	13.15	92.59	30.35
				FORAGE				
GIZZARD SHAD	-	-	-	-	441.98	46.20	441.98	46.20
THREADFIN SHAD	4979.01	10.78	-	-	-	-	4979.01	10.78
MIXED & UNID MINNOWS	69.14	0.07	-	-	-	-	69.14	0.07
GROUP TOTAL	5048.15	10.85	0.00	0.00	441.98	46.20	5490.12	57.05
FINAL TOTAL	5456.79	12.63	174.07	20.75	500.00	63.47	6130.86	96.85

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 1 SAMPLES IN WATTS BAR RESERVIOR, 1951

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
GAME								
WHITE BASS	22.22	0.17	13.58	1.27	19.75	3.12	55.56	4.57
WARMOUTH	7.41	0.03	2.47	0.04	-	-	9.88	0.08
BLUEGILL	338.27	0.87	64.20	1.36	30.86	2.25	433.33	4.47
LONGEAR SUNFISH	4.94	0.02	-	-	-	-	4.94	0.02
SPOTTED BASS	14.81	0.16	7.41	0.45	-	-	22.22	0.61
LARGEMOUTH BASS	25.93	0.24	27.16	1.89	9.88	2.75	62.96	4.88
WHITE CRAPPIE	211.11	0.67	13.58	0.18	2.47	0.37	227.16	1.21
BLACK CRAPPIE	2.47	0.01	1.23	0.05	-	-	3.70	0.06
SAUGER	28.40	0.73	1.23	0.20	1.23	0.64	30.86	1.57
GROUP TOTAL	655.56	2.90	130.86	5.45	64.20	9.13	850.62	17.48
ROUGH								
SKIPJACK HERRING	6.17	0.09	11.11	0.66	4.94	1.44	22.22	2.19
CARP	-	-	-	-	1.23	0.58	1.23	0.58
SMALLMOUTH BUFFALO	-	-	3.70	1.46	13.58	7.25	17.28	8.71
BLACK BUFFALO	-	-	-	-	1.23	0.91	1.23	0.91
SPOTTED SUCKER	1.23	0.05	-	-	-	-	1.23	0.05
GOLDEN REDHORSE	-	-	-	-	1.23	0.72	1.23	0.72
BLUE CATFISH	-	-	-	-	1.23	0.39	1.23	0.39
CHANNEL CATFISH	-	-	3.70	0.35	3.70	2.18	7.41	2.53
FLATHEAD CATFISH	2.47	T	2.47	0.34	1.23	0.44	6.17	0.78
FRESHWATER DRUM	77.78	0.76	24.69	1.37	12.35	2.08	114.81	4.21
GROUP TOTAL	87.65	0.90	45.68	4.17	40.74	15.99	174.07	21.06
FORAGE								
GIZZARD SHAD	255.56	1.40	-	-	50.62	6.91	306.17	8.32
THREADFIN SHAD	1333.33	8.05	-	-	-	-	1333.33	8.05
MIXED SHAD	-	-	-	-	2990.12	24.66	2990.12	24.66
UNIDENTIFIED SHINER	1.23	T	-	-	-	-	1.23	T
BULLHEAD MINNOW	1.23	T	-	-	-	-	1.23	T
BROOK SILVERSIDE	1.23	T	-	-	-	-	1.23	T
MIXED & UNID MINNOWS	311.11	0.31	-	-	-	-	311.11	0.31
GROUP TOTAL	1903.70	9.77	0.00	0.00	3040.74	31.58	4944.44	41.34
FINAL TOTAL	2646.91	13.57	176.54	9.62	3145.68	56.69	5969.14	79.88

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 1 SAMPLES IN WATTS BAR RESERVIOR, 1953

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
GAME								
WHITE BASS	19.75	0.39	1.23	0.08	1.23	0.26	22.22	0.73
WARMOUTH	2.47	†	1.23	0.02	-	-	3.70	0.03
BLUEGILL	249.38	0.61	101.23	2.29	33.33	2.62	383.95	5.52
LONGEAR SUNFISH	-	-	2.47	0.07	-	-	2.47	0.07
SMALLMOUTH BASS	-	-	-	-	1.23	0.17	1.23	0.17
SPOTTED BASS	14.81	0.16	1[illegible].35	0.39	2.47	0.34	29.63	0.89
LARGEMOUTH BASS	11.11	0.11	[illegible]9.51	2.41	12.35	3.34	62.96	5.86
WHITE CRAPPIE	2.47	†	3.70	0.04	1.23	0.26	7.41	0.30
BLACK CRAPPIE	2.47	0.01	-	-	1.23	0.28	3.70	0.28
SAUGER	1.23	0.05	2.47	0.22	1.23	0.34	4.94	0.60
GROUP TOTAL	303.70	1.33	164.20	5.52	54.32	7.60	522.22	14.45
ROUGH								
SKIPJACK HERRING	7.41	0.03	4.94	0.43	-	-	12.35	0.45
CARP	-	-	-	-	1.23	0.58	1.23	0.58
UNIDENTIFIED CARPSUCKERS	-	-	1.23	0.14	1.23	0.35	2.47	0.49
SMALLMOUTH BUFFALO	-	-	-	-	25.93	18.35	25.93	18.35
UNIDENTIFIED REDHORSE	1.23	0.03	1.23	0.11	2.47	1.28	4.94	1.41
CHANNEL CATFISH	-	-	8.64	0.63	4.94	7.65	13.58	8.2[illegible]
FLATHEAD CATFISH	6.17	0.04	1.23	0.04	-	-	7.41	0.08
FRESHWATER DRUM	19.75	0.32	29.63	2.12	13.58	2.38	62.96	4.81
GROUP TOTAL	34.57	0.41	46.91	3.46	49.38	30.59	130.86	34.46
FORAGE								
GIZZARD SHAD	1.23	0.02	-	-	285.19	36.99	286.42	37.01
THREADFIN SHAD	1686.42	9.61	-	-	6.17	0.25	1692.59	9.86
MIXED & UNID MINNOWS	633.33	3.52	-	-	-	-	633.33	3.52
GROUP TOTAL	2320.99	13.15	0.00	0.00	291.36	37.25	2612.35	50.39
FINAL TOTAL	2659.26	14.89	211.11	8.98	395.06	75.43	3265.43	99.31

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 2 SAMPLES IN WATTS BAR RESERVIOR, 1957

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
GAME								
WHITE BASS	22.56	0.32	1.10	0.09	0.83	0.27	24.49	0.68
WARMOUTH	38.87	0.15	8.93	0.20	0.41	0.03	48.21	0.38
REDBREAST SUNFISH	3.15	0.02	0.68	0.02	3.42	0.32	7.26	0.36
BLUEGILL	1420.94	3.78	511.24	10.30	83.49	6.18	2015.68	20.25
SMALLMOUTH BASS	2.61	0.03	8.80	0.23	1.78	0.67	13.19	0.93
SPOTTED BASS	54.79	0.56	35.12	1.39	4.12	0.64	94.03	2.59
LARGEMOUTH BASS	26.07	0.23	51.18	1.67	13.19	5.38	90.44	7.28
WHITE CRAPPIE	8.80	0.03	10.45	0.17	3.16	0.44	22.41	0.64
SAUGER	-	-	1.78	0.27	5.35	1.60	7.13	1.88
GROUP TOTAL	1577.80	5.12	629.28	14.34	115.76	15.53	2322.85	34.99
ROUGH								
SKIPJACK HERRING	2.34	0.05	19.52	1.36	1.92	0.69	23.78	2.09
MOONEYE	0.41	0.01	2.07	0.45	-	-	2.48	0.47
CARP	-	-	-	-	6.33	5.63	6.33	5.63
UNIDENTIFIED CARPSUCKERS	0.41	0.02	-	-	-	-	0.41	0.02
NORTHERN HOG SUCKER	-	-	-	-	0.41	0.12	0.41	0.12
SMALLMOUTH BUFFALO	-	-	-	-	31.50	35.61	31.50	35.61
BLACK BUFFALO	-	-	-	-	0.83	3.74	0.83	3.74
BLACK REDHORSE	-	-	-	-	0.83	0.46	0.83	0.46
CHANNEL CATFISH	3.15	0.02	0.41	0.04	6.31	1.48	9.87	1.54
FLATHEAD CATFISH	2.88	0.01	-	-	1.10	0.91	3.98	0.92
FRESHWATER DRUM	116.47	1.27	45.22	3.08	114.39	22.13	276.08	26.48
GROUP TOTAL	125.67	1.39	67.22	4.93	163.61	70.76	356.50	77.08
FORAGE								
GIZZARD SHAD	7.00	0.11	-	-	134.27	30.22	141.28	30.33
THREADFIN SHAD	10782.89	65.90	-	-	0.68	0.02	10783.57	65.92
BULLHEAD MINNOW	0.68	T	-	-	-	-	0.68	T
LOGPERCH	0.68	T	-	-	-	-	0.68	T
MIXED & UNID MINNOWS	547.48	4.56	-	-	-	-	547.48	4.56
GROUP TOTAL	11338.74	70.58	0.00	0.00	134.96	30.24	11473.70	100.82
FINAL TOTAL	13042.22	77.08	696.50	19.28	414.34	116.53	14153.06	212.89

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 1 SAMPLES IN WATTS BAR RESERVIOR, 1958

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
				GAME				
WHITE BASS	47.01	0.72	-	-	-	-	47.01	0.72
WARMOUTH	32.84	0.07	1.49	0.04	2.99	0.25	37.31	0.36
BLUEGILL	431.34	1.09	91.79	2.00	58.21	4.63	581.34	7.71
SMALLMOUTH BASS	2.99	0.03	2.99	0.17	0.75	0.10	6.72	0.31
SPOTTED BASS	3.73	0.04	11.19	0.26	5.22	1.16	20.15	1.46
LARGEMOUTH BASS	10.45	0.11	18.66	0.85	15.67	5.80	44.78	6.76
WHITE CRAPPIE	105.97	0.35	18.66	0.33	2.99	0.34	127.61	1.01
SAUGER	3.73	0.16	0.75	0.12	10.45	4.17	14.93	4.45
GROUP TOTAL	638.06	2.56	145.52	3.76	96.27	16.46	879.85	22.78
				ROUGH				
SKIPJACK HERRING	63.43	0.49	14.18	0.82	7.46	3.98	85.07	5.30
CARP	-	-	-	-	6.72	6.16	6.72	6.16
SMALLMOUTH BUFFALO	-	-	0.75	0.29	13.43	14.94	14.18	15.23
GOLDEN REDHORSE	-	-	-	-	2.24	1.01	2.24	1.01
CHANNEL CATFISH	7.46	0.02	2.99	0.19	11.19	4.46	21.64	4.67
FLATHEAD CATFISH	16.42	0.06	1.49	0.12	0.75	0.87	18.66	1.06
FRESHWATER DRUM	257.46	1.41	105.97	6.65	167.91	33.83	531.34	41.89
GROUP TOTAL	344.78	1.99	125.37	8.08	209.70	65.26	679.85	75.33
				FORAGE				
GIZZARD SHAD	191.04	0.70	-	-	90.30	22.25	281.34	22.94
THREADFIN SHAD	8462.69	53.55	-	-	-	-	8462.69	53.55
MIXED & UNID MINNOWS	347.01	0.27	-	-	-	-	347.01	0.27
GROUP TOTAL	9000.75	54.52	0.00	0.00	90.30	22.25	9091.04	76.76
FINAL TOTAL	9983.58	59.07	270.90	11.84	396.27	103.96	10650.75	174.88

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 1 SAMPLES IN WATTS BAR RESERVIOR, 1959

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
GAME								
WHITE BASS	26.87	0.28	-	-	0.75	0.27	27.61	0.55
WARMOUTH	32.09	0.09	4.48	0.08	1.49	0.20	38.06	0.37
BLUEGILL	340.30	0.67	64.18	2.01	74.63	5.68	479.10	8.36
SMALLMOUTH BASS	2.99	0.03	4.48	0.29	2.99	0.81	10.45	1.13
SPOTTED BASS	17.16	0.18	9.70	0.41	-	-	26.87	0.59
LARGEMOUTH BASS	5.22	0.06	25.37	2.16	8.21	3.28	38.81	5.49
WHITE CRAPPIE	-	-	19.40	1.03	14.93	2.34	34.33	3.38
SAUGER	-	-	10.45	1.47	1.49	0.32	11.94	1.79
GROUP TOTAL	424.63	1.31	138.06	7.45	104.48	12.90	667.16	21.66
ROUGH								
UNIDENTIFIED GAR	0.75	0.01	-	-	-	-	0.75	0.01
SKIPJACK HERRING	7.46	0.16	10.45	1.54	8.96	2.06	26.87	3.75
CARP	-	-	-	-	4.48	4.26	4.48	4.26
NORTHERN HOG SUCKER	-	-	-	-	0.75	0.28	0.75	0.28
SMALLMOUTH BUFFALO	-	-	-	-	36.57	42.51	36.57	42.51
GOLDEN REDHORSE	-	-	0.75	0.13	3.73	2.11	4.48	2.24
BLUE CATFISH	-	-	1.49	0.11	1.49	0.28	2.99	0.39
CHANNEL CATFISH	1.49	0.01	4.48	0.38	0.75	0.35	6.72	0.73
FLATHEAD CATFISH	2.99	0.01	-	-	1.49	0.82	4.48	0.83
FRESHWATER DRUM	50.75	0.43	56.72	2.86	49.25	9.10	156.72	12.40
GROUP TOTAL	63.43	0.62	73.88	5.01	107.46	61.77	244.78	67.40
FORAGE								
GIZZARD SHAD	55.97	0.78	-	-	144.03	30.40	200.00	31.17
THREADFIN SHAD	3626.87	14.49	-	-	-	-	3626.87	14.49
MIXED & UNID MINNOWS	329.85	0.27	-	-	-	-	329.85	0.27
GROUP TOTAL	4012.69	15.53	0.00	0.00	144.03	30.40	4156.72	45.93
FINAL TOTAL	4500.75	17.46	211.94	12.46	355.97	105.07	5068.66	134.99

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 3 SAMPLES IN WATTS BAR RESERVIOR, 1960

SPECIES	YOUNG OF YEAR		INTERMEDIATE		HARVESTABLE		TOTAL	
	NUMBER	WEIGHT	NUMBER	WEIGHT	NUMBER	WEIGHT	NUMBER	WEIGHT
GAME								
WHITE BASS	8.11	0.07	1.45	0.15	-	-	9.56	0.22
WARMOUTH	17.01	0.06	5.23	0.15	1.20	0.08	23.44	0.29
REDBREAST SUNFISH	0.46	T	0.46	0.01	1.37	0.09	2.28	0.09
BLUEGILL	285.37	0.53	54.46	1.46	45.94	3.64	385.78	5.63
LONGEAR SUNFISH	-	-	2.42	0.05	-	-	2.42	0.05
SMALLMOUTH BASS	2.65	0.01	0.50	0.05	0.75	0.13	3.90	0.19
SPOTTED BASS	32.54	0.16	3.94	0.28	2.28	0.32	38.77	0.75
LARGEMOUTH BASS	30.30	0.19	7.09	0.71	6.91	2.54	44.30	3.45
WHITE CRAPPIE	59.18	0.18	2.42	0.14	3.38	0.50	64.98	0.82
BLACK CRAPPIE	-	-	-	-	0.50	0.05	0.50	0.05
SAUGER	2.28	0.03	1.45	0.23	0.73	0.17	4.47	0.43
GROUP TOTAL	437.91	1.22	79.41	3.23	63.07	7.53	580.39	11.98
ROUGH								
SKIPJACK HERRING	-	-	1.00	0.15	3.18	0.93	4.17	1.08
CARP	-	-	-	-	38.42	35.30	38.42	35.30
NORTHERN HOG SUCKER	-	-	-	-	0.48	0.18	0.48	0.18
SMALLMOUTH BUFFALO	-	-	0.25	0.10	47.24	58.53	47.49	58.63
SHORTHEAD REDHORSE	-	-	-	-	0.73	0.24	0.73	0.24
RIVER REDHORSE	-	-	-	-	0.97	1.56	0.97	1.56
GOLDEN REDHORSE	-	-	0.97	0.17	0.98	0.47	1.95	0.64
CHANNEL CATFISH	3.69	0.03	2.12	0.14	3.94	1.39	9.75	1.56
FLATHEAD CATFISH	-	-	0.48	0.03	0.25	0.14	0.73	0.16
FRESHWATER DRUM	33.50	0.32	219.89	12.46	167.06	30.50	420.45	43.27
GROUP TOTAL	37.19	0.35	224.70	13.04	263.24	129.25	525.14	142.63
FORAGE								
GIZZARD SHAD	31.55	0.21	-	-	88.42	24.46	119.96	24.66
THREADFIN SHAD	23045.94	30.04	-	-	-	-	23045.94	30.04
LOGPERCH	0.48	T	-	-	-	-	0.48	T
MIXED & UNID MINNOWS	73.71	0.19	-	-	-	-	73.71	0.19
GROUP TOTAL	23151.68	30.44	0.00	0.00	88.42	24.46	23240.09	54.89
FINAL TOTAL	23626.78	32.01	304.12	16.27	414.73	161.23	24345.62	209.51

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 20 SAMPLES IN WATTS BAR RESERVIOR, 1964

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
GAME								
WHITE BASS	25.79	0.14	3.54	0.31	3.98	0.87	33.32	1.33
WARMOUTH	36.24	0.08	14.38	0.32	2.93	0.25	53.55	0.65
REDBREAST SUNFISH	2.89	T	2.83	0.07	2.37	0.21	8.10	0.29
BLUEGILL	1607.84	1.22	119.88	2.90	49.34	4.29	1777.06	8.41
LONGEAR SUNFISH	0.51	T	1.23	0.03	-	-	1.74	0.04
REDEAR SUNFISH	-	-	0.06	T	0.07	0.01	0.13	0.02
SMALLMOUTH BASS	9.93	0.09	6.90	0.58	2.49	0.54	19.32	1.21
SPOTTED BASS	25.45	0.11	5.47	0.47	1.58	0.24	32.50	0.82
LARGEMOUTH BASS	66.39	0.41	13.53	1.39	5.70	1.67	85.62	3.47
WHITE CRAPPIE	42.30	0.07	11.48	0.52	2.62	0.51	56.40	1.09
BLACK CRAPPIE	0.32	T	0.27	0.02	0.27	0.05	0.86	0.07
SAUGER	12.94	0.37	7.65	0.68	0.60	0.18	21.19	1.22
GROUP TOTAL	1830.60	2.50	187.23	7.28	71.95	8.83	2089.78	18.62
ROUGH								
LONGNOSE GAR	0.54	0.03	-	-	0.12	0.35	0.66	0.38
SHORTNOSE GAR	0.16	T	-	-	-	-	0.16	T
SKIPJACK HERRING	0.90	0.01	1.21	0.23	2.95	0.75	5.06	0.99
MOONEYE	0.12	0.01	0.29	0.03	-	-	0.41	0.04
CARP	7.00	0.60	0.86	0.24	19.04	20.01	26.90	20.85
UNIDENTIFIED CARPSUCKERS	-	-	-	-	0.09	0.05	0.09	0.05
RIVER CARPSUCKER	0.79	0.01	0.16	0.04	2.29	3.40	3.25	3.45
NORTHERN HOG SUCKER	-	-	0.36	0.05	-	-	0.36	0.05
SMALLMOUTH BUFFALO	0.17	0.03	1.52	0.38	50.83	64.89	52.51	65.30
BIGMOUTH BUFFALO	-	-	-	-	3.18	3.55	3.18	3.55
BLACK BUFFALO	-	-	-	-	0.06	0.16	0.06	0.16
SPOTTED SUCKER	0.05	T	0.11	0.02	0.23	0.10	0.39	0.12
SHORTHEAD REDHORSE	0.06	0.01	0.21	0.04	0.26	0.05	0.53	0.10
BLACK REDHORSE	-	-	-	-	0.25	0.25	0.25	0.25
GOLDEN REDHORSE	0.11	T	2.31	0.39	4.11	2.05	6.53	2.45
UNIDENTIFIED CATFISH	-	-	0.14	0.01	-	-	0.14	0.01
BLUE CATFISH	-	-	0.34	0.02	0.07	0.01	0.41	0.03
YELLOW BULLHEAD	0.05	T	-	-	-	-	0.05	T
CHANNEL CATFISH	3.84	0.05	14.52	0.64	8.34	2.86	26.70	3.56
FLATHEAD CATFISH	0.40	0.01	0.62	0.13	1.21	1.11	2.23	1.25
FRESHWATER DRUM	35.90	0.20	188.75	10.02	90.90	15.44	315.55	25.66
GROUP TOTAL	50.09	0.96	211.41	12.25	183.93	115.03	445.43	128.24

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 20 SAMPLES IN WATTS BAR RESERVIOR, 1964

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
				FORAGE				
GIZZARD SHAD	67.56	0.21	-	-	250.10	50.27	317.66	50.48
THREADFIN SHAD	2539.85	6.82	-	-	2.71	0.10	2542.56	6.92
MIXED SHAD	196.77	0.65	-	-	-	-	196.77	0.65
UNIDENTIFIED SHINER	0.30	T	-	-	-	-	0.30	T
EMERALD SHINER	0.20	T	-	-	-	-	0.20	T
WHITETAIL SHINER	0.57	T	-	-	-	-	0.57	T
SPOTFIN SHINER	0.21	T	-	-	-	-	0.21	T
BLUNTNOSE MINNOW	10.62	0.02	-	-	-	-	10.62	0.02
FATHEAD MINNOW	1.81	0.04	-	-	-	-	1.81	0.04
UNIDENTIFIED MADTOM	0.09	T	-	-	-	-	0.09	T
LOGPERCH	1.20	T	-	-	-	-	1.20	T
BROOK SILVERSIDE	0.78	T	-	-	-	-	0.78	T
MIXED & UNID MINNOWS	499.10	0.55	-	-	-	-	499.10	0.55
GROUP TOTAL	3319.07	8.29	0.00	0.00	252.81	50.37	3571.87	58.65
FINAL TOTAL	5199.76	11.75	398.64	19.53	508.68	174.23	6107.08	205.51

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 10 SAMPLES IN WATTS BAR RESERVIOR, 1973

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
GAME								
WHITE BASS	33.36	0.29	6.53	0.63	7.05	1.13	46.94	2.05
YELLOW BASS	2.00	0.03	0.50	0.03	-	-	2.50	0.06
ROCK BASS	0.14	T	0.14	T	0.27	0.04	0.54	0.04
WARMOUTH	39.44	0.22	39.70	0.82	6.09	0.50	85.22	1.54
REDBREAST SUNFISH	4.92	0.01	7.89	0.19	28.57	2.91	41.37	3.12
BLUEGILL	1542.38	4.01	506.71	12.57	223.29	16.12	2272.38	32.70
LONGEAR SUNFISH	2.00	0.02	3.16	0.09	1.02	0.07	6.18	0.18
REDEAR SUNFISH	-	-	1.19	0.03	2.57	0.28	3.77	0.31
SMALLMOUTH BASS	67.20	0.42	12.69	0.50	3.73	1.01	83.61	1.93
SPOTTED BASS	-	-	0.15	0.01	-	-	0.15	0.01
LARGEMOUTH BASS	68.74	0.42	11.43	0.99	7.78	4.24	87.94	5.65
UNIDENTIFIED CRAPPIE	0.40	T	-	-	-	-	0.40	T
WHITE CRAPPIE	66.59	0.07	3.96	0.15	10.30	1.59	80.85	1.81
BLACK CRAPPIE	0.14	T	0.20	0.01	2.06	0.34	2.40	0.36
SAUGER	0.20	0.01	1.03	0.14	1.43	0.33	2.65	0.48
WALLEYE	0.46	T	-	-	-	-	0.46	T
GROUP TOTAL	1827.96	5.51	595.27	16.16	294.15	28.56	2717.38	50.23
ROUGH								
SPOTTED GAR	1.17	0.04	0.29	0.08	1.25	1.00	2.71	1.12
SKIPJACK HERRING	17.52	0.07	-	-	0.14	0.04	17.66	0.11
MOONEYE	0.39	0.01	-	-	-	-	0.39	0.01
CARP	-	-	1.65	0.53	31.53	51.62	33.18	52.16
RIVER CARPSUCKER	-	-	-	-	0.14	0.07	0.14	0.07
WHITE SUCKER	-	-	-	-	0.55	0.66	0.55	0.66
NORTHERN HOG SUCKER	0.14	T	-	-	0.27	0.06	0.41	0.06
SMALLMOUTH BUFFALO	0.87	0.03	1.12	0.24	18.69	36.92	20.67	37.18
BIGMOUTH BUFFALO	-	-	-	-	3.86	7.09	3.86	7.09
BLACK BUFFALO	-	-	-	-	0.57	2.00	0.57	2.00
SPOTTED SUCKER	-	-	-	-	0.19	0.11	0.19	0.11
BLACK REDHORSE	0.14	T	1.16	0.12	4.26	1.97	5.55	2.09
GOLDEN REDHORSE	0.57	0.02	0.39	0.04	4.07	3.18	5.03	3.25
CHANNEL CATFISH	29.92	0.31	44.32	2.34	10.14	3.18	84.38	5.83
FLATHEAD CATFISH	2.66	0.03	1.90	0.19	2.34	1.15	6.89	1.36
FRESHWATER DRUM	120.99	1.10	208.37	10.47	95.31	18.18	424.66	29.74
GROUP TOTAL	174.35	1.60	259.19	14.02	173.29	127.23	606.84	142.85

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 10 SAMPLES IN WATTS BAR RESERVIOR, 1973

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
FORAGE								
GIZZARD SHAD	323.69	0.75	-	-	761.46	130.57	1085.15	131.32
THREADFIN SHAD	5997.43	16.02	-	-	8.92	0.27	6006.34	16.29
MIXED SHAD	218.49	0.30	-	-	-	-	218.49	0.30
STONEROLLER	0.67	T	-	-	-	-	0.67	T
SILVER CHUB	0.61	T	-	-	-	-	0.61	T
GOLDEN SHINER	0.13	T	-	-	-	-	0.13	T
EMERALD SHINER	107.52	0.09	-	-	-	-	107.52	0.09
STEELCOLOR	71.54	0.21	-	-	-	-	71.54	0.21
BLUNTNOSE MINNOW	873.89	0.81	-	-	-	-	873.89	0.81
FATHEAD MINNOW	5.83	0.02	-	-	-	-	5.83	0.02
GREENSIDE DARTER	0.14	T	-	-	-	-	0.14	T
LOGPERCH	53.61	0.66	-	-	-	-	53.61	0.66
BROOK SILVERSIDE	8.58	0.01	-	-	-	-	8.58	0.01
MIXED & UNID MINNOWS	3572.44	3.74	-	-	-	-	3572.44	3.74
GROUP TOTAL	11234.56	22.62	0.00	0.00	770.38	130.84	12004.94	153.46
FINAL TOTAL	13236.87	29.72	854.46	30.18	1237.82	286.64	15329.16	346.54

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 6 SAMPLES IN WATTS BAR RESERVIOR, 1975

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
GAME								
WHITE BASS	8.15	0.02	3.69	0.23	0.63	0.08	12.46	0.33
YELLOW BASS	-	-	0.33	0.03	-	-	0.33	0.03
STRIPED BASS	0.31	T	-	-	-	-	0.31	T
HYBRID WHITE X STRIPE BAS	1.89	0.06	0.31	T	-	-	2.20	0.06
WARMOUTH	99.22	0.22	22.52	0.38	5.83	0.31	127.57	0.91
REDBREAST SUNFISH	35.56	0.05	8.50	0.17	16.56	1.46	60.61	1.68
BLUEGILL	730.43	1.23	222.30	4.32	184.28	12.66	1137.01	18.22
LONGEAR SUNFISH	4.07	0.02	5.05	0.13	4.15	0.25	13.26	0.39
REDEAR SUGFISH	-	-	-	-	1.28	0.07	1.23	0.07
HYBRID SUNFISH	1.26	T	0.63	0.01	-	-	1.89	0.01
SMALLMOUTH BASS	23.29	0.06	1.90	0.10	0.63	0.64	25.82	0.80
SPOTTED BASS	57.71	0.13	0.41	0.01	-	-	58.12	0.14
LARGEMOUTH BASS	99.35	0.27	33.23	2.17	13.61	4.92	146.19	7.36
WHITE CRAPPIE	9.79	0.01	16.58	0.42	5.53	0.57	31.91	1.00
BLACK CRAPPIE	0.83	T	1.69	0.04	1.28	0.16	3.80	0.20
SAUGER	1.94	0.09	8.12	0.83	0.31	0.06	10.37	0.98
GROUP TOTAL	1073.80	2.17	325.24	8.84	234.09	21.17	1633.14	32.18
ROUGH								
LONGNOSE GAR	2.19	0.03	-	-	-	-	2.19	0.03
SKIPJACK HERRING	2.79	0.03	6.86	0.81	0.64	0.13	10.29	0.97
MOONEYE	-	-	0.43	0.08	-	-	0.43	0.08
CARP	-	-	-	-	88.20	134.17	88.20	134.17
NORTHERN HOG SUCKER	1.06	0.03	-	-	0.43	0.26	1.48	0.30
SMALLMOUTH BUFFALO	-	-	-	-	21.15	36.41	21.15	36.41
SPOTTED SUCKER	2.97	0.14	7.26	0.59	11.49	7.74	21.73	8.47
SHORTHEAD REDHORSE	0.31	0.01	-	-	-	-	0.31	0.01
BLACK REDHORSE	0.83	0.03	0.41	0.06	2.87	2.11	4.11	2.21
GOLDEN REDHORSE	4.50	0.19	2.54	0.34	11.46	6.92	18.51	7.45
BLACK BULLHEAD	-	-	0.31	0.01	-	-	0.31	0.01
YELLOW BULLHEAD	1.22	T	2.85	0.09	-	-	4.07	0.09
CHANNEL CATFISH	-	-	4.58	0.25	6.86	2.66	11.44	2.90
FLATHEAD CATFISH	1.57	T	0.98	0.15	1.37	0.90	3.93	1.05
FRESHWATER DRUM	9.15	0.15	222.75	12.44	126.51	16.81	358.41	29.39
GROUP TOTAL	26.60	0.62	248.97	14.80	270.98	208.11	546.55	223.53

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 6 SAMPLES IN WATTS BAR RESERVIOR, 1975

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
				FORAGE				
GIZZARD SHAD	13.93	0.03	-	-	504.96	85.40	518.89	85.42
THREADFIN SHAD	205.52	0.48	-	-	101.97	2.82	307.49	3.29
STONEROLLER	0.41	†	-	-	-	-	0.41	†
GOLDEN SHINER	0.85	0.06	-	-	-	-	0.85	0.06
UNIDENTIFIED SHINER	42.17	0.09	-	-	-	-	42.17	0.09
EMERALD SHINER	5.77	0.03	-	-	-	-	5.77	0.03
SILVER SHINER	17.21	0.05	-	-	-	-	17.21	0.05
BLACKTAIL SHINER	21.65	0.06	-	-	-	-	21.65	0.06
STEELCOLOR	16.19	0.04	-	-	-	-	16.19	0.04
UNIDENTIFIED MINNOW	124.67	0.22	-	-	-	-	124.67	0.22
BLUNTNOSE MINNOW	81.63	0.15	-	-	-	-	81.63	0.15
FATHEAD MINNOW	33.16	0.11	-	-	-	-	33.16	0.11
BULLHEAD MINNOW	150.49	0.22	-	-	-	-	150.49	0.22
MOSQUITOFISH	0.43	†	-	-	-	-	0.43	†
LOGPERCH	53.45	0.72	-	-	-	-	53.45	0.72
BROOK SILVERSIDE	5.26	0.01	-	-	-	-	5.26	0.01
GROUP TOTAL	772.82	2.26	0.00	0.00	606.93	88.22	1379.75	90.48
FINAL TOTAL	1873.22	5.05	574.21	23.64	1112.00	317.50	3559.43	346.19

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 8 SAMPLES IN WATTS BAR RESERVIOR, 1976

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
GAME								
WHITE BASS	7.47	0.14	9.02	0.54	1.80	0.22	18.29	0.90
YELLOW BASS	1.31	0.05	3.35	0.25	0.54	0.06	5.21	0.35
UNIDENTIFIED SUNFISH	4.93	T	-	-	-	-	4.93	T
WARMOUTH	10.05	0.02	26.39	0.41	6.58	0.36	43.02	0.80
REDBREAST SUNFISH	151.33	0.27	83.41	1.44	15.07	1.26	249.81	2.97
BLUEGILL	802.57	1.69	450.48	7.28	170.33	12.70	1423.38	21.67
LONGEAR SUNFISH	3.37	0.02	9.19	0.16	4.24	0.23	16.81	0.41
REDEAR SUNFISH	-	-	1.29	0.03	2.53	0.24	3.82	0.27
SMALLMOUTH BASS	16.41	0.07	3.02	0.19	1.64	0.24	21.07	0.51
SPOTTED BASS	16.49	0.05	0.25	0.01	-	-	16.74	0.06
LARGEMOUTH BASS	195.53	0.38	29.38	1.78	14.75	7.58	239.65	9.73
WHITE CRAPPIE	0.57	T	1.62	0.05	1.11	0.15	3.30	0.20
BLACK CRAPPIE	-	-	0.28	0.02	0.49	0.04	0.77	0.06
YELLOW PERCH	-	-	-	-	0.30	0.03	0.30	0.03
SAUGER	0.26	T	1.87	0.24	5.06	1.24	7.18	1.47
GROUP TOTAL	1210.29	2.70	619.54	12.38	224.44	24.35	2054.27	39.43
ROUGH								
CHESTNUT LAMPREY	-	-	-	-	0.23	T	0.23	T
LONGNOSE GAR	2.66	0.01	0.53	0.05	-	-	3.19	0.06
SKIPJACK HERRING	-	-	5.32	0.54	0.98	0.18	6.30	0.72
MOONEYE	-	-	0.46	0.09	-	-	0.46	0.09
CARP	0.25	T	-	-	42.80	82.12	43.04	82.12
RIVER CARPSUCKER	-	-	0.27	0.02	-	-	0.27	0.02
WHITE SUCKER	-	-	0.51	0.05	-	-	0.51	0.05
NORTHERN HOG SUCKER	2.40	0.10	2.89	0.33	1.09	0.22	6.38	0.65
SMALLMOUTH BUFFALO	-	-	-	-	6.28	12.27	6.28	12.27
BLACK BUFFALO	-	-	-	-	1.25	3.34	1.25	3.34
SPOTTED SUCKER	2.34	0.09	2.91	0.24	9.61	5.82	14.86	6.15
SHORTHEAD REDHORSE	-	-	0.28	0.03	0.28	0.09	0.57	0.12
BLACK REDHORSE	0.25	0.01	0.25	0.02	2.65	1.42	3.14	1.45
GOLDEN REDHORSE	8.94	0.53	8.06	0.90	16.10	8.96	33.10	10.39
YELLOW BULLHEAD	0.57	T	0.28	0.01	0.75	0.10	1.60	0.11
BROWN BULLHEAD	-	-	0.27	0.01	-	-	0.27	0.01
CHANNEL CATFISH	0.37	T	7.68	0.44	10.73	5.62	18.77	6.07
FLATHEAD CATFISH	0.95	T	1.02	0.08	1.04	0.57	3.01	0.66
FRESHWATER DRUM	21.61	0.31	159.34	8.10	96.84	19.20	277.80	27.61
GROUP TOTAL	40.33	1.06	190.07	10.91	190.63	139.93	421.04	151.89

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 8 SAMPLES IN WATTS BAR RESERVIOR, 1976

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
FORAGE								
GIZZARD SHAD	3.07	0.01	-	-	324.43	57.62	327.50	57.64
THREADFIN SHAD	1231.76	4.51	-	-	103.49	2.97	1335.25	7.48
HYBRID SHAD	-	-	-	-	0.27	0.01	0.27	0.01
UNIDENTIFIED SHINER	8.67	0.01	-	-	-	-	8.67	0.01
SILVER CHUB	1.14	0.04	-	-	-	-	1.14	0.04
GOLDEN SHINER	1.09	0.03	-	-	-	-	1.09	0.03
EMERALD SHINER	32.47	0.13	-	-	-	-	32.47	0.13
SPOTFIN SHINER	88.64	0.24	-	-	-	-	88.64	0.24
STEELCOLOR	25.82	0.10	-	-	-	-	25.82	0.10
BULLHEAD MINNOW	496.18	0.79	-	-	-	-	496.18	0.79
MOSQUITOFISH	0.74	T	-	-	-	-	0.74	T
LOGPERCH	57.25	0.51	-	-	-	-	57.25	0.51
BANDED SCULPIN	0.27	T	-	-	-	-	0.27	T
BROOK SILVERSIDE	10.59	0.02	-	-	-	-	10.59	0.02
MIXED & UNID MINNOWS	14.34	T	-	-	-	-	14.34	T
GROUP TOTAL	1972.02	6.40	0.00	0.00	428.20	60.61	2400.22	67.01
FINAL TOTAL	3222.65	10.15	809.62	23.29	843.27	224.89	4875.54	258.33

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 8 SAMPLES IN WATTS BAR RESERVIOR, 1977

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
GAME								
WHITE BASS	34.52	0.14	6.97	0.53	6.16	0.86	47.66	1.53
YELLOW BASS	68.31	0.28	5.14	0.40	1.70	0.23	75.15	0.91
STRIPED BASS	0.40	0.01	-	-	-	-	0.40	0.01
UNIDENTIFIED SUNFISH	28.39	0.02	-	-	-	-	28.39	0.02
WARMOUTH	18.99	0.04	13.06	0.19	3.53	0.28	35.58	0.51
REDBREAST SUNFISH	27.46	0.07	15.62	0.21	7.12	0.59	50.20	0.87
BLUEGILL	1329.43	2.63	194.79	3.13	92.76	5.98	1616.98	11.74
LONGEAR SUNFISH	48.18	0.11	23.05	0.38	1.79	0.08	73.02	0.58
REDEAR SUNFISH	0.64	T	0.52	0.01	-	-	1.16	0.01
SMALLMOUTH BASS	22.07	0.06	3.35	0.16	0.76	0.08	26.18	0.29
SPOTTED BASS	4.47	0.01	-	-	-	-	4.47	0.01
LARGEMOUTH BASS	201.33	0.60	42.95	2.66	23.73	8.65	268.02	11.90
WHITE CRAPPIE	11.09	0.02	4.74	0.05	4.29	0.64	20.13	0.71
BLACK CRAPPIE	0.23	T	0.46	T	0.47	0.07	1.17	0.08
YELLOW PERCH	1.54	T	0.23	T	4.49	0.10	6.26	0.11
SAUGER	-	-	0.98	0.12	4.52	2.03	5.51	2.15
GROUP TOTAL	1797.07	4.01	311.88	7.84	151.33	19.58	2260.27	31.43
ROUGH								
CHESTNUT LAMPREY	-	-	-	-	1.04	0.02	1.04	0.02
SPOTTED GAR	0.24	T	-	-	-	-	0.24	T
LONGNOSE GAR	1.31	0.01	-	-	0.56	1.22	1.87	1.23
SHORTNOSE GAR	1.07	0.01	-	-	-	-	1.07	0.01
SKIPJACK HERRING	35.32	0.16	1.21	0.07	0.87	0.32	37.40	0.55
MOONEYE	0.47	T	0.52	0.06	0.52	0.14	1.51	0.20
CARP	-	-	-	-	16.99	33.12	16.99	33.12
RIVER CARPSUCKER	0.33	T	0.36	0.03	1.24	1.29	1.92	1.32
QUILLBACK CARPSUCKER	0.33	T	-	-	-	-	0.33	T
NORTHERN HOG SUCKER	-	-	2.20	0.21	0.52	0.17	2.72	0.39
SMALLMOUTH BUFFALO	-	-	-	-	5.19	9.46	5.19	9.46
BIGMOUTH BUFFALO	-	-	-	-	0.24	1.04	0.24	1.04
SPOTTED SUCKER	1.97	0.02	0.52	0.05	2.60	0.84	5.09	0.91
SILVER REDHORSE	0.36	T	-	-	-	-	0.36	T
RIVER REDHORSE	0.46	0.01	-	-	-	-	0.46	0.01
GOLDEN REDHORSE	0.75	0.03	-	-	3.24	2.00	4.00	2.02
CHANNEL CATFISH	8.14	0.06	17.18	1.08	16.78	7.27	42.09	8.41
FLATHEAD CATFISH	2.49	0.01	0.23	0.01	0.76	0.20	3.47	0.22
FRESHWATER DRUM	63.75	0.39	111.05	5.57	63.91	10.87	238.70	16.83
GROUP TOTAL	116.97	0.70	133.27	7.09	114.46	67.95	364.70	75.74

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 8 SAMPLES IN WATTS BAR RESERVIOR, 1977

SPECIES	YOUNG OF YEAR		INTERMEDIATE		HARVESTABLE		TOTAL	
	NUMBER	WEIGHT	NUMBER	WEIGHT	NUMBER	WEIGHT	NUMBER	WEIGHT
FORAGE								
GIZZARD SHAD	5676.01	14.27	-	-	609.92	102.18	6285.93	116.45
THREADFIN SHAD	241.52	1.42	-	-	0.52	0.02	242.04	1.43
HYBRID SHAD	-	-	-	-	1.04	0.03	1.04	0.03
STONEROLLER	0.75	T	-	-	-	-	0.75	T
SILVER CHUB	2.14	T	-	-	-	-	2.14	T
UNIDENTIFIED SHINER	1.04	T	-	-	-	-	1.04	T
EMERALD SHINER	30.98	0.05	-	-	-	-	30.98	0.05
COMMON SHINER	0.52	T	-	-	-	-	0.52	T
WHITETAIL SHINER	0.36	T	-	-	-	-	0.36	T
SILVER SHINER	0.52	T	-	-	-	-	0.52	T
SPOTFIN SHINER	124.83	0.27	-	-	-	-	124.83	0.27
STEELCOLOR	2.29	0.01	-	-	-	-	2.29	0.01
BULLHEAD MINNOW	769.64	0.90	-	-	-	-	769.64	0.90
ORANGESPOTTED SUNFISH	-	-	0.52	T	-	-	0.52	T
LOGPERCH	55.98	0.32	-	-	-	-	55.98	0.32
BROOK SILVERSIDE	28.89	0.04	-	-	-	-	28.89	0.04
GROUP TOTAL	6935.47	17.29	0.52	0.00	611.49	102.23	7547.47	119.52
FINAL TOTAL	8849.50	22.01	445.67	14.93	877.27	189.75	10172.44	226.69

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 2 SAMPLES IN WATTS BAR RESERVIOR, 1978

SPECIES	YOUNG OF YEAR		INTERMEDIATE		HARVESTABLE		TOTAL	
	NUMBER	WEIGHT	NUMBER	WEIGHT	NUMBER	WEIGHT	NUMBER	WEIGHT
GAME								
WHITE BASS	383.88	0.44	-	-	-	-	383.88	0.44
WARMOUTH	1.25	T	22.50	0.34	10.95	0.68	34.70	1.02
REDBREAST SUNFISH	1.72	0.01	118.84	2.01	23.15	1.11	143.71	3.12
BLUEGILL	678.49	1.52	322.16	5.22	62.76	4.00	1063.41	10.74
REDEAR SUNFISH	-	-	3.75	0.12	16.42	1.40	20.17	1.53
UNIDENTIFIED BASS	1.25	T	-	-	-	-	1.25	T
SMALLMOUTH BASS	247.54	0.40	17.84	0.79	3.75	1.01	269.14	2.20
SPOTTED BASS	116.25	0.14	-	-	-	-	116.25	0.14
LARGEMOUTH BASS	172.16	0.29	9.22	0.69	2.97	0.45	184.35	1.42
WHITE CRAPPIE	24.57	0.02	1.25	0.02	-	-	25.82	0.04
YELLOW PERCH	149.22	0.32	-	-	19.57	0.77	168.79	1.09
GROUP TOTAL	1776.34	3.13	495.56	9.20	139.57	9.42	2411.47	21.74
ROUGH								
LONGNOSE GAR	1.25	0.01	-	-	-	-	1.25	0.01
CARP	-	-	-	-	1.25	3.20	1.25	3.20
NORTHERN HOG SUCKER	2.50	0.07	-	-	-	-	2.50	0.07
GOLDEN REDHORSE	2.50	0.07	-	-	-	-	2.50	0.07
CHANNEL CATFISH	24.22	0.11	23.19	1.21	9.70	3.06	57.11	4.38
FLATHEAD CATFISH	15.00	0.08	10.00	0.67	2.50	0.70	27.50	1.45
FRESHWATER DRUM	32.54	0.45	92.33	3.15	39.57	12.44	164.44	16.05
GROUP TOTAL	78.02	0.80	125.52	5.03	53.02	19.40	256.55	25.24
FORAGE								
GIZZARD SHAD	53.79	0.02	-	-	146.94	13.78	200.73	13.79
EMERALD SHINER	5.00	0.02	-	-	-	-	5.00	0.02
SPOTFIN SHINER	39.57	0.17	-	-	-	-	39.57	0.17
BULLHEAD MINNOW	499.09	1.16	-	-	-	-	499.09	1.16
LOGPERCH	28.02	0.20	-	-	-	-	28.02	0.20
BROOK SILVERSIDE	30.09	0.03	-	-	-	-	30.09	0.03
GROUP TOTAL	655.56	1.60	0.00	0.00	146.94	13.78	802.50	15.38
FINAL TOTAL	2509.91	5.53	621.08	14.23	339.53	42.60	3470.52	62.36

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 2 SAMPLES IN WATTS BAR RESERVIOR, 1979

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
GAME								
WHITE BASS	-	-	0.89	0.08	-	-	0.89	0.08
YELLOW BASS	67.74	1.01	5.75	0.37	1.79	0.30	75.27	1.68
WARMOUTH	44.16	0.25	15.61	0.35	8.31	0.66	68.09	1.26
REDBREAST SUNFISH	48.28	0.32	14.22	0.38	12.43	1.03	74.93	1.73
GREEN SUNFISH	1.28	0.01	1.28	0.02	-	-	2.56	0.03
BLUEGILL	548.15	2.70	292.72	6.89	178.94	15.17	1019.80	24.76
LONGEAR SUNFISH	5.24	0.04	14.84	0.50	2.17	0.14	22.25	0.68
REDEAR SUNFISH	0.89	0.01	2.68	0.05	1.28	0.11	4.85	0.16
SMALLMOUTH BASS	0.89	0.01	0.89	0.02	1.28	0.25	3.07	0.28
LARGEMOUTH BASS	43.54	0.12	9.48	0.63	14.33	4.98	67.35	5.73
WHITE CRAPPIE	-	-	11.10	0.40	2.68	0.51	13.78	0.91
BLACK CRAPPIE	-	-	2.68	0.12	-	-	2.68	0.12
YELLOW PERCH	-	-	2.56	0.05	13.83	0.67	16.39	0.72
SAUGER	-	-	0.89	0.08	6.02	2.39	6.91	2.47
GROUP TOTAL	760.19	4.47	375.60	9.94	243.06	26.21	1378.85	40.61
ROUGH								
SKIPJACK HERRING	-	-	2.17	0.16	-	-	2.17	0.16
MOONEYE	-	-	0.89	0.04	-	-	0.89	0.04
CARP	-	-	-	-	18.06	34.02	18.06	34.02
QUILLBACK CARPSUCKER	1.79	0.12	-	-	-	-	1.79	0.12
NORTHERN HOG SUCKER	-	-	3.46	0.53	1.28	0.49	4.74	1.02
SMALLMOUTH BUFFALO	-	-	-	-	15.38	29.77	15.38	29.77
SPOTTED SUCKER	2.68	0.08	3.07	0.52	6.25	2.51	12.00	3.12
BLACK REDHORSE	-	-	0.89	0.09	9.32	4.79	10.21	4.88
GOLDEN REDHORSE	0.89	0.06	-	-	4.46	3.43	5.36	3.49
YELLOW BULLHEAD	0.89	0.01	-	-	-	-	0.89	0.01
CHANNEL CATFISH	-	-	2.17	0.12	14.33	11.11	16.51	11.22
FLATHEAD CATFISH	-	-	1.28	0.32	-	-	1.28	0.32
FRESHWATER DRUM	0.89	0.02	79.65	4.66	54.44	11.30	134.98	15.98
GROUP TOTAL	7.14	0.29	93.59	6.44	123.53	97.42	224.27	104.15
FORAGE								
GIZZARD SHAD	749.91	5.93	-	-	538.55	53.11	1288.46	59.04
THREADFIN SHAD	153.85	2.24	-	-	5.13	0.14	158.97	2.38
EMERALD SHINER	1.79	0.01	-	-	-	-	1.79	0.01
SPOTFIN SHINER	14.61	0.07	-	-	-	-	14.61	0.07
BULLHEAD MINNOW	261.45	0.70	-	-	-	-	261.45	0.70
LOGPERCH	43.89	0.51	-	-	-	-	43.89	0.51
BROOK SILVERSIDE	6.52	0.01	-	-	-	-	6.52	0.01
GROUP TOTAL	1232.01	9.46	0.00	0.00	543.68	53.26	1775.69	62.72
FINAL TOTAL	1999.34	14.22	469.18	16.38	910.28	176.89	3378.80	207.49

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 4 SAMPLES IN WATTS BAR RESERVIOR, 1980

SPECIES	YOUNG OF YEAR		INTERMEDIATE		HARVESTABLE		TOTAL	
	NUMBER	WEIGHT	NUMBER	WEIGHT	NUMBER	WEIGHT	NUMBER	WEIGHT
				GAME				
WHITE BASS	0.91	T	-	-	-	-	0.91	T
YELLOW BASS	143.36	3.96	14.12	0.88	-	-	157.48	4.85
UNIDENTIFIED SUNFISH	546.98	0.34	-	-	-	-	546.98	0.34
WARMOUTH	22.29	0.08	14.97	0.36	3.58	0.26	40.84	0.69
REDBREAST SUNFISH	21.80	0.08	6.41	0.20	8.66	0.82	36.86	1.11
BLUEGILL	2211.84	2.29	235.93	6.78	132.92	9.69	2580.68	18.76
LONGEAR SUNFISH	90.63	0.30	9.47	0.31	1.09	0.07	101.19	0.68
REDEAR SUNFISH	-	-	4.01	0.07	3.44	0.60	7.45	0.67
UNIDENTIFIED BASS	0.58	T	-	-	-	-	0.58	T
SMALLMOUTH BASS	25.78	0.10	4.33	0.23	1.19	0.19	31.30	0.52
SPOTTED BASS	28.57	0.06	1.09	0.04	0.51	0.08	30.17	0.18
LARGEMOUTH BASS	190.96	0.55	7.91	0.80	5.31	2.28	204.18	3.63
WHITE CRAPPIE	11.86	0.01	282.34	13.06	3.53	0.35	297.73	13.42
BLACK CRAPPIE	-	-	1.75	0.13	1.60	0.19	3.35	0.31
YELLOW PERCH	2.79	T	-	-	4.97	0.32	7.76	0.33
SAUGER	-	-	1.54	0.23	1.75	0.36	3.29	0.59
GROUP TOTAL	3298.35	7.80	583.87	23.09	168.55	15.20	4050.77	46.09
				ROUGH				
UNIDENTIFIED GAR	0.30	T	-	-	-	-	0.30	T
SPOTTED GAR	1.24	0.01	-	-	-	-	1.24	0.01
LONGNOSE GAR	1.09	0.04	-	-	-	-	1.09	0.04
SKIPJACK HERRING	1.82	T	-	-	0.51	0.12	2.33	0.12
CARP	-	-	-	-	43.51	97.88	43.51	97.88
NORTHERN HOG SUCKER	-	-	-	-	2.99	1.52	2.99	1.52
SMALLMOUTH BUFFALO	-	-	-	-	7.47	17.20	7.47	17.20
SPOTTED SUCKER	-	-	-	-	7.77	4.27	7.77	4.27
BLACK REDHORSE	-	-	0.66	0.11	5.11	3.12	5.76	3.23
GOLDEN REDHORSE	0.66	0.01	-	-	6.71	4.39	7.37	4.41
CHANNEL CATFISH	6.87	0.04	30.52	1.86	48.13	15.09	85.52	16.99
FLATHEAD CATFISH	0.58	T	1.77	0.23	1.80	0.79	4.15	1.02
FRESHWATER DRUM	15.04	0.25	289.83	18.77	102.06	22.75	406.93	41.77
GROUP TOTAL	27.60	0.35	322.78	20.97	226.06	167.13	576.45	188.45
				FORAGE				
GIZZARD SHAD	21.43	0.04	-	-	4394.58	266.54	4416.01	266.57
THREADFIN SHAD	6892.71	8.25	-	-	39.07	1.01	6931.78	9.26
STONEROLLER	1.97	0.01	-	-	-	-	1.97	0.01
EMERALD SHINER	5.22	0.01	-	-	-	-	5.22	0.01
SPOTFIN SHINER	14.77	0.04	-	-	-	-	14.77	0.04
BLUNTNOSE MINNOW	61.22	0.08	-	-	-	-	61.22	0.08
BULLHEAD MINNOW	518.19	0.38	-	-	-	-	518.19	0.38
MOSQUITOFISH	0.30	T	-	-	-	-	0.30	T
LOGPERCH	34.91	0.27	-	-	-	-	34.91	0.27
BROOK SILVERSIDE	5.19	0.01	-	-	-	-	5.19	0.01
GROUP TOTAL	7555.92	9.08	0.00	0.00	4433.65	267.55	11989.57	276.63

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 4 SAMPLES IN WATTS BAR RESERVIOR, 1980

SPECIES	YOUNG OF YEAR		INTERMEDIATE		HARVESTABLE		TOTAL	
	NUMBER	WEIGHT	NUMBER	WEIGHT	NUMBER	WEIGHT	NUMBER	WEIGHT
FINAL TOTAL	10881.87	17.23	906.65	44.06	4828.26	449.88	16616.79	511.17

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 71 SAMPLES IN WATTS BAR RESERVOIR -- ALL YEARS

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
GAME								
WHITE BASS	31.25	0.17	4.37	0.35	3.41	0.60	39.04	1.11
YELLOW BASS	18.11	0.29	2.01	0.14	0.30	0.04	20.43	0.47
STRIPED BASS	0.07	T	-	-	-	-	0.07	T
HYBRID WHITE X STRIPE BAS	0.16	T	0.03	T	-	-	0.19	T
ROCK BASS	0.02	T	0.02	T	0.04	0.01	0.08	0.01
UNIDENTIFIED SUNFISH	34.57	0.02	-	-	-	-	34.57	0.02
WARMOUTH	32.82	0.10	18.51	0.36	4.18	0.30	55.52	0.76
REDBREAST SUNFISH	27.40	0.06	17.93	0.33	10.24	0.92	55.57	1.31
GREEN SUNFISH	0.04	T	0.04	T	-	-	0.07	T
BLUEGILL	1202.97	1.92	249.44	5.33	112.21	8.30	1564.62	15.56
LONGEAR SUNFISH	15.51	0.05	5.96	0.13	1.30	0.07	22.77	0.25
REDEAR SUNFISH	0.10	T	0.80	0.02	1.47	0.15	2.36	0.17
HYBRID SUNFISH	0.11	T	0.05	T	-	-	0.16	T
UNIDENTIFIED BASS	0.07	T	-	-	-	-	0.07	T
SMALLMOUTH BASS	27.28	0.12	5.76	0.33	1.91	0.47	34.95	0.93
SPOTTED BASS	23.34	0.09	3.61	0.21	0.83	0.13	27.77	0.44
LARGEMOUTH BASS	102.21	0.38	21.35	1.51	10.38	4.09	133.94	5.98
UNIDENTIFIED CRAPPIE	0.06	T	-	-	-	-	0.06	T
WHITE CRAPPIE	32.77	0.06	23.44	1.00	4.11	0.62	60.32	1.68
BLACK CRAPPIE	0.36	T	0.52	0.02	0.73	0.11	1.62	0.13
YELLOW PERCH	4.53	0.01	0.10	T	1.76	0.07	6.39	0.08
SAUGER	4.43	0.13	3.74	0.38	2.16	0.70	10.33	1.21
WALLEYE	0.07	T	-	-	-	-	0.07	T
GROUP TOTAL	1558.26	3.41	357.67	10.12	155.04	16.58	2070.96	30.11
ROUGH								
CHESTNUT LAMPREY	-	-	-	-	0.14	T	0.14	T
UNIDENTIFIED GAR	0.02	T	-	-	-	-	0.02	T
SPOTTED GAR	0.26	0.01	0.04	0.01	0.18	0.14	0.48	0.16
LONGNOSE GAR	0.90	0.02	0.06	0.01	0.10	0.24	1.06	0.26
SHORTNOSE GAR	0.16	T	-	-	-	-	0.16	T
UNIDENTIFIED GAR	0.01	T	-	-	-	-	0.01	T
SKIPJACK HERRING	8.31	0.05	3.01	0.31	1.63	0.46	12.95	0.81
MOONEYE	0.15	T	0.31	0.05	0.06	0.02	0.52	0.06
CARP	2.00	0.17	0.59	0.18	29.15	45.70	31.74	46.05
UNIDENTIFIED CARPSUCKERS	0.01	T	0.02	T	0.04	0.02	0.07	0.02
RIVER CARPSUCKER	0.26	T	0.12	0.02	0.80	1.11	1.18	1.13
QUILLBACK CARPSUCKER	0.09	T	-	-	-	-	0.09	T
WHITE SUCKER	-	-	0.06	0.01	0.08	0.09	0.13	0.10
NORTHERN HOG SUCKER	0.45	0.02	0.77	0.09	0.50	0.19	1.72	0.30
UNIDENTIFIED BUFFALO	-	-	0.30	0.11	0.04	0.02	0.35	0.13
SMALLMOUTH BUFFALO	0.17	0.01	1.18	0.37	25.18	35.54	26.53	35.93
BIGMOUTH BUFFALO	-	-	-	-	1.47	2.11	1.47	2.11
BLACK BUFFALO	-	-	-	-	0.28	0.82	0.28	0.82
SPOTTED SUCKER	0.84	0.03	1.13	0.11	3.05	1.76	5.03	1.89
UNIDENTIFIED REDHORSE	0.07	T	0.03	T	0.07	0.03	0.18	0.04
SILVER REDHORSE	0.04	T	-	-	-	-	0.04	T
SHORTHEAD REDHORSE	0.04	T	0.09	0.02	0.14	0.03	0.27	0.05
RIVER REDHORSE	0.05	T	-	-	0.04	0.07	0.09	0.07

MEAN NUMBER AND WEIGHT (KG) OF FISH PER HECTARE IN 71 SAMPLES IN WATTS BAR RESERVOIR -- ALL YEARS

SPECIES	YOUNG OF YEAR NUMBER	YOUNG OF YEAR WEIGHT	INTERMEDIATE NUMBER	INTERMEDIATE WEIGHT	HARVESTABLE NUMBER	HARVESTABLE WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
BLACK REDHORSE	0.12	T	0.29	0.03	1.78	1.01	2.19	1.05
GOLDEN REDHORSE	1.72	0.09	1.88	0.26	5.53	3.26	9.12	3.61
UNIDENTIFIED CATFISH	-	-	0.04	T	-	-	0.04	T
BLUE CATFISH	-	-	0.12	0.01	0.06	0.01	0.18	0.02
BLACK BULLHEAD	-	-	0.03	T	-	-	0.03	T
YELLOW BULLHEAD	0.21	T	0.27	0.01	0.08	0.01	0.56	0.02
BROWN BULLHEAD	-	-	0.03	T	-	-	0.03	T
CHANNEL CATFISH	7.69	0.07	16.40	0.88	11.50	4.50	35.59	5.45
FLATHEAD CATFISH	1.95	0.01	1.18	0.14	1.25	0.76	4.38	0.91
FRESHWATER DRUM	49.85	0.42	166.74	8.97	89.99	16.25	306.58	25.65
GROUP TOTAL	75.40	0.91	194.69	11.56	173.14	114.17	443.23	126.64
FORAGE								
GIZZARD SHAD	1389.65	2.76	-	-	615.49	78.71	2005.14	81.47
THREADFIN SHAD	3696.64	9.90	-	-	24.81	0.71	3721.44	10.60
MIXED SHAD	86.20	0.22	-	-	42.11	0.35	128.31	0.57
HYBRID SHAD	-	-	-	-	0.15	0.01	0.15	0.01
ORANGESPOTTED SUNFISH	-	-	0.06	T	-	-	0.06	T
MIXED & UNID MINNOWS	1158.19	1.82	-	-	-	-	1158.19	1.82
GROUP TOTAL	6330.68	14.71	0.06	0.00	682.55	79.77	7013.29	94.47
FINAL TOTAL	7964.33	19.03	552.42	21.68	1010.73	210.52	9527.49	251.23

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NX0403RF JOB NUMBER 5423
NX0403RF JOB NUMBER 5423

SJOLLY
SJOLLY

ORIGIN RMT02RD1
ORIGIN RMT02RD1

START DATE 18 AUG 80.231
START TIME 16.40.57

STOP DATE 18 AUG 80.231
STOP TIME 16.56.00

XEQ   TIME 00.15.02

PRINTER 808
END   TIME 10.50.15

52 CARDS READ
0 CARDS PUNCHED
4,696 LINES PRINTED

SJOLLY

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NN         N  XX       XX    00000000          44      00000000     3333333333   RR        RR  FF
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NX0403RF JOB NUMBER 5423
NX0403RF JOB NUMBER 5423

SJOLLY
SJOLLY

ORIGIN RMT02RD1
ORIGIN RMT02RD1

START DATE 18 AUG 80.231
START TIME 16.40.57

STOP DATE 18 AUG 80.231
STOP TIME 16.56.00

XEQ TIME 00.15.02

PRINTER 808
END TIME 16.56.15

52 CARDS READ
0 CARDS PUNCHED
4,696 LINES PRINTED

SJOLLY

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NN         NN    XX          XX   WW           WW   AA        AA        TT        BBBBBBBBBBB   AA        AA   RR        RR
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NXWATBAR JOB NUMBER 8122
NXWATBAR JOB NUMBER 8122

TMCDONOUGH
TMCDONOUGH

ORIGIN RMT02RD1
ORIGIN RMT02RD1

START DATE 19 AUG 80.232
START TIME 10.14.48

STOP DATE 19 AUG 80.232
STOP TIME 10.17.50

XEQ TIME 00.03.02

PRINTER 808
START TIME 10.50.29

26 CARDS READ
0 CARDS PUNCHED
982 LINES PRINTED

TMCDONOUGH

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4/-C

LEPHONE CONFERENCE MEMORANDUM

C260-139-80

Section 2.7.2, reference 115

DATE October 20, 1980

INCOMING [x] OUTGOING C.O. G.O.

MR. Anders Myhr OF THE Tennessee Wildlife Resources Agency 615/484-95/1

MR. OF THE

REFERENCE 2-50

ES TO: G. A. Valiulis

L. L. Simmons

W. A. Beimborn

JECT: Fish in Watts Bar Reservoir TIME 0900

COST

E C-260 CHARGE

TAIL OF CONFERENCE

Mr. Myhr i the state biologist in charge of Watts Bar Reservoir.

I. Striped Bass

Anders confirmed that the Clinch River is a cool water refuge for large (8+ pounds, 3+ years) striped bass. He said 24°C seems to be the trigger temperature, making them seek cooler water. He said the fish stay in the river from about mid July through October. The breeder site is near a big holding area, extending from Caney Creek downstream to the bluffs by the power line.

He is concerned for two reasons: the Tennessee River used to be used as a refuge also, but since the closing of Tellico Dam, the water temperature has raised from about 19-20°C to 26°C; now all the larger fish go to the Clinch River. Secondly, he read that Koppers has proposed a gasification plant upstream of the breeder on the Oak Ridge Reservation. He fears the effects of this even more than the breeder.

Miscellany

- o Smaller fish (< 8 lbs., up to 3 yrs. old) are not as sensitive to warm water, stay in the main reservoir.
- o Stocking began in 1972; in 1975, increased rate to current 200,000/year (2-inch fish). They are trying to establish a density of 5 fish/acre. He confirmed there is no natural reproduction.
- o Closest regular stocking point is Kingston Steam Plant.
- o Their first tournament this year attracted 17 entries and resulted in 19 stripers caught. Interest in stripers is building.

DEPT. Resource Analysis D. J. Wagner *D J Wagner* (SIGNATURE) EXT. NO. 175

- Besides Mike van Den Avyle and Chuck Coutant, contact Terry Cheek, Mike's grad student at Tennessee Tech who has been working on this for 2 yrs. He will have current year's information.

II. Creel surveys were begun in 1976. Printout of data on number of trips, fish sought, catch rates, etc. is available. Contact Hudson Nichols, Chief of Fisheries, Nashville, 615/741-1575.

This info plus TVA's rotenone data show fishing pressure and success relative to standing stock.

III. Sauger

Anders knew of potential sauger spawning near site. I asked about local interest in sauger. He said sauger is one of the most sought-after fish in the reservoir, from data in Item II above. Most fishing occurs in dam tailwaters.

REFERENCE 2-51

~~PHONE~~ CONFERENCE MEMORANDUM

C260-154-80

Sec 2.7.2, reference 116

DATE October 23, 1980

~~IN~~COMING [X] OUTGOING C.O. ______ G.O. ______

~~MR.~~ Dr. C. C. Coutant OF THE Oak Ridge National Laboratories
615/574-7386

~~MR.~~ ______ OF THE ______

~~COPIE~~S TO: G. A. Valiulis

L. L. Simmons

W. A. Beimborn

~~SUBJ~~ECT: Striped bass in Clinch River TIME a.m.

COST ______

C260 CHARGE ______

~~DETAI~~L OF CONFERENCE

Dr. Coutant had the following information on striped bass:

They do prefer cool water. All large stripers are in Clinch except a few in a hole in the Tennessee where groundwater (approx. 16°C) provides a refuge from ambient (26°C).

In Clinch River, they are throughout, but concentrate in areas such as those described by Terry Cheek (see C260-151-80): several spots along Jones Island, a few fish above Grubb Islands; greatest concentrations are adjacent to site from lower end of Grubb Islands down to about S.R. 58 bridge. Fish are mainly on outside of bends, near forested, steep banks - perhaps snags provide attractive cover.

Dr. Coutant mentioned concern about quarry area close to Grubb Island, but indicated no apprehension over barge unloading area.

Dr. Coutant discussed data from Clinch River and elsewhere on temperature relations of striped bass:

- o There is a shift in temperature preference with age
  - small fish (3-4") prefer 26-28°C
  - 8-10" fish prefer 24-25°C
  - 10 lb+ fish in Cherokee Reservoir located in 18-20°C water
- o In Watts Bar, big fish appear to prefer 20 ± 2°C, avoid temperatures above 24-25°C. The entire river thus is thermally acceptable.
- o No hard data on upper lethal temp., but fish observed in Cherokee died quickly when exposed to 25°C +.

~~DE~~PT. Resource Analysis D. J. Wagner (SIGNATURE) D J Wagner EXT. NO. 175

The Watts Bar data set is small (~ 20 fish?), but is substantiated by other observations: shocking near tagged fish often results in capture of other, untagged fish as well, while shocking in areas where no tagged fish are present produces no large striped bass at all.

In sum, Dr. Coutant is not very concerned about thermal discharge. Rather, he thinks the chemical discharge is worth "raising as an issue" since the fish may be exposed to low levels of metals that could produce chronic effects. This type of thing has been postulated to occur in Cherokee Reservoir, where the concentrations of cadmium and zinc are elevated in the thermal refuges.

Dr. Coutant thinks the whole business is resolvable, perhaps by at most moving the discharge to a more downstream location.

I also asked Dr. Coutant about avoidance of surface waters. Again, there is no hard data, but the fish are rarely collected from the surface two meters. He has even seen them avoid the surface when the preferred temperature was available only at the surface. Also, "breaks" (where stripers push prey species to surface when they splash around) occur at dawn and dusk, when light levels are low.

Dr. Coutant finished by pointing out that the state is encouraging striped bass fishing, and anglers are beginning to discover the Clinch in the summer. He feels early resolution of potential problems will be the best course of action for all concerned.

LEPHONE-CONFERENCE MEMORANDUM C260-151-80 [Woodward-Clyde] Associates

Sec. 2.7.2, reference 117

DATE October 21, 1980

INCOMING ☐ OUTGOING C.O. G.O.

MR. Terry Cheek OF THE Tennessee Technological University

MR. OF THE

REFERENCE 2-52

ES TO: G. A. Valiulis

L. L. Simmons

W. A. Beimborn

JECT: Striped Bass in Watts Bar Reservoir TIME 3:00 pm

COST

E C260 CHARGE

TAIL OF CONFERENCE

Terry was returning my call. He is a graduate student under Mike van Den Avyle and Chuck Coutant, studying movement of large (10 lb+) striped bass. A summary of his results (based on a relatively small number of tagged fish):

- In the spring, fish respond to warming of main reservoir and make spawning runs up the Tennessee (Paint Rock Bluff to Ft. Loudon Dam) and Clinch Rivers. They do not reproduce successfully. In fact, at this time (through early July), cool Clinch River temperatures may just confuse them. After this run, the fish may return to the reservoir or stay in the rivers.

- In fall (mid-August - end of October) the still warming reservoir (hottest in late September) forces large fish into cooler areas - the Clinch and a few spring areas of the Tennessee. Terry says that at first the two rivers are about equally used, but as temperatures in the Tennessee continue to climb, more fish move to the Clinch. By September, he feels nearly all the large stripers in Watts Bar are in the Clinch River.

- Best areas are where structure is available near the main channel, e.g., the submerged bar near mile 16, or the Grubb Islands. The area from Caney Creek (mile 17) to approximately mile 15, on the outside of the curve (away from the CRBRP site) is a favorite area. Terry said they consistently electroshock 5-10 large fish there in hot period, and fish are all in excellent condition (not emaciated as fish in reservoirs with no cool refuges typically ar[illegible] He has tracked fish all over the river th re - over the bar, [illegible]e inside of the curve, etc. - but they have only shocked them on the outside.

- There is a lot of variation between individuals.

PT. Resource Analysis D. J. Wagner (SIGNATURE) [signature] EXT. NO. 175

I asked Terry about light avoidance. He said he knew of no specific information, other than that surface fishing is most productive in early morning and late evening.

Terry expressed concern about any thermal discharge in the Clinch River, feeling it would decrease the condition of the fish. He also expressed strong concern about the proposed Koppers gasification plant to be located below Gallaher Bridge (Anders Myhr said this plant would be upstream of CRBRP); he saw a newspaper report which said the plant would process 200,000 tons of coal per day.

LEPHONE CONFERENCE MEMORANDUM C260-131-80

Sec 2.7.2, ref. 118

DATE October 13, 1980

INCOMING [x] OUTGOING C.O. C.O.

MR. Dr. Michael van Den Avyle, Assistant Leader OF THE Cooperative Fisheries Research Unit, Tennessee Tech. University, 615/528-3094

MR. OF THE

REFERENCE 2-53

ES TO: G. A. Valiulis

L. L. Simmons

W. A. Beimborn

JECT: Blue sucker, striped bass in Watts Bar Reservoir TIME

COST

E C-260 CHARGE

AIL OF CONFERENCE

I was first interested in information on the blue sucker. Mike was Fred Heitman's advisor at the end, but not beginning. Heitman's thesis was on effect of commercial fishing on striped bass in Watts Bar. He (Mike) had no direct knowledge of the sucker. Heitman is currently at the Lake Eufalla Fishery Management Unit, Rt. 4, Box 168, Eufalla, Oklahoma 74432; phone: 918/689-5954.

Mike is involved with research on striped bass in Watts Bar and passed on the following. In his opinion, the Clinch River is extremely important to the striped bass of Watts Bar Reservoir during the summer (and to a lesser extent in winter). This is because oxygenated cool water near their preferred temperature (20-25°C, although he says Coutant suggests a more precise 22.5°C) is available. He thinks the entire river up to Melton Hill Dam is used as a refuge, but described the area immediately downstream of Caney Creek, outside (south) of the submerged bar with milfoil as the real "Honey Hole." This area has consistently produced stripers in heat of the summer, ranging from 5-30 lbs.

Mike said he thought temperatures above 25°C were less preferred by these fish, but he felt 1°C or so would have little effect on the population as long as the temperature was not lethal.

He further indicated that no natural reproduction occurs in Watts Bar; the population is due to Tennessee's stocking program. He said stocking began in 1971 and greatly increased in 1976. Considering that it takes about 6 years for a fish to grow to 8-9 lbs (anything else he calls a small striper), he thinks the reservoir is right on the verge of having a tremendous resource. He agreed that Anders Myhr (Tenn. Wild. Res. Agency) is the guy to talk to about stocking and sportfishing.

Mike also indicated the importance of talking with Chuck Coutant of ORNL about temperature and stripers in general and those near ORNL in particular.

EPT. Resource Analysis D. J. Wagner (SIGNATURE) D J Wagner EXT. NO. 175

On the side, Mike's impression was that milfoil near Caney Creek did not appear worse this year, was perhaps less developed than in 1979.

Also on the side, he said someone had called him about 3 weeks ago and misrepresented himself as a DOE employee, when in fact he was a consultant to ORNL. Such misrepresentation had angered Mike, although he pointed out he had no ax to grind with anyone. I had very precisely indicated my position, affiliation and interest, so we had no problem on this point.

Mike will send a copy of Heitman's thesis, copies of some papers he wrote, and some references, but said he was going to be out the rest of the week.

Sec. 2.7.2, ref 119
5.1. 8c

TENNESSEE VALLEY AUTHORITY
NORRIS, TENNESSEE 37828

22 August 1980

Donald J. Wagner
Energy Impact Associates
P.O. Box 1899
Pittsburgh, PA 15230

Dear Don,

Here is a copy of Fletcher's thesis "Assessment of Adult Fish Populations in the Lower Clinch River Below Melton Hill Dam". He included an emphasis on the life history of sauger in the study area. The last I heard, he is employed at Resource Consultants, in Nashville, Tennessee, phone (615) 373-5040.

I am convinced that sauger spawn in the Clinch River in the vicinity of the proposed breeder site, but additional data should be gathered. I have proposed to the TVA Fisheries and Aquatic Ecology Branch that a further study be conducted during the spring of 1981, but I have not yet gotten a response.

I will send copies of the Kingston Steam Plant impingement and larval fish reports shortly, as well as rotenone information from Clinch River mile 4.9.

Regards,

Ed

Ed Scott

Tennessee Valley Authority
Division of Water Resources
Eastern Area Field Operations
Norris, Tennessee 37828

#100

ASSESSMENT OF ADULT AND LARVAL FISH POPULATIONS OF THE LOWER CLINCH RIVER BELOW MELTON HILL DAM

A Thesis

Presented to

the Faculty of the Graduate School

Tennessee Technological University

by

John W. Fletcher

In Partial Fulfillment

of the Requirements for the Degree

MASTER OF SCIENCE

Biology

December 1977

CERTIFICATE OF APPROVAL OF THESIS

ASSESSMENT OF ADULT AND LARVAL FISH
POPULATIONS OF THE LOWER CLINCH RIVER
BELOW MELTON HILL DAM

by

John W. Fletcher

Graduate Advisory Committee:

______________________ ________
Chairman date

______________________ ________
Member date

______________________ ________
Member date

Approved for the Faculty:

____
Dean, Graduate School

____
Date

AN ABSTRACT OF A THESIS

ASSESSMENT OF ADULT AND LARVAL FISH POPULATIONS OF THE LOWER CLINCH RIVER BELOW MELTON HILL DAM

John W. Fletcher

Master of Science in Biology

In order to meet the increasing needs for the storage and reprocessing of nuclear fuel, the Exxon Nuclear Company, Inc., has taken steps toward the construction and operation of the Nuclear Fuel Recovery and Recycling Center, which is to be located on the ERDA reservation in Roane County, Tennessee. In an effort to determine whether or not the proposed facility will meet the national environmental goals, federal law requires a detailed environmental assessment of the project.

The purpose of the one-year study described herein was to provide baseline information concerning the fish populations in the immediate area of the proposed facility. Four lines of investigation were emphasized: To provide an accurate determination of the species composition and abundance of fishes in the Clinch River, kilometers 19.3 to 24.1; to generate life history data, including age and growth analysis, length-weight relationships, fecundity, food habits, and spawning season, for Stizostedion canadense (Smith) which represented the second greatest species biomass taken; to produce basic units of information concerning the Clinch River larval fish population; and to provide species composition and abundance data on the portions of Grassy and Bear Creeks likely to be affected.

ACKNOWLEDGEMENTS

Sincere appreciation is expressed to Dr. Eric L. Morgan for his support and guidance throughout this study. Gratitude is also extended to Dr. B. L. Ridley and Dr. C. B. Coburn for their advice and suggestions in the completion of this study.

This research was made possible by a grant from the Exxon Nuclear Corporation to the Biology Department of Tennessee Technological University. Thanks are due to the Biology Department and the Tennessee Cooperative Fisheries Research Unit, both of Tennessee Technological University, for the use of facilities and equipment.

Thanks and appreciation are extended to the following people who have been instrumental in the completion of this study: Bob Martin, Eddie Scott, Ken Eagleson, Jeff Sinks, Art Bogan, David Duggan, Debbie McLain, Randall Morton, Bruce Bauer, Boris Kondratieff, Larry Liden, Donna Livingston, Sue Eagleson, John W. S. Foster, III, Rick Davies, Craig Harvey, Mike Reynolds, Belinda Stovall, and Neal Robison.

The author wishes to thank his family for their support and encouragement.

Finally, very deep and special gratitude is expressed to Vechere M. Vaughn for her help with larval fish and her understanding and encouragement.

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Chapter 1

INTRODUCTION

In order to meet the increasing needs for the storage and reprocessing of nuclear fuel, the Exxon Nuclear Company, Inc., has taken steps toward the construction and operation of the Nuclear Fuel Recovery and Recycling Center (NFRRC), which is to be located on the Oak Ridge Reservation of the U.S. Energy Research and Development Administration (ERDA) in Roane County, Tennessee. The intended design for the facility will allow for the yearly storage of up to 7000 metric tons of irradiated fuels and recovery of approximately 2100 metric tons of uranium and plutonium from spent light-water power reactor fuel. A two-stage construction format has been proposed which will permit the interim storage of irradiated fuels to begin by 1980-82. This will be followed by the implementation of the fuel reprocessing center in 1984-86 (Exxon Nuclear Co., 1976).

The decay of short-lived radioactive materials kept in the fuel storage component of the facility will significantly reduce the rate of self-heating. The long-lived radionuclides uranium and plutonium, are to be recovered and purified from the irradiated fuel by the reprocessing center for later use. The remaining radioactive materials will be processed in a manner which will allow for their disposition by the Federal Government. As late as 1975, the concept of using plutonium upon recovery from the irradiated fuel in a dioxide state in conjunction with uranium oxide as a nuclear fuel was invisioned. The uranium will be converted to a hexaflouride for transportation to an enrichment plant where concentration of fissile uranium 235 to nuclear fuel occurs, or the uranium in an oxide form could be combined with plutonium dioxide (Exxon Nuclear Co., 1976).

Presently, there are no nuclear fuel reprocessing centers operating within the United States. The Allied General Nuclear Services (AGNS) Barnwell Nuclear Fuel Plant (BNFP) is inactive pending regulatory decisions involving plutonium use. Other than the BNFP, the NFRRC is the only other full scale nuclear reprocessing facility believed to be taking measures toward operational status. By the year 2000 A.D., five fuel recycling plants with capacities of approximately 1500 metric tons each will be needed to utilize the estimated amounts of spent nuclear fuel. Pressing demands for storage capacity for spent fuel have arisen due to delays in implementation of nuclear reprocessing facilities. Nuclear utilities are currently meeting the shortage, but the questions of future storage problems remain unresolved (Exxon Nuclear Co., 1976).

Once removed from the reactor, nuclear fuels with their interim radioactivity and resultant heat content require conscientious treatment in storage procedures. Currently the nuclear industries store spent fuels in water shielded tanks within the reactor facilities. Under proposed plans, spent nuclear fuels, after a period of stabilization for several months, are to be transported to a fuel reprocessing center. Since there are no large scale operative reprocessing plants, increased capacities of present storage facilities and construction of new ones have become necessary to care for fuel now being discharged. Presently there are approximately 5000 metric tons of spent nuclear fuel in storage from nuclear utilities with a predicted storage need of about 14,000 metric tons by 1983 (Exxon Nuclear Co., 1976). The extent of military generated nuclear wastes are not known, but their impact should not be overlooked.

Before a facility such as the NFRRC may receive a permit for construction or license for operation, the Nuclear Regulatory Commission (NRC) is required to examine the possible environmental impacts to ascertain if the construction and operation of the facility will meet the requirements of the National Environmental Policy Act of 1969 (Public Law 91-190, 83 Stat. 852). In an effort to determine whether or not the proposed facilities will meet the national environmental goals of the law, the NRC requires a detailed environmental assessment of the project (Exxon Nuclear Co., 1976).

The purpose of the one-year study described herein was to provide baseline information concerning the fish populations in the immediate area of the proposed NFRRC facility. Several other segments of the aquatic ecology section of the Exxon Nuclear environmental report were concurrently researched at Tennessee Technological University: periphyton, phytoplankton, zooplankton, and benthic macroinvertebrates. The fishery component emphasized the development of the following four basic lines of investigation:

1. To provide an accurate determination of the species composition in the Clinch River, miles 12-15 (km 19.3-24.1), their overall and seasonal abundance; and to supplement previous collections made in the general vicinity of the NFRRC site. Prior fishery surveys in Watts Bar and Melton Hill reservoirs have been reported by Tebo (1965), TVA (1965), Fitz (1968), Project Management Corporation (1975), Sheddan (1976) and Heitman (personal communication, 1977).

2. To generate life history data on Stizostedion canadense (Smith) which represented the second greatest species biomass taken and was the second most abundant game fish.

3. To produce basic units of information concerning the larval fish populations in the study area of the Clinch River. Additional larval fish population studies in the vicinity of the NFRRC site have been conducted by the Tennessee Valley Authority (TVA) in the Clinch River, miles 15-18 (km 24.1-29.0), (TVA, 1976a), in Melton Hill Reservoir near the Bull Run Steam Plant (TVA, 1976b), and in Watts Bar Reservoir in the vicinity of the Kingston Steam Plant (TVA, 1976c).

4. To provide species composition and abundance data on the portions of Grassy and Bear Creeks likely to be affected. The present study is the first intensive qualitative and quantitative fishery research conducted on these creeks.

The preconstruction baseline information drawn from the above areas of investigation should furnish a useful reference for monitoring or assessing important changes in the status of the fish populations within the proposed area.

Chapter 2

DESCRIPTION OF STUDY AREA

Three principal bodies of water, which will be affected by the construction and operation of the NFRRC, comprised the study area. The Clinch River will be subject to plant discharge and will furnish the source of intake water. Grassy Creek will serve as the site where the NFRRC will be constructed; additionally, intake and discharge pipes will follow in close proximity to the creek. Bear Creek will be affected primarily by siltation resulting from the construction of a railroad spur to the facility (Exxon Nuclear Co., 1976). The drainage relationships of Grassy and Bear Creeks to the Clinch River appear in Figure 1. Data concerning the temperature, flow, and pH of the Clinch River and Grassy and Bear Creeks over the sample period are presented in Appendix A.

CLINCH RIVER

The Clinch River, a river of moderate hardness, originates in Tazewell Co., Virginia, and flows southwesterly for 350 miles (km 560) to its confluence with the Tennessee River at mile 568 (km 908). Approximately one half of the Clinch River drainage is forested. Five sampling stations were located in the Clinch River miles (CRM 12-15) (km 19.3-24.1). The Clinch River in this portion of its drainage, although technically a part of Watts Bar Reservoir, is a riverine, and not the typical lacustrine habitat. The flow of the Clinch River in the

1. Clinch River - Watts Bar Reservoir
2. Poplar Creek
3. East Fork Poplar Creek
4. Oak Ridge
5. Bear Creek
6. Grassy Creek
7. Whiteoak Lake
8. Melton Hill Dam

N

0 1 2 3

Scale in Miles

1 mile = 1.6 kilometers

Figure 1. Map of Clinch River below Melton Hill Dam

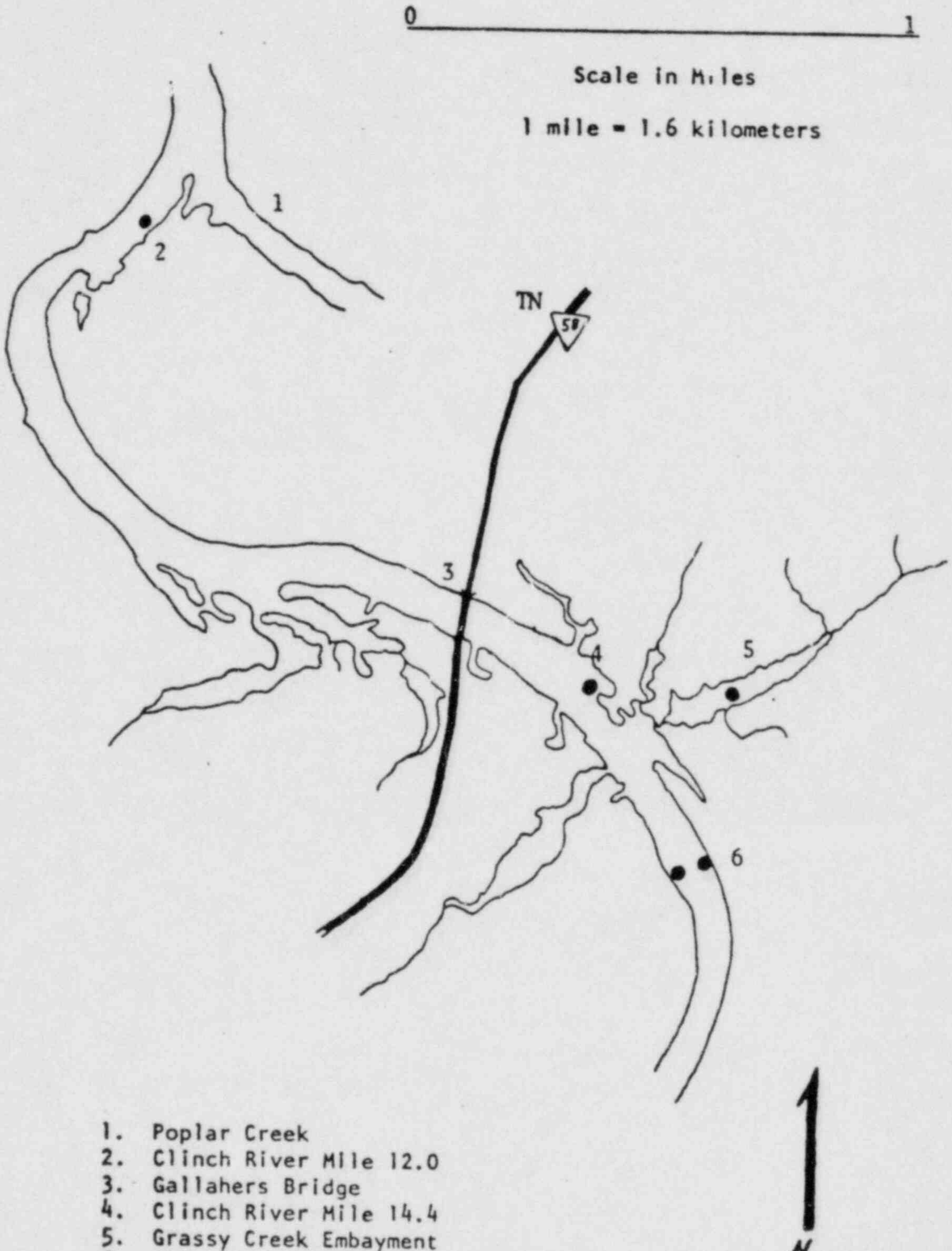
sample area is controlled by water fluctuations of Watts Bar and Melton Hill Reservoirs.

Watts Bar Reservoir in Meigs, Rhea, Roane, Anderson, Loudon, and Morgan Counties was completed in 1942. Watts Bar Dam is located at Tennessee River mile 530 (km 853) which is approximately 61 km downstream from the mouth of the Clinch River. The 117 km long reservoir has an area of 15,628 ha at normal full pool (225.9 m above mean sea level) with a minimum pool area of 13,320 ha at 224.0 m elevation (Moss, 1967).

Melton Hill Dam located at CRM 23 (km 37) was closed in 1963. The reservoir in Roane, Loudon, Anderson and Knox Counties has an area of 2,316 ha and an elevation of 242.3 m above mean sea level. Normal reservoir fluctuations are about 1.5 m. The backwaters of Melton Hill extend 71 km to CRM 80, 21 km below Norris Dam (Fitz, 1965).

Presently there are several existing factors influencing the water quality of the Clinch River in the vicinity of the sampling area. The TVA reservoirs, Norris, Melton Hill, and Watts Bar, have contributed to an alteration of the habitat, species composition, and the relative abundance of fishes in the lower portion of the Clinch River. Bull Run Steam Plant operates at CRM 47.5 (km 76.4). Whiteoak Lake which receives discharges from the Oak Ridge National Laboratory drains into the Clinch River at CRM 20.8 (km 13.5). Poplar Creek enters the Clinch River at CRM 12 (km 19.3). This creek is subject to discharges from the Y-12 plant, the Oak Ridge sewage treatment plant, and the Oak Ridge Gaseous Diffusion Plant (ORGDP). Additionally, the Kingston Steam Plant at CRM 2.7 (km 4.3) withdraws water from the Emory River and discharges it into the Clinch River.

Four of the five sampling stations (Figure 2), CRM 12, 14.4,



1. Poplar Creek
2. Clinch River Mile 12.0
3. Gallahers Bridge
4. Clinch River Mile 14.4
5. Grassy Creek Embayment
6. Clinch River Mile 15.0
● Sample stations

Figure 2. Map of Clinch River Sample Stations

15 east bank, and CRM 15 west bank (km 19.3, 23.2, and 24.1), were located in the mainstream, with the fifth site being found in the Grassy Creek embayment of the Clinch River. The current of the river was generally swiftest at CRM 15 and slowed as it approached CRM 12. The substrate, for the most part, consisted of sand and silt with smaller areas of shale. Deciduous shrubs and trees were the primary bank cover. Fallen trees, especially at CRM 15 east and west banks, also provided excellent fish cover. During the winter drawdown, bank cover was sparse at CRM 12 and CRM 15 east bank with large exposed areas of sand and silt. Cover, though to a lesser extent, continued to be available at CRM 14.4 and CRM 15 west bank in the winter months. The river width varied from approximately 140 m in the summer to 80 m in the winter. The average depth was about 6 m. Presence of large aboriginal shell middens in the study area indicated a basically different habitat, probably one of cleaner, faster moving water with gravel substrate, than the one now found there.

The Grassy Creek embayment of the Clinch River at CRM 14.6 was typical of several large, shallow embayments of creeks within the study area. Environmental stresses were limited to discharges from the U.S. Nuclear Fuel Fabrication Plant, currently the only facility operating in the Oak Ridge Industrial Park (Exxon Nuclear Co., 1976). Depending upon the activities of Melton Hill and Watts Bar Dams, water flowed into or exited from the embayment through a small concrete channel. The substrate of the embayment consisted primarily of mud, clay, and silt with some areas of gravel. Bank cover of deciduous shrubs and trees was generally abundant during the summer when the embayment was 0.70 km long, but was very limited following winter drawdown which reduced the area of the embayment by 1/2 to 2/3 and resulted in areas of exposed mud flats. The average water depth ranged from approximately 2 m to 5 m.

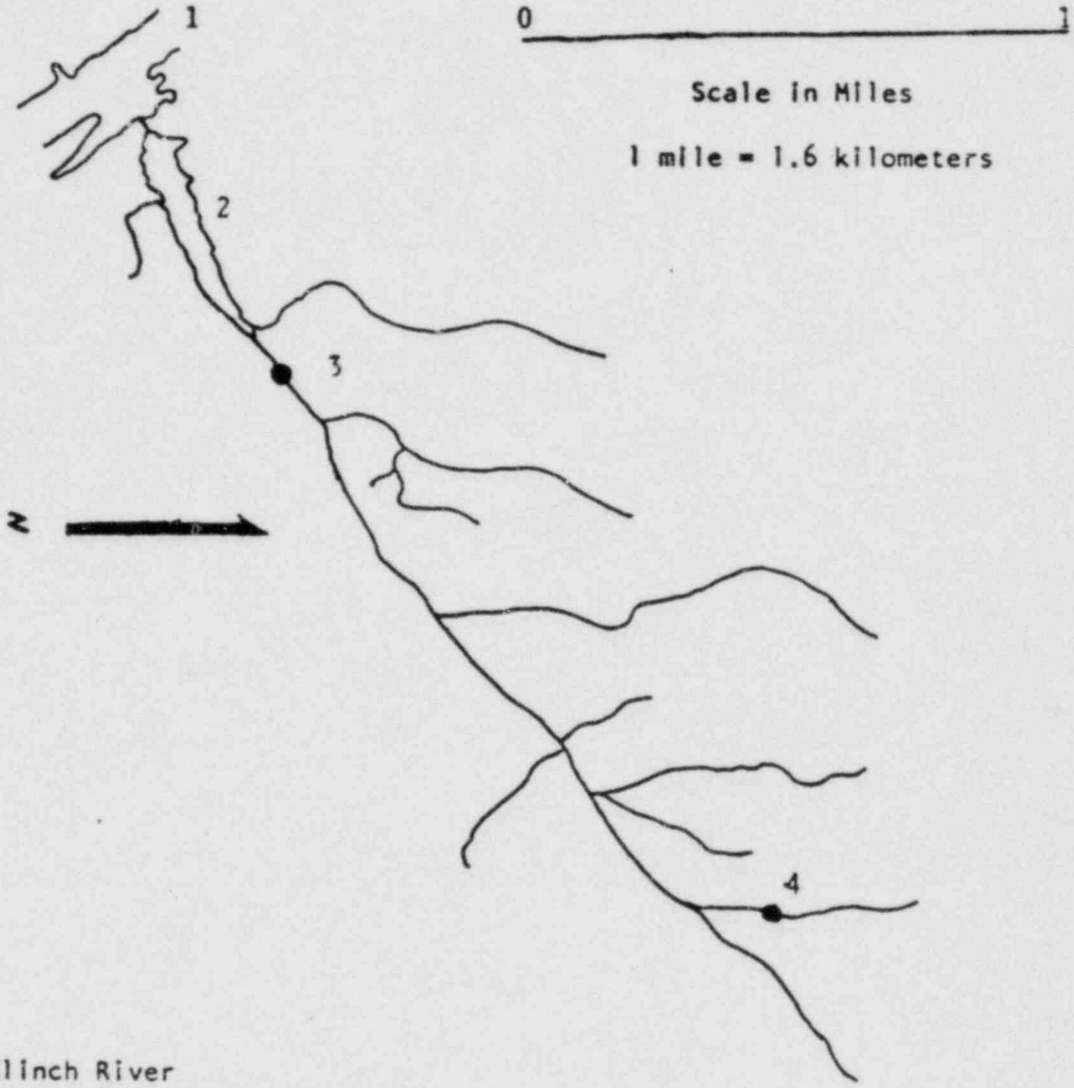
GRASSY CREEK

Grassy Creek, a small springfed stream of moderate hardness that flows southwesterly for 3.3 km into Grassy Creek embayment, has been classed as one of the few uncontaminated streams in the vicinity of the study area. The creek's drainage area of 492 ha consisted largely of deciduous forest and some grassland areas (Exxon Nuclear Co., 1976).

Two stations, Grassy Creek miles 1.0 and 2.2 (km 1.6 and 3.5), (Figure 3) were sampled during the study period. Grassy Creek 1.0 was located in a heavily wooded section with a steep ridge on the east side. A series of pools and riffles with substrates of primarily gravel with lesser amounts of sand, rock, and mud occurred at this site. Stream width varied from about 2.3 m to 4.5 m and depth ranged from approximately 6 cm to 140 cm. Grassy Creek 2.2, surrounded by old field and a sparse forest, had considerably less flow than mile 1.0. The substrate was made up of gravel for the most part with a few areas of bedrock, sand, and mud. Stream width ranged from approximately 0.5 m to 1.5 m, and depth varied from around 5 cm to 60 cm.

BEAR CREEK

Bear Creek, larger than Grassy Creek and with a slightly higher water hardness, flows northwestward to its confluence with the East Fork of Poplar Creek. Bear Creek is 12.1 km in length and has a drainage area of 1,917 ha. At its upper end, Bear Creek is subject to waste



1. Clinch River
2. Grassy Creek embayment
3. Grassy Creek mile 1.0
4. Grassy Creek mile 2.2

Figure 3. Map of Grassy Creek Sample Stations

discharges and acid-settling pond seepage from the Y-12 plant and the Rust Engineering Company, making this portion of the stream virtually devoid of aquatic life (Exxon Nuclear Co., 1976). By the time Bear Creek reaches the NFRRC sampling area, the aquatic life is both varied and abundant; however, this portion of the creek is still periodically subject to heavy loads of silt from reforestation and road construction projects.

Three sites on Bear Creek, miles 0.5, 1.2, and 3.0 (km 0.8, 1.9, and 4.8), were sampled during the study period (Figure 4). Pools and riffles present at each site had substrates composed of silt, sand, gravel, and bedrock. Silt was the predominant substrate at Bear Creek mile (BCM) 3.0, but some graveled areas were present. This silt accumulation may have been due in part to a small gauging impoundment located immediately above BCM 3.0. Gravel, sand and isolated regions of bedrock were the principal substrates at BCM 1.2 and 0.5. The bank cover, as well as much of the drainage area of Bear Creek, was made up of a mixed deciduous and evergreen forest. Stream widths varied from approximately 3 m to 9 m and depth from about 5 cm to 170 cm.

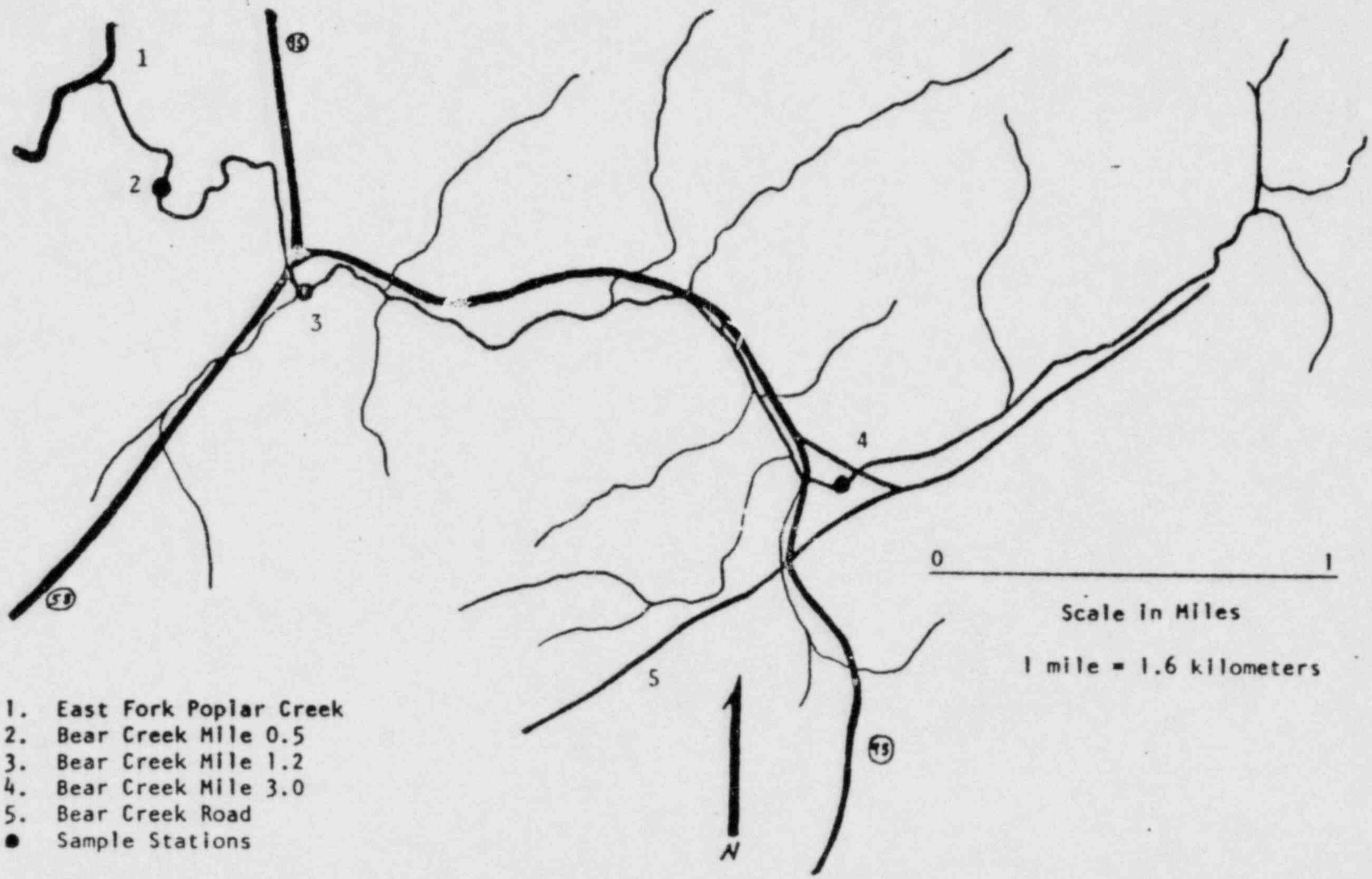


Figure 4. Map of Bear Creek Sample Stations

Chapter 3

METHODS AND MATERIALS

As stated in Chapter 1, four principal lines of investigation, Clinch River adult fish, sauger life history data, Clinch River larval fish, and fish populations in Grassy and Bear Creeks, were emphasized in this study. A number of methods and materials were used to achieve the specified research goals. A conscientious attempt was made to standardize collection procedures and efforts; but in a few instances, variations due to weather conditions and equipment availability did occur. Tables 11-15 in Appendix A contain records of sample date, method, and effort. The study period extended from May, 1975, to April, 1976.

Common and scientific names of the fish collected are in accord with those approved by the American Fisheries Society (American Fisheries Society, Committee on Names of Fishes, 1970). Fishes that were not released are currently housed in the reference collections of Tennessee Technological University, Environmental Biology Research Center of Tennessee Technological University, and the University of Tennessee.

CLINCH RIVER ADULT FISH

The results of fisheries research are influenced by several factors: the type of gear used, the habitats sampled, the efficiency in capturing different species and sizes present, and the distribution of fish within the habitat which may vary diurnally and seasonally (Tebo, 1965). Adult fish were collected monthly in the Clinch River by gill netting and electrofishing. Two methods of collection were employed to determine more accurately species composition and relative abundance (Tebo, 1965; Garton and Harkin, 1970; Powell et al., 1971).

Multifilament experimental gill nets, 45.7 m long and 1.8 m deep, were anchored to the shore, small mesh first, and fished along the bottom. Each net was composed of six 7.6 m long panels of 19, 25, 38, 44, 51, and 76 mm bar-measure mesh. The nets were set perpendicular to the shore at each station shortly after dark and pulled approximately 12 hours later.

Shoreline electrofishing was conducted at each station the night following the gill net sets for a measured period of time, usually 30 minutes per station. A probe shocking boat equipped with flood lights described by Stubbs (1965) was employed in the study. In this design the boat serves as the negative while the positive probe with a normal off switch was hand held. The power source was a Homelite 180 cycle generator operated at 220 volts A.C.

The following data were obtained from each sample: (1) identification of species, (2) enumeration of each species, (3) individual lengths and weights of all fish with two exceptions, Dorosoma sp. and small cyprinids, (4) fish biomass by species, and (5) scales from each game fish. Weight was measured to the nearest gram (g) and total length to the nearest millimeter (mm).

Identifications were made based on characters found in Etnier (1973), Eddy (1969), and Hubbs and Lagler (1958).

SAUGER LIFE HISTORY DATA

A total of 278 sauger were collected from the Clinch River by gill netting (98%) and electrofishing (2%). Two hundred and fifty-five of the sauger were taken in the regular monthly sampling program while the remaining 23 were collected by gill net sets of 3 to 12 hours duration which were not in the sampling schedule.

Shortly after capture, total length and total weight were measured. Scales for age and growth analysis were removed from the left side of the fish below the lateral line near the tip of the pectoral fin. In addition to the length and weight, sex and stomach contents were also recorded on the scale envelopes.

Impressions of five to six scales from each fish were made on cellulose acetate strips (Butler and Smith, 1953) by a Carver laboratory press operated at 15,000-17,000 psi and 80 degrees centigrade (C) for the age and growth study. Distances from the focus of the scale to each annular ring and to the scale margin were measured on an Eberback scale projector at 48x. This information was used in a computer program based on a formula described in Lagler (1956) to calculate total length at each annulus by the direct proportion method:

$$Ln = a + \frac{Sn}{Sc}(Lc - a)$$

where: Ln = length of the fish at the time of annulus formation, n

Sn = measurement from scale focus to anterior margin of the scale

Lc = length of the fish at capture

a = intercept value that will give the best straight line relationship.

The a value was determined by a SPSS computer program which plotted the scale radius (x) against the total length of the fish (y).

The y intercept represented the correctional factor a.

The length-weight relationships for 127 males, 81 females, and 278 total sauger were derived from the formula (Lagler, 1956):

$$\text{Log } W = \text{Log } a + n \log L.$$

Where: W = weight in grams

L = length in millimeters

a = a constant

n = a constant.

The sauger were placed in 10 mm class sizes and mean length and weight for each class were calculated. A regression line was then fitted for the different size groups by the method of the least squares of the logarithms of the mean lengths and weights (Hassler, 1957). The resulting equations are useful in calculating either the length or the weight when one of the measurements are known. Additionally, the regression coefficient, n, may be used as a measure of condition or plumpness of a fish with change in length (Mense, 1976).

Food habits were found by field dissection of the stomachs of 189 sauger collected from June, 1975, to April, 1976. Quantitative determinations were made by counting the fish and fish fragments removed from the sauger stomachs and reporting them in a numerical form. Sand and pebbles, probably taken incidentally in feeding, were not recorded (Priegel, 1969).

Sex and state of maturity were determined for 208 sauger also collected from June, 1975, to April, 1976. In mature adults the testes were a whitish gray color, and the ovaries had a yellowish cast with readily visible ova.

Fecundity estimates were made on 8 mature females captured in

March, 1976. The ovaries were removed shortly after capture and preserved in 20% formalin. The egg production measurements were made by the dry weight method. The ovaries were stripped of fatty tissues and weighed on a Sartorius balance. A trasverse section from an ovary was taken and weighed; and the number of eggs, determined by actual count, were then used in a direct proportion to calculate the total number of eggs in both ovaries (Scott, 1976).

CLINCH RIVER LARVAL FISH

Larval fish were collected twice a month from May until September, 1975, with a 0.5 m x 1.8 m, 1000 μ mesh plankton net which was towed at night from a fixed point near the bow of the boat for 5-minute intervals. Tows were taken at 0 m along the shore and at 0 m and 5 m depth at 25% of the river width at CRM 12, 14.4, 15 east bank, and CRM 15 west bank. Larval fish were sampled in Grassy Creek embayment by two 0 m, mid-channel tows.

The larval fish were preserved in a 5% to 10% formalin solution depending upon the mass of plankton in the sample. Water temperatures were recorded in C for each sample taken at 0 m.

The following data were obtained from each sample: (1) identification to the lowest possible taxon level using polarized stereomicroscopy, (2) enumeration of each level, (3) individual lengths of all fish, and (4) biomass of each level. Identifications were made based on characters and descriptions found in Fish (1932), Hough (1975), Mansueti and Hardy (1967), May and Gasaway (1967), Meyer (1970), Norden (undated), and Siefert (1969).

FISHES OF GRASSY AND BEAR CREEKS

The stream surveys on Grassy and Bear Creeks were conducted by seining and backpack electrofishing. A Smith-Root battery-powered backpack shocker and two seines, one 3 m x 3 mm mesh and the other 1.8 m x 6 mm mesh, were employed in the study. Fish were preserved in 10% formalin for transport back to the laboratory. Identifications were made based on characters found in Etnier (1973), Eddy (1969), and Hubbs and Lagler (1958). The following data were obtained from each sample: (1) identification of species, (2) enumeration of each species, (3) individual lengths, and (4) biomass by species.

Chapter 4

RESULTS AND DISCUSSION

CLINCH RIVER ADULT FISH

A total of 50 species and two hybrids, white bass x striped bass and sauger x walleye, from 14 families have been collected at CRM 12-15 in the course of this study (Table 1). The results of ten fishery surveys within the region of the Clinch River impounded by Watts Bar and Melton Hill Dams are summarized in Table 2. Seventy-six species from 16 families were taken in the collection (1960-1977) which ranged from a low of 24 to a high of 50 species. Seventeen species were found in nine or more of the studies while 25 species were collected in two surveys or less.

Table 3 presents the number, weight (kg), size range (mm), and mean length of the fish taken in the present study. The community was dominated by 21 species of rough fish (42%); 16 species of game fish (32%); and 13 species of forage fish (26%). The bulk of the catch (70% of the total number and 72% of the total weight) was comprised of six species: gizzard shad, threadfin shad, carp, skipjack herring, bluegill, and sauger. Threadfin shad were the most numerous at 39% of the total number of fish; carp, at 20%, had the greatest total weight. Bluegill were the most abundant game fish at 10% of the total number; sauger contributed the highest percentage of game fish weight at 19% of the total weight. Generally, it appears that forage fish dominated the

Table 1. A List of the Fishes Collected in the Clinch River below Melton Hill Dam, May, 1975, through April, 1976

Common Name	Scientific Name
	Family - Polyodontidae
Paddlefish	Polyodon spathula (Walbaum)
	Family - Lepisosteidae
Spotted gar	Lepisosteus oculatus (Winchell)
Longnose gar	Lepisosteus osseus (Linnaeus)
	Family - Clupeidae
Skipjack herring	Alosa chrysochloris (Rafinesque)
Gizzard shad	Dorosoma cepedianum (LeSueur)
Threadfin shad	Dorosoma petenense (Gunther)
	Family - Hiodontidae
Mooneye	Hiodon tergisus LeSueur
	Family - Cyprinidae
Carp	Cyprinus carpio Linnaeus
Silver chub	Hybopsis storeriana (Kirtland)
Golden shiner	Notemigonus crysoleucas (Mitchill)
Emerald shiner	Notropis atherinoides Rafinesque
Spotfin shiner	Notropis spilopterus (Cope)
Bluntnose minnow	Pimephales notatus (Rafinesque)
Bullhead minnow	Pimephales vigilax (Baird and Girard)
	Family - Catostomidae
River carpsucker	Carpiodes carpio (Rafinesque)
Quillback carpsucker	Carpiodes cyprinus (LeSueur)
White sucker	Catostomus commersoni (Lacepede)
Northern hog sucker	Hypentelium nigricans (LeSueur)
Smallmouth buffalo	Ictiobus bubalus (Rafinesque)
Bigmouth buffalo	Ictiobus cyprinellus (Valenciennes)
Black buffalo	Ictiobus niger (Rafinesque)
Spotted sucker	Minytrema melanops (Rafinesque)
Silver redhorse	Moxostoma anisurum (Rafinesque)
River redhorse	Moxostoma carinatum (Cope)
Black redhorse	Moxostoma duquesnei (LeSueur)
Golden redhorse	Moxostoma erythrurum (Rafinesque)

Table 1. (Continued)

Common Name	Scientific Name
	Family - Ictaluridae
Channel catfish	_Ictalurus punctatus_ (Rafinesque)
Flathead catfish	_Pylodictis olivaris_ (Rafinesque)
	Family - Poeciliidae
Mosquitofish	_Gambusia affinis_ (Baird and Girard)
	Family - Percichthyidae
White bass	_Morone chrysops_ (Rafinesque)
Yellow bass	_Morone mississippiensis_ (Jordon and Eigenmann)
Striped bass	_Morone saxatilis_ (Walbaum)
	Family - Atherinidae
Brook silverside	_Labidesthes sicculus_ (Cope)
	Family - Centrarchidae
Rock bass	_Ambloplites rupestris_ (Rafinesque)
Redbreast sunfish	_Lepomis auritus_ (Linnaeus)
Warmouth	_Lepomis gulosus_ (Cuvier)
Bluegill	_Lepomis macrochirus_ Rafinesque
Longear sunfish	_Lepomis megalotis_ (Rafinesque)
Redear sunfish	_Lepomis microlophus_ (Gunther)
Smallmouth bass	_Micropterus dolomieui_ Lacepede
Spotted bass	_Micropterus punctulatus_ (Rafinesque)
Largemouth bass	_Micropterus salmoides_ (Lacepede)
White crappie	_Pomoxis annularis_ Rafinesque
Black crappie	_Pomoxis nigromaculatus_ (LeSueur)
	Family - Percidae
Tennessee snubnose darter	_Etheostoma simoterum_ (Cope)
Logperch	_Percina caprodes_ (Rafinesque)
Sauger	_Stizostedion canadense_ (Smith)
Walleye	_Stizostedion vitreum vitreum_ (Mitchill)
	Family - Sciaenidae
Freshwater drum	_Aplodinotus grunniens_ Rafinesque

Table 1. (Continued)

Common Name	Scientific Name
	Family - Cottidae
Banded sculpin	*Cottus carolinae* (Gill)

Table 2. Check List of Species Collected in the Clinch River in the Vicinity of the Study Area

Species	1960[1]	1960-62[2]	1963[3]	1965[4]	1968[5]	1968[6]	1975[7]	1976[8]	1977[9]	1977[10]
Game										
Rock bass	x		x		x	x	x	x	x	
Redbreast sunfish		x		x		x	x	x	x	
Warmouth			x	x	x	x		x	x	
Bluegill	x	x	x	x	x	x	x	x	x	x
Dollar sunfish					x					
Longear sunfish	x	x	x	x			x	x	x	
Redear sunfish			x	x		x	x	x	x	x
Smallmouth bass	x		x	x	x	x		x	x	
Spotted bass	x	x	x	x	x	x	x	x	x	
Largemouth bass	x	x	x	x		x	x	x	x	x
White crappie	x	x		x	x	x	x	x	x	x
Black crappie	x		x	x				x	x	
White bass	x	x		x	x	x	x	x	x	x
Yellow bass								x	x	x
Striped bass							x		x	
Yellow perch							x			
Sauger	x	x	x	x	x	x	x	x	x	x
Walleye	x	x	x			x		x	x	x
Rainbow trout					x	x				
Forage										
Brook silverside			x	x				x	x	
Gizzard shad	x	x	x	x	x	x	x	x	x	x
Threadfin shad		x	x	x	x	x	x	x	x	x
Banded sculpin					x	x	x		x	
Stoneroller					x	x		x		

Table 2. (Continued)

Species	1960[1]	1960-62[2]	1963[3]	1965[4]	1968[5]	1968[6]	1975[7]	1976[8]	1977[9]	1977[10]
<u>Forage</u> (Continued)										
Bigeye chub					x					
Silver chub							x	x	x	
River chub					x					
Golden shiner						x		x	x	
Rosefin shiner							x			
Emerald shiner			x	x		x	x	x	x	
Warpaint shiner					x					
Common shiner			x		x	x				
Whitetail shiner				x	x	x				
Spotfin shiner			x	x	x	x			x	
Steelcolor shiner								x		
Bluntnose minnow				x		x		x	x	
Fathead minnow				x	x	x		x		
Bullhead minnow			x						x	
Blacknose dace					x					
Blackspotted topminnow					x					
Tadpole madtom				x						
Mosquito fish						x			x	
Greenside darter					x			x		
Blueside darter					x					
Johnny darter						x				
Tennessee snubnose darter									x	
Logperch		x	x	x	x	x	x	x	x	
<u>Rough</u>										
River carpsucker			x	x	x	x		x	x	

Table 2. (Continued)

Species	1960[1]	1960-62[2]	1963[3]	1965[4]	1968[5]	1968[6]	1975[7]	1976[8]	1977[9]	1977[10]
<u>Rough</u> (Continued)										
Quillback carpsucker			x		x	x	x		x	x
Highfin carpsucker			x			x				
White sucker					x	x		x	x	
Blue sucker					x					x
Northern hog sucker		x	x	x	x	x	x	x	x	x
Smallmouth buffalo	x	x	x	x	x	x	x	x	x	x
Bigmouth buffalo	x			x	x	x		x	x	x
Black buffalo	x		x	x	x			x	x	x
Spotted sucker				x		x		x	x	
Silver redhorse					x	x			x	
River redhorse	x	x			x	x	x		x	
Black redhorse	x	x	x	x	x	x	x	x	x	
Golden redhorse	x	x	x	x	x	x	x	x	x	x
Shorthead redhorse		x		x	x	x				
Skipjack herring	x	x	x	x	x	x	x	x	x	x
Goldfish						x				
Carp	x	x	x	x	x	x	x	x	x	x
Mooneye	x	x		x	x		x	x	x	x
Blue catfish	x	x		x						
Yellow bullhead	x			x						
Brown bullhead						x				
Channel catfish	x	x		x	x	x	x	x	x	x
Flathead catfish	x	x		x	x	x		x	x	x
Spotted gar					x			x	x	
Longnose gar	x	x	x	x	x	x			x	
Shortnose gar				x						
Paddlefish									x	x

Table 2. (Continued)

Species	1960[1]	1960-62[2]	1963[3]	1965[4]	1968[5]	1968[6]	1975[7]	1976[8]	1977[9]	1977[10]
Rough (Continued)										
Freshwater drum	x	x	x	x	x	x	x	x	x	x
Total No. of Species 76	27	26	31	41	47	48	30	43	50	24

[1]Hoop net samples in vicinity of White Oak Creek collected July 6 through September 21, 1960, and April 12 through July 13, 1961, by biologists of TVA, Tennessee Department of Game and Fish (Tebo, 1965).

[2]Rotenone, hoop net and gill net samples from vicinity of mile 4.9 (km 7.8) collected during 1960, 1961, and 1962 by TVA biologists (Tebo, 1965).

[3]Rotenone and electric shocker samples collected July 30, 31, and August 1, 1973, in vicinity of Gallahers Bridge, CRM 14.5 (km 23.2), by Water Pollution Surveillance System Stations (WPSS) personnel and TVA biologists (Tebo, 1965).

[4]Watts Bar Reservoir 1964 fish inventory; fish were collected by rotenone (TVA, 1965).

[5]Preimpoundment survey of Melton Hill Reservoir; fish were collected by gill nets and rotenone from November, 1960, to June 1962 (Fitz, 1968).

[6]Postimpoundment survey of Melton Hill Reservoir; fish were collected by gill nets, bottom trawls, bag seining, and rotenone from November, 1963, to October, 1964 (Fitz, 1968).

[7]Gill net and electrofishing samples (CRM 15-18) collected from March through September, 1974 (Project Management Corp., 1975).

Table 2. (Continued)

[8] Watts Bar Reservoir 1973 fish inventory; fish were collected by rotenone (Sheddan, 1976).

[9] Present study, gill net and electrofishing samples (CRM 12-15) collected from May, 1975, through April, 1976.

[10] Trammel and gill net samples from Watts Bar Reservoir, 1976-1977 (Heitman, personal communication, 1977).

Table 3. Results of Fish Collections from the Clinch River below Melton Hill Dam (1975-1976)

Species	Total Number	% Total Number	Total Weight (Kg)	% Total Weight	Size Range (mm)	Mean Length (mm)
<u>Game</u>						
Rock bass	31	0.59	0.96	0.11	37-197	105.6
Redbreast sunfish	11	0.21	0.76	0.09	47-208	134.4
Warmouth	4	0.08	0.18	0.02	44-157	108.0
Bluegill	519	9.90	13.12	1.48	29-222	86.0
Longear sunfish	1	0.02	0.07	0.01	-	140.0
Redear sunfish	5	0.10	0.39	0.04	113-210	151.6
Smallmouth bass	4	0.08	0.07	0.01	71-130	110.8
Spotted bass	47	0.90	2.62	0.30	60-510	111.4
Largemouth bass	62	1.18	16.74	1.89	75-565	222.8
White crappie	70	1.34	4.73	0.53	51-302	156.6
Black crappie	8	0.15	0.60	0.07	65-257	167.1
White bass	54	1.03	14.66	1.65	123-376	262.1
Yellow bass	24	0.46	2.70	0.30	130-245	199.2
Striped bass	7	0.13	14.09	1.59	290-551	448.3
Striped bass x white bass	1	0.02	0.13	0.01	-	209.0
Sauger	255	4.86	171.05	19.31	214-535	397.0
Walleye	1	0.02	1.06	0.12	-	565.0
Walleye x sauger	1	0.02	2.88	0.33	-	625.0
<u>Forage</u>						
Brook silverside	110	2.10	0.14	0.02	33-84	66.9
Gizzard shad	389	7.42	66.91	7.55	-	*
Threadfin shad	2050	39.10	42.77	4.83	-	*
Banded sculpin	8	0.15	0.08	0.01	56-88	79.8

Table 3. (Continued)

Species	Total Number	% Total Number	Total Weight (Kg)	% Total Weight	Size Range (mm)	Mean Length (mm)
<u>Forage</u> (Continued)						
Silver chub	31	0.59	0.44	0.05	65-154	113.7
Golden shiner	4	0.08	0.01	-	34-79	55.8
Emerald shiner	386	7.36	2.56	0.29	40.121	97.0
Spotfin shiner	29	0.55	0.05	0.01	32-86	55.6
Bluntnose minnow	68	1.30	0.13	0.01	19-78	56.2
Bullhead minnow	329	6.28	0.66	0.07	31-78	55.7
Tennessee snubnose darter	1	0.02	0.00	-	-	52.0
Logperch	15	0.29	0.18	0.02	70-148	109.5
Mosquitofish**	2	0.04	0.00	-	22-24	23.0
<u>Rough</u>						
River carpsucker	5	0.10	7.54	0.85	430-555	485.8
Quillback carpsucker	29	0.55	27.08	3.06	264-482	406.5
White sucker	1	0.02	0.45	0.05	-	322.0
Hog sucker	2	0.04	0.47	0.05	232-311	271.5
Smallmouth buffalo	20	0.38	37.85	4.27	281-686	466.5
Bigmouth buffalo	1	0.02	1.50	0.17	-	450.0
Black buffalo	4	0.08	6.02	0.68	449-503	480.5
Spotted sucker	5	0.10	1.26	0.14	186-329	277.2
Silver redhorse	9	0.17	10.56	1.19	100-573	439.4
River redhorse	6	0.11	3.64	0.41	304-405	373.7
Black redhorse	5	0.10	2.74	0.31	350-398	386.0
Golden redhorse	48	0.92	28.36	3.20	101-435	359.1
Skipjack herring	269	5.13	159.82	18.04	130-498	369.4

Table 3. (Continued)

Species	Total Number	% Total Number	Total Weight (Kg)	% Total Weight	Size Range (mm)	Mean Length (mm)
Rough (Continued)						
Carp	186	3.55	177.54	20.04	150-619	394.5
Mirror carp	4	0.08	2.66	0.30	150-476	341.5
Mooneye	27	0.51	6.79	0.77	265-311	287.0
Channel catfish	32	0.61	22.26	2.51	283-604	400.7
Flathead catfish	1	0.02	0.52	0.06	-	365.0
Spotted gar	16	0.31	14.93	1.69	459-859	589.8
Longnose gar	7	0.13	5.85	0.66	446-905	669.7
Paddlefish	1	0.02	2.54	0.29	-	935.0
Freshwater drum	38	0.72	4.89	0.55	154-350	231.4

Value	Total Number	% Total Number	Total Weight (Kg)	% Total Weight	Total No. of Species	% Total No. of Species
Rough	716	13.66	525.27	59.28	21	42.00
Game	1105	21.08	246.81	27.86	16	32.00
Forage	3422	65.27	113.93	12.86	13	26.00
	5243		886.01		50	

*Lengths were not recorded for Gizzard shad and Threadfin shad
**Collected December, 1975, with dip net at CRM 12

community in terms of numbers (65%) while rough fish contributed the greatest percentage of the fish biomass (59%).

The results of the 1964 (TVA, 1965) and the 1973 (Sheddan, 1976) Watts Bar Reservoir fish inventories are similar to those found by the present research. The relative abundances of the species in the three collections are as follows: 1964 - rough, 46%; game, 29%; and forage, 24%; 1973 - rough, 37%; game, 35%; and forage, 28%; and 1975-76 - rough, 42%; game, 32%; and forage, 26%. Each of the studies found that threadfin shad were the most abundant fish and that bluegill were the most numerous game fish found in the collections. The three surveys also found that forage fish dominated the total number of fishes taken (57% to 73% of the total number) and that rough fish represented the greatest percentage of fish biomass with values ranging from 44% to 62% of the total weight.

Two methods of population estimation were used to measure the relative abundance of the fishes within the study area. Table 3 in the text and Tables 1-5 in Appendix A measure the abundance in terms of relative density and fish biomass. The second method, catch per unit effort presented in Tables 4 and 5, serves as an index for determining the abundance or density of a species on the basis of collection efficiency (Jester, 1971). As mentioned in Chapter 3, a number of factors concerning habitat and gear selectivity may affect the results of fisheries research and should be considered in the interpretation of data.

A total of 25 hours of electrofishing and 131 net nights (1 net night = 1 net set overnight for approximately 12 hours) were fished in the Clinch River. Of the 50 species collected, 38 were found in gill nets and 36 were collected by electrofishing. Fifty-seven percent of the total number of fish were taken by electrofishing while gill netting

Table 4. Number of Fishes Per Hour Collected from the Clinch River below Melton Hill Dam by Electrofishing (1975-1976)

Species	Hours	CRM 12 5	CRM 14.4 5.5	Grassy Crk. 0.4 5	CRM 15 (East) 5	CRM 15 (West) 4.5	All Locations 25
Game							
Rock bass		0.60	2.55	0.20	1.00	1.56	1.20
Redbreast sunfish		-	1.27	0.20	-	0.22	0.36
Warmouth		-	0.18	0.60	-	-	0.16
Bluegill		12.40	17.64	46.20	8.40	10.22	19.12
Longear sunfish		-	0.18	-	-	-	0.04
Redear sunfish		-	-	0.80	-	-	0.16
Smallmouth bass		-	-	-	0.80	-	0.16
Spotted bass		0.20	2.18	5.20	0.80	0.67	1.84
Largemouth bass		2.00	3.45	3.00	1.80	1.56	2.40
White crappie		0.40	1.27	8.00	0.20	0.67	2.12
Black crappie		0.20	-	1.00	-	-	0.24
White bass		0.80	0.18	0.20	-	0.44	0.32
Yellow bass		0.20	0.55	-	-	-	0.16
Sauger		0.20	0.18	0.60	-	0.22	0.24
Forage							
Brook silverside		-	2.36	17.20	1.20	1.11	4.40
Gizzard shad		3.00	14.91	12.60	3.80	2.00	7.52
Threadfin shad		7.40	23.82	59.20	7.80	104.67	38.96
Banded sculpin		0.80	0.36	-	0.40	-	0.32
Silver chub		1.60	-	-	1.60	3.11	1.20
Golden shiner		0.40	-	0.40	-	-	0.16
Emerald shiner		8.00	10.73	8.80	13.60	38.89	15.44
Spotfin shiner		0.20	0.36	3.80	0.60	0.89	1.16

Table 4. (Continued)

Species Hours	CRM 12 5	CRM 14.4 5.5	Grassy Crk. 0.4 5	CRM 15 (East) 5	CRM 15 (West) 4.5	All Locations 25
Forage (Continued)						
Bluntnose minnow	5.00	0.91	6.20	1.00	0.44	2.72
Bullhead minnow	24.00	2.55	21.40	12.00	6.22	13.16
Tennessee snubnose darter	-	-	-	-	0.22	0.04
Logperch	-	0.73	1.00	0.20	0.22	0.44
Rough						
Quillback carpsucker	-	0.36	-	-	0.22	0.12
Hog sucker	0.20	-	-	-	-	0.04
Smallmouth buffalo	-	0.18	-	-	0.22	0.08
Spotted sucker	0.20	0.18	0.20	0.20	-	0.16
Silver redhorse	-	-	0.40	-	-	0.08
Black redhorse	-	-	-	-	0.44	0.08
Golden redhorse	-	0.55	0.60	-	0.22	0.28
Skipjack herring	0.40	0.18	-	0.60	-	0.24
Carp	0.60	4.18	11.20	5.20	1.56	4.60
Mirror carp	-	0.18	-	0.20	-	0.08
Freshwater drum	-	2.36	0.40	-	0.22	0.64
TOTALS	68.80	94.53	209.40	61.40	176.21	120.44

Table 5. Number of Fishes Per Net Night Collected from the Clinch River below Melton Hill Dam with Gill Nets (1975-1976)

Species	CRM 12	CRM 14.4	Grassy Crk. 0.4	CRM 15 (East)	CRM 15 (West)	All Locations
Net Nights	33	33	11	33	21	131
Game						
Rock bass	-	-	-	-	0.05	0.01
Redbreast sunfish	0.03	0.03	-	-	-	0.02
Bluegill	0.24	0.18	0.18	0.30	0.71	0.31
Redear sunfish	-	0.03	-	-	-	0.01
Spotted bass	-	-	-	-	0.05	0.01
Largemouth bass	0.03	0.03	-	-	-	0.02
White crappie	-	0.09	0.82	0.12	0.05	0.13
Black crappie	-	0.03	0.09	-	-	0.02
White bass	0.52	0.52	0.09	0.27	0.10	0.35
Yellow bass	0.12	0.12	0.18	0.15	0.24	0.15
Striped bass	0.06	0.09	-	0.03	0.05	0.05
Striped bass x white bass	-	-	-	0.03	-	0.01
Sauger	1.73	2.09	0.18	2.67	1.57	1.90
Walleye	0.03	-	-	-	-	0.01
Walleye x sauger	-	0.03	-	-	-	0.01
Forage						
Gizzard shad	1.73	1.85	2.82	1.45	0.19	1.53
Threadfin shad	1.15	13.97	2.91	10.61	9.29	8.21
Silver chub	-	-	-	0.03	-	0.01
Logperch	-	-	-	0.06	0.10	0.03

Table 5. (Continued)

Species Net Nights	CRM 12 33	CRM 14.4 33	Grassy Crk. 0.4 11	CRM 15 (East) 33	CRM 15 (West) 21	All Locations 131
<u>Rough</u>						
River carpsucker	0.06	0.06	-	-	0.05	0.04
Quillback carpsucker	0.12	0.30	-	0.36	-	0.20
White sucker	-	0.03	-	-	-	0.01
Hog sucker	-	-	-	0.03	-	0.01
Smallmouth buffalo	0.30	0.09	0.09	0.03	0.14	0.14
Bigmouth buffalo	0.03	-	-	-	-	0.01
Black buffalo	0.03	0.03	-	0.03	0.05	0.03
Spotted sucker	0.03	-	-	-	-	0.01
Silver redhorse	-	0.09	-	0.06	0.10	0.05
River redhorse	0.03	-	-	0.15	-	0.05
Black redhorse	-	0.03	-	0.06	-	0.02
Golden redhorse	0.48	0.30	0.27	0.27	0.14	0.31
Skipjack herring	1.97	2.58	0.18	2.55	1.29	2.01
Carp	0.91	0.85	0.45	0.18	0.10	0.54
Mirror carp	0.03	0.03	-	-	-	0.02
Mooneye	0.42	0.27	-	0.12	-	0.21
Channel catfish	0.52	0.18	0.18	0.15	0.10	0.24
Flathead catfish	-	-	-	0.03	-	0.01
Spotted gar	0.03	-	1.27	0.03	-	0.12
Longnose gar	0.15	-	0.18	-	-	0.05
Paddlefish	0.03	-	-	-	-	0.01
Freshwater drum	0.12	0.09	0.64	0.21	0.05	0.17
TOTALS	10.90	23.99	10.53	19.98	14.42	17.05

accounted for 43% of the total.

The overall abundance expressed in terms of density and biomass are presented in Table 3 while these measures of abundance are shown in Table 1-5 in Appendix A as a function of sampling station and season of collection. Higher totals of game and rough fish were taken in the fall quarter, but the greater biomasses of these two groups were found in the spring collections. The highest number of forage fish was found during the winter quarter, and forage fish biomass was greatest in the fall quarter.

The catch per unit effort results of electrofishing and gill netting are summarized in Tables 4 and 5 respectively. The collections in the Clinch River averaged 120 fish per hour electrofishing and 17 fish per net night. Threadfin shad, bluegill, emerald shiner, and bullhead minnow were taken in the greatest numbers per hour of electrofishing. In take per net night effort, threadfin shad, skipjack herring, sauger, and gizzard shad were the most numerous fishes collected.

Specimens of largemouth bass, gizzard shad, and carp at CRM 14.5 (Tebo, 1965); white crappie, freshwater drum, white bass, channel catfish and bluegill at CRM 10 (km 16) (D. Nelson, 1969); and Corbicula, CRM 12-15 (Eagleson, personal communication, 1977) have been analyzed for redionuclides. Tebo (1965) reported that largemouth bass and carp had counts only slightly above background radioactivity while gizzard shad levels were considerably higher with the presence of Cs^{137}, Ru^{106}, Rh^{106}, Co^{60}, and K^{40} indicated. Concentrations of Cs^{137} were reported by D. Nelson (1969) to range from 0.344 mg/g fresh weight in bluegill to 1.60 mg/g fresh weight in white bass. D. Nelson also found that the average concentration of Cs^{137} in fish tissues can be predicted from the average concentration of Cs^{137} in waters subject to chronic releases of this radionuclide. After a one-year period of exposure, Eagleson (personal communication, 1977) found that for Corbicula, both hard and soft parts, radiation levels of Co^{60} and Cs^{137} were at background; additionally, measurements made on Corbicula native to the site returned similar results.

The total production of fish in 1964 (TVA, 1965) in the Clinch River arm of Watts Bar Reservoir was slightly higher (216 kg/ha) than that of the lower portion of the reservoir (213 kg/ha). In the 1973 Watts Bar fish inventory (Sheddan, 1976) found that the standing crop of the Clinch River portion of Watts Bar had increased to 237 kg/ha while that of the reservoir had risen to 313 kg/ha. The average standing crop of Watts Bar Reservoir was lower than that of Fort Loudon Reservoir (363 kg/ha), located upstream on the Tennessee River; but was higher than the standing crop value of 221 kg/ha at the downstream reservoir, Chickamauga (Sheddan, 1976).

The 1972 commercial fish harvest was low within a 10 mile (16 km) radius of the NFRRC site amounting to approximately 1% of the total catch from Watts Bar Reservoir of 106,786 pounds (48,539 kg) which was composed of 56% buffalo, 22% catfish, 12% paddlefish, 9% carp, and 1% drum. This return represented a considerable decrease in the commercial harvest since 1962 when 200,603 pounds (91,183 kg) of buffalo (80%), carp (12%), and carpsucker (8%) were taken (Exxon Nuclear Co., 1976).

SAUGER LIFE HISTORY DATA

The sauger, Stizostedion canadense (Smith), is a member of the perch family, Percidae (Class Osteichthyes; Order Perciformes). Over

100 species found in North America and northern Europe belong to the perch family which is composed of three subfamilies and eight genera. The subfamily Etheostominae (darters) restricted to North America, consists of three genera, Ammocrypta, Percina, and Etheostoma. Four genera, Perca, Acerina, Aspro, and Percarina, belong to the subfamily Percinae which is represented in North America by a single species, Perca flavescens, the yellow perch. The subfamily of the pike perches, Luciopercinae, contains five species belonging to the single genus Stizostedion. Two of the five are found in North America (sauger, Stizostedion canadense, and walleye, S. vitreum) with the remaining three restricted to northern Europe (Collette, 1963).

The sauger from the present NFRRC preconstruction study ranged in length from 214 mm to 535 mm and weight from 78 g to 1860 g. Morphologically the sauger has an elongate and cylindrical body form (Figure 5). The posterior margin of the preopercle is strongly serrate, and the canine teeth which are present on both jaws are well developed. Sauger are probably most frequently confused with walleye. Etnier (1973) lists the following characteristics for the identification of the two species: soft dorsal rays, sauger 17-20, walleye 19-22; sauger dorsal fin spotted with discrete black, halfmoon, blotches, and lacking a concentration of pigment at the posterior base; in walleye the dorsal fin is dusky or mottled with a predominant black spot at the posterior base; cheeks are fully scaled in sauger but partially naked in walleye; the lower lobe of the caudal fin is mottled in sauger, but in walleye a creamy white area is present; in sauger the base of the pectoral fin is black, but is usually not strongly pigmented in walleye; and the pyloric cacae count of sauger is 5-6 while that of walleye is 3-4.

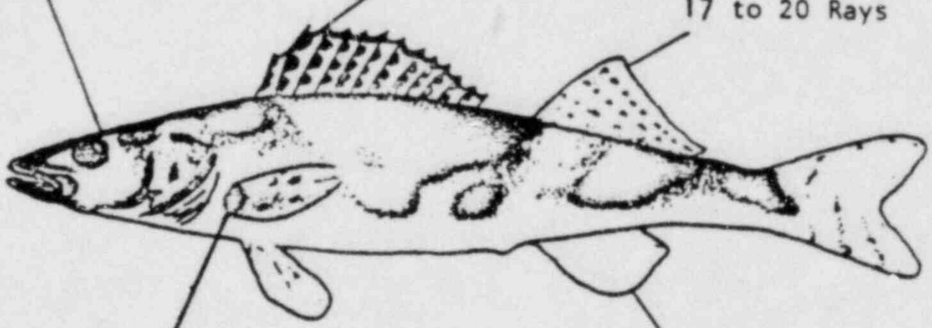


Figure 5. Sauger, Stizostedion canadense (Smith)

In Canada, sauger are found in the St. Lawrence and Champlain river systems (Scott and Crossman, 1973). Sauger distribution in the United States is to the south from the Great Lakes region, west of the Appalachians, to the Tennessee River in Alabama, to the Red River in Texas, to eastern Kansas, Nebraska, Wyoming, southwestern Iowa and Montana (Hubbs and Lagler, 1958). Preferred sauger habitat is that of large slow-flowing silty rivers and large lakes (Scott and Crossman, 1973; Hubbs and Lagler, 1958).

Age and growth determinations were made on 47 sauger collected in March, 1976, from the Clinch River. The a value was calculated to be 68 mm. Priegel (1969) reported annulus formation to occur in mid-May for sauger in Lake Winnebago, Wisconsin. Hassler (1957) stated that sauger from Norris Reservoir, Tennessee, completed annulus formation during mid-spring. Exact time of annulus formation was not determined for the Clinch River sauger in the present study. The greatest growth rate was exhibited in the first year of life with a declining rate thereafter. Table 6 compares the calculated growth rate of the Clinch River sauger with age and growth results reported from various bodies of water. Growth rates in the Clinch River arm of Watts Bar Reservoir were: higher than those of the main body of Watts Bar Reservoir (TVA, 1965; Sheddan, 1976); similar to those of Melton Hill Reservoir (Fitz, 1965); slower than the growth rates of Cherokee and Douglas Reservoir in Tennessee (Stroud, 1949 as cited by Priegel, 1969); and faster than those reported for Lake Erie (Deason, 1933 as cited by Priegel, 1969), Lake of the Woods, Minnesota (Carlander, 1950 as cited by Priegel, 1969), and Lake Winnebago, Minnesota (Priegel, 1969). Initial growth in the Clinch River arm of Watts Bar Reservoir was better, but by age class 3

Table 6. Calculated Growth of Saugers from Various Waters

Study Area	No. of Fish	Average Total Length (mm) at End of Year									
		1	2	3	4	5	6	7	8	9	10
Clinch River, CRM 12-15 Tenn. (Present study)	47	238	338	382	418	445					
Watts Bar Reservoir, Tenn. (TVA, 1965)	24	209	300	367	417						
Watts Bar Reservoir, Tenn. (Sheddan, 1976)	5	221									
Melton Hill Reservoir, Tenn. Preimpoundment (Fitz, 1968)	15	223	313	384	441						
Melton Hill Reservoir, Tenn. Postimpoundment (Fitz, 1968)	8	228	336	368							
Norris Reservoir, Tenn. (Hassler, 1957)	3393	212	336	396	438	473	498	518			
Cherokee Reservoir, Tenn.* (Stroud, 1949)	64	235	374	441							
Douglas Reservoir, Tenn.* (Stroud, 1949)	39	250	396								

Table 6. (Continued)

Study Area	No. of Fish	Average Total Length (mm) at End of Year									
		1	2	3	4	5	6	7	8	9	10
Lake Winnebago, Wis. (Priegel, 1969)	784 ♂	125	241	305	333	355	376	388	401		
	957 ♀	125	251	307	335	358	378	391	401		
Garrison Reservoir, N. D. (Carufel, 1963)	96 ♂	122	216	292	358	447					
	222 ♀	127	223	317	399	467	587				
Lewis and Clark Lake, S. D. (W. Nelson, 1969)	1112	188	324	404	466	514	560	596	625		
Lewis and Clark Lake, S. D.* (Vanicek, 1964)	479	160	312	413	520	538					
Lake Erie* (Deason, 1933)	905	99	200	264	310	345	401				
Lake of the Woods, Minn.* (Carlander, 1950)	883	167	195	264	317	348	360	383	398	424	399

*As cited by Priegel, 1969

growth was greater in Norris Reservoir, Tennessee (Hassler, 1957). In ages 1 through 4, growth rates were faster in the Clinch River than in Garrison Reservoir, North Dakota, but were slower at age class 5 (Carufel, 1963). The growth rates in Lewis and Clark Lake, South Dakota, for age classes 1 and 2 were lower than those in the Clinch River, but were greater in classes 3 through 5 (Vanicek, 1964, as reported by Priegel, 1969; W. Nelson, 1969). Priegel (1969) stated that an earlier spawning season, longer growing season, and abundant food supply were the factors most likely responsible for the rapid growth rates in Tennessee storage reservoirs. Hassler (1957) concluded that the slower growth rates in northern waters were associated with increased longevity.

Of the 278 sauger collected in the present study, 10 females surpassed 3 pounds (1362 g) in weight. The largest male taken weighed 2.7 pounds (1220 g) while the largest sauger found in the study, a female, weighed 4.1 pounds (1860 g). The largest sauger taken by Hassler (1957) in Norris Reservoir, Tennessee, was a 4.1 pound (1873 g) female; the largest male weighed 3 pounds (1362 g). Only ten fish (9 females and 1 male) of the 5,500 sauger examined by Hassler (1957) weighed 3 or more pounds. Hassler (1957) attributed the larger size reached by females to a longer life span and a more rapid rate of growth. Priegel (1969) examined 1,824 sauger in Lake Winnebago, Wisconsin, of which only one, a 2.1 pound female, surpassed 2 pounds (908 g); the largest male taken by Priegel weighed 1.4 pounds (636 g). W. Nelson (1969) reported that the maximum weight of sauger from Lewis and Clark Lake, South Dakota, to be 5.6 pounds (2,550 g). Carufel (1963) recorded a 6.7 pound (3042 g) sauger in Garrison Reservoir, North Dakota, and stated that the largest sauger taken from the reservoir weighed 8.2

pounds (3723 g). The world record sauger (8.3 pounds, 3774 g) was taken from the Missouri River in Nebraska in 1961 (Schaffer, 1962, as cited by Priegel, 1969). Etnier (1973) and Priegel (1969) stated that some of the larger sauger records could possibly be those of sauger x walleye hybrids. In the current study, one sauger x walleye hybrid (625 mm in length and 6.3 pounds, 2880 g in weight) was identified based on characters described by Stroud (1948).

Equations from the length-weight relationship are useful in calculating either the length or the weight when one of the measurements is known. In the present study, equations were derived for 278 total fish, 127 males, and 81 females. The male sauger ranged in length from 304 mm to 497 mm and in weight from 230 g to 1220 g; female sauger varied from 287 mm to 535 mm in length and 180 g to 1860 g in weight. The formula of the length-weight relationship of the combined sexes was computed to be:

$$\text{Log } W = -6.249 + 3.479 \log L.$$

Where: W = weight in grams

L = total length in millimeters.

For male sauger the equation is:

$$\text{Log } W = -5.277 + 3.102 \log L.$$

For female sauger the equation is:

$$\text{Log } W = -7.001 + 3.767 \log L.$$

Using the above equations, a sauger of unknown sex at 450 mm would weigh 958 g; a male of that length, 898 g; and a female, 985 g. A graphical illustration of the formula for the combined sexes appears in Figure 6.

Mense (1976) stated that the regression coefficient may be used

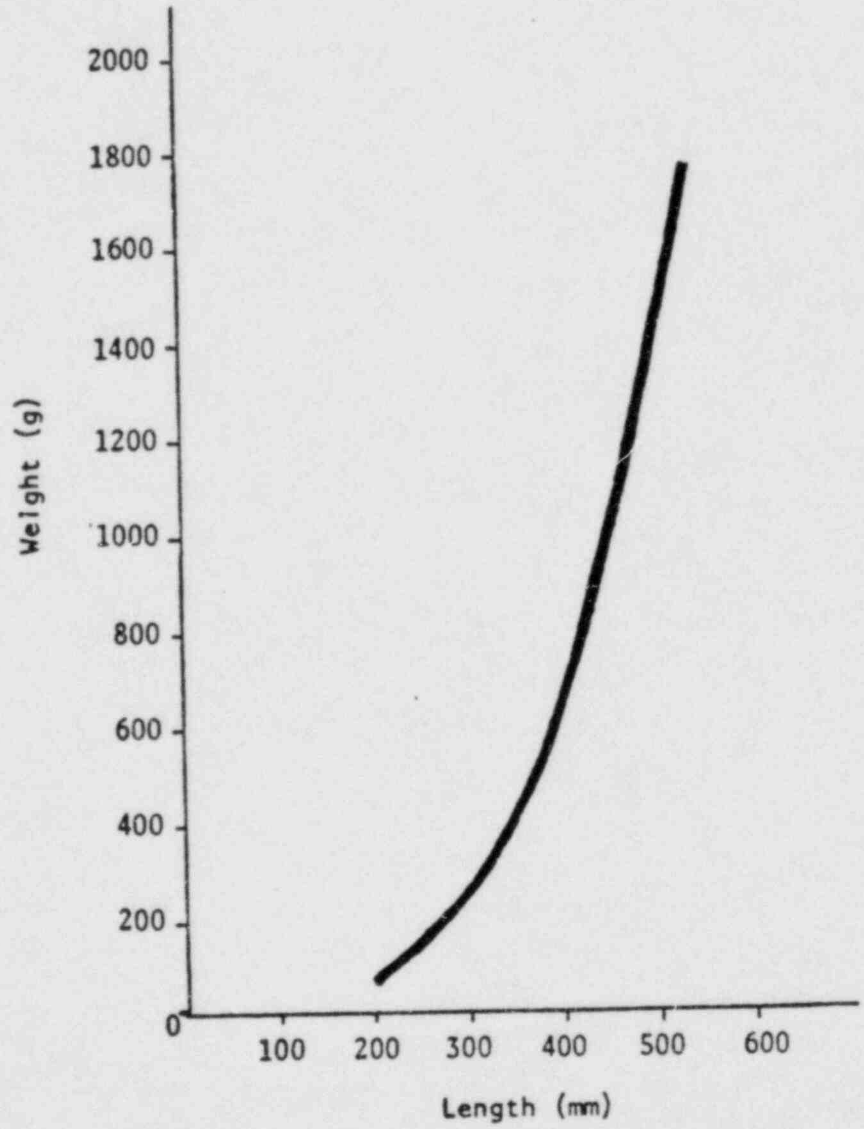


Figure 6. Graphical Representation of Length-Weight Relationships of Combined Sexes for the Clinch River Sauger

as a measure of condition with change in length. A value of 3 (weight varies with the cube of the length) would indicate that the form of the fish remained the same over the length range sampled. If the value should be below 3, a decrease in plumpness with change in length is shown; if the value is greater than 3, an increase in weight with increased length is indicated. The weight of sauger in the present study increased faster than the cube of the length.

A comparison of calculated fish weights at a given length from the Clinch River (present study), Norris Reservoir, Tennessee (Hassler, 1957); Lake of the Woods, Minnesota (Carlander, 1950); and Lewis and Clark Lake, South Dakota (W. Nelson, 1969) is presented in Table 7. In the lower length ranges, fish from the Clinch River were lighter than those from Lake of the Woods and Lewis and Clark Lake and heavier than the fish from Norris Reservoir. Sauger from the Clinch River, 300 mm in length or greater, were heavier than those from the other bodies of water.

Larval sauger began feeding before completion of yolk-sac absorption primarily on Cyclops at an average length of 9.5 mm with larger sauger utilizing Daphnia and Diaptomus in Lewis and Clark Lake, South Dakota (Nelson, 1968). Priegel (1969) found that sauger, 12 mm-75 mm, fed on Daphnia, Cyclops, Leptodora, and Diaptomus in Lake Winnebago, Wisconsin. As the sauger increased in size, chironomid larvae and pupae along with Baetis and Hexagenia nymphs became important food items in Lewis and Clark Lake (Nelson, 1968); young sauger in Lake Winnebago also utilized chironomid larvae (Priegel, 1969).

Adult sauger are primarily piscivorous but also feed on invertebrates. In the present study only 30% of the 189 sauger stomachs

Table 7. Calculated Weight of Total Length Groups of Saugers from Various Waters

Total Length (mm)	Calculated Weights (g)			
	Clinch River[1]	Norris Reservoir[2]	Lake of the Woods[3]	Lewis and Clark Lake[4]
50				1
100				7
150				25
200	57	52	65	62
250	124	111	127	123
300	234	208	219	216
350	400	347	355	349
400	636	544	533	528
450	958	802		761
500	1,383	1,142		1,055
550		1,559		1,413
600				1,858
650				2,381

[1]Present study

[2]Hassler, 1957

[3]Carlander, 1950, as cited by W. Nelson, 1969

[4]W. Nelson, 1969

examined contained food items (Table 8). Among the organisms which could be identified, threadfin shad was the predominant food item. Dorosoma sp., log perch, and a mayfly naiad also contributed to the diet of the Clinch River sauger. Dendy (1945) reported that gizzard shad were important forage fishes for sauger in Norris Reservoir, Tennessee; troutperch and freshwater drum were the predominant forage fishes of sauger in Lake Winnebago, Wisconsin (Priegel, 1969); and in Lewis and Clark Lake, South Dakota, emerald shiners and gizzard shad were the most important forage fishes (Nelson, 1968).

Fecundity estimates made on eight sauger collected in March, 1976, from the Clinch River are presented in Table 9. The average number of eggs produced by the sauger, which ranged in length from 340 mm to 531 mm and in weight from 408 g to 1860 g, was 69,625 eggs (27,300/454 g). Fecundity ranged from 22,000 eggs for a 304 mm, 408 g sauger to 117,000 eggs for a 459 mm, 1390 g fish. Hassler (1958) calculated the average fecundity for 14 sauger in Norris Reservoir, Tennessee, to be 41,139 (29,053/454 g) in fish 286 mm to 482 mm in length and 182 g to 1271 g in weight. The estimates varied from a low of 9,360 eggs for a 297 mm, 286 g fish to a high of 96,277 in a 482 mm, 1271 g sauger. The average egg production for 50 sauger (328 mm to 625 mm, and 272 g to 2043 g) from Garrison Reservoir, North Dakota, was 43,197 (26,260/454 g) with a low of 10,488 eggs in a 327 mm sauger and high of 152,110 eggs in a 546 mm fish (Carufel, 1963). W. Nelson (1969) examined sauger in Lewis and Clark Lake, South Dakota, which ranged in length from 374 mm to 627 mm and in weight from 440 g to 2550 g. Nelson found an average of 29,624 eggs/454 g in the sample which had a low estimate of 19,130 eggs and a high of 209,920 eggs. The average

Table 8. Food Items of Sauger Collected from the Clinch River below Melton Hill Dam, June, 1975, to April, 1976

Month	No. of Fish	% with Food	No. Food Items	Threadfin Shad	Unident. Shad	Unident. Fish	Log Perch	Mayfly Naiad
June	1	100	1					1 (100)*
July	0							
Aug.	1	0						
Sept.	2	50	1	1 (100)				
Oct.	0							
Nov.	3	33	2	2 (100)				
Dec.	28	46	20	6 (30)		14 (70)		
Jan.	11	100	36	9 (25)	11 (31)	16 (44)		
Feb.	32	50	24	7 (29)	1 (04)	16 (67)		
March	65	28	26	5 (19)		20 (77)	1 (04)	
April	46	13	8	2 (25)		5 (62)	1 (13)	
TOTAL	189	30	118	32 (27)	12 (10)	71 (60)	2 (02)	1 (01)

*Actual numbers of food items listed under heading with percentage of abundance in parenthesis

Table 9. Fecundity Estimates of Eight Sauger Collected from the Clinch River below Melton Hill Dam in March, 1976

Length (mm)	Weight (g)	Egg Production	Eggs/Pound (454 g) of Weight
340	408	22,000	24,500
391	620	36,000	26,400
422	830	41,000	22,400
459	1,390	117,000	38,200
465	1,240	91,000	33,300
484	1,190	83,000	31,700
524	1,780	101,000	25,800
531	1,860	66,000	16,100

number of eggs per ovary for 192 sauger, 256 mm to 371 mm in length, in Lake Winnebago, Wisconsin, was 15,871 eggs (Priegel, 1969). Fecundity estimates for the Clinch River sauger were lower than those found by W. Nelson and Hassler but higher than those reported by Carufel and Priegel.

Hassler (1958) found that both sexes were mature by age two in Norris Reservoir, Tennessee. Studies by Priegel (1969) in Lake Winnebago, Wisconsin, and by W. Nelson (1969) in Lewis and Clark Lake, South Dakota, also found that males matured at age two but that the maturation of females did not occur until ages four and three respectively.

Sauger are random spawners and do not build nests or give parental care to the young. In the gill net sample of April 17, 1976, 52 sauger (14 females, 33 males, and 9 immatures) were taken. Of the 14 females collected, 8 were gravid and 2 were spent; milt was easily extracted from males taken on this date. A number of males were found clustered in the nets around two of the gravid females indicating capture during the act of spawning. As stated in Chapter 2, the substrate of the Clinch River miles 12 to 15 consists largely of sand, silt, and lesser areas of shale. Water temperatures recorded from the Clinch River in April varied from 14.0 C at mile 15 west to 14.8 C at mile 12, and averaged 14.5 C.

where?

15 = 60°F

Haslbauer and Manges (1947) found both spent and mature sauger in spring collections in Norris Reservoir, Tennessee; however, extensive upstream movement of sauger appeared to indicate that spawning occurred in the running waters of the Clinch and Powell Rivers at the head of the reservoir. The 1945-46 spawning season in Norris Reservoir lasted several weeks to a month. In 1943, Cady (1945) reported that many sauger had not spawned as late as mid-March in Norris Reservoir. Eschmeyer and Smith (1943) found no evidence of sauger spawning below Norris Reservoir dam, when water temperatures were below 10 C. Large late winter and early spring spawning runs often concentrate sauger in the tailwaters of Tennessee reservoirs, where the sauger utilize riprap areas for spawning substrates (Etnier, 1973). Nelson (1968) found that sauger in Lewis and Clark Lake, South Dakota, migrate up the Missouri River to spawn in the tailwaters of Fort Randall Dam. In Garrison Reservoir, North Dakota, sauger spawn in both the reservoir and Garrison Dam tailwaters (Carufel, 1963). Priegel (1969) reported that most sauger in Lake Winnebago, Wisconsin, spawn on an 8-mile (12.8 km) stretch of shoreline on the northern side of the lake over a substrate of sand and fine gravel. In Canada, sauger spawn over gravel to rubble substrates in large turbid rivers and lakes (Scott and Crossman, 1973).

Males reach the spawning grounds first and are followed by the females which leave the area shortly after spawning (Scott and Crossman, 1973; Nelson, 1968). One or more smaller males usually attend a female in spawning activities which occur at night (Scott and Crossman, 1973).

In Lewis and Clark Lake, sauger began spawning toward the end of April when the water temperature was 5.6 C to 6.1 C and lasted for two weeks (Nelson, 1968). Sauger spawned from early May to late June in Garrison Reservoir when water temperatures varied from 3.9 C to 11.6 C (Carufel, 1963). Spawning occurred in Lake Winnebago over a 2-week period in late April and early May at temperatures of 6.1 C to 11.1 C (Priegel, 1969). Scott and Crossman (1973) reported that Canadian sauger spawn in late May and early June (water temperatures of 3.9 C to 6.1 C). Lab studies by Smith and Koenst (1975) found that 9 C to 15 C was the optimum temperature range for sauger egg fertilization.

Sauger eggs which range in size from 1.44 mm to 1.86 mm are initially adhesive, but after water hardening become nonadhesive and semibouyant (Priegel, 1969; Scott and Crossman, 1973); however, Nelson (1968) found that sauger eggs in Lewis and Clark Lake remained strongly adhesive even after water hardening. Scott and Crossman (1973) reported incubation periods of 25 to 29 days at 4.5 C to 12.8 C. Nelson (1968) found that sauger eggs hatch in 21 days at 8.4 C. Priegel (1969) stated sauger eggs incubate in 13 to 15 days at 10.5 C in a hatchery. Optimum incubation temperatures for sauger eggs were found by Smith and Koenst (1975) to range from 12 C to 15 C; at 12 C the sauger hatch began in 12 days and was concluded on the twenty-first day, and at 15 C incubation was completed in 9-13 days.

Larval sauger hatch at 4.5 mm to 6.2 mm in length. Yolk-sac absorption is completed in 7 to 9 days (Scott and Crossman, 1973). Smith and Koenst (1975) found that survival of hatched fry is best at 9 C to 21 C until the yolk-sac is absorbed; thereafter, until the juvenile stage is reached, 21 C is the preferred temperature.

Four studies on larval fish in the Clinch River miles 1-51 (km 1.6-81.6) conducted from 1974 to 1976 yielded only six Stizostedion sp. larvae. Project Management Corp. (1975) collected one Stizostedion sp. at CRM 15-18 on March 28, 1974; TVA (1976b) took two larvae near Bullrun Steam Plant in 1975, one on April 30 and the other on May 14; TVA (1976c) found two larvae near the Kingston Steam Plant in 1975, the first on April 9 and the second on April 23. One post larval

Stizostedion sp., 8.8 mm in length was taken on April 9, 1976, at CRM 12 in supplementary tows of the present study (water temperature 15 C). Nelson (1968) captured a number of larval sauger from the Missouri River and Lewis and Clark Lake. The larvae averaged 6.38 mm in length; larvae captured in the reservoir usually exceeded 8.5 mm, the smallest being 7.79 mm.

It is probable that the spawning period extends from mid-March until early May for the Clinch River sauger; and that the headwaters of Watts Bar, Melton Hill, and Norris Reservoirs are utilized by sauger for spawning sites.

CLINCH RIVER LARVAL FISH

A total of 135 larval tows were made from May, 1975, through September, 1975. Fifty-eight percent of the tows contained larval fish. Nine genera and five species from six families were collected (Table 10). The dates of earliest and latest collection of each taxon, as well as numbers, weights, and lengths of the larval fish are presented in Table 11. The catch distribution of the 2,328 larval fish is shown in Figure 7. Clupeidae were the dominant larval fish at 90% of the total number and 76% of the total weight; white crappie at 9% of the total number and 18% of the total weight was the second most abundant larval fish.

In addition to the present research, three larval fish studies were conducted by TVA in the vicinity of the NFRRC site in 1975. Eight families of larval fish were represented in the samples from Melton Hill (TVA, 1976b), five families at CRM 15-18 (TVA, 1976a), six families at CRM 12-15 in the present (NFRRC) preconstruction study, and nine

Table 10. A List of Larval Fishes Collected in the Clinch River below Melton Hill Dam, May through September, 1975

Common Name	Scientific Name
	Family - Clupeidae
Shad	Clupeidae
	Family - Cyprinidae
Carp	*Cyprinus carpio* Linnaeus
Shiner	*Notropis* sp.
Bluntnose minnow	*Pimephales notatus* (Rafinesque)
	Family - Catostomidae
Redhorse	*Moxostoma* sp.
	Family - Ictaluridae
Channel catfish	*Ictalurus punctatus* (Rafinesque)
	Family - Atherinidae
Brook silversides	*Labidesthes sicculus* (Cope)
	Family - Centrarchidae
Sunfish	*Lepomis* sp.
Black bass	*Micropterus* sp.
White crappie	*Pomoxis annularis* Rafinesque

Table 11. Larval Fish Found in the Clinch River below Melton Hill Dam, May through September, 1975*

Taxa	Date of Collection (Month/Day) Earliest	Latest	No.	% No.	Wt.	% Wt.	Mean Length	Length Range
Clupeidae	5-17	8-29	2,089	89.73	4.5382	75.94	8.84	4.5-22.0
Cyprinus carpio	8-29	8-29	2	0.09	0.0111	0.19	10.25	8.5-12.0
Notropis sp.	5-30	5-30	3	0.13	0.0051	0.09	6.66	6.0-7.0
Pimephales notatus	7-10	7-10	1	0.04	0.0505	0.85	16.00	-
Moxostoma sp.	5-30	5-30	2	0.09	0.0017	0.03	6.50	-
Ictalurus punctatus	7-10	7-10	1	0.04	0.0357	0.60	13.00	-
Labidesthes sicculus	8-29	8-29	1	0.04	0.0653	1.09	23.50	-
Lepomis sp.	5-30	8-12	16	0.69	0.1336	2.24	10.91	5.0-13.0
Micropterus sp.	6-15	6-15	1	0.04	0.0878	1.47	20.00	-
Pomoxis annularis	5-30	7-25	212	9.11	1.0468	17.52	7.44	4.0-16.0
			2,328		5.9758			

*Weights expressed in grams; lengths expressed in mm

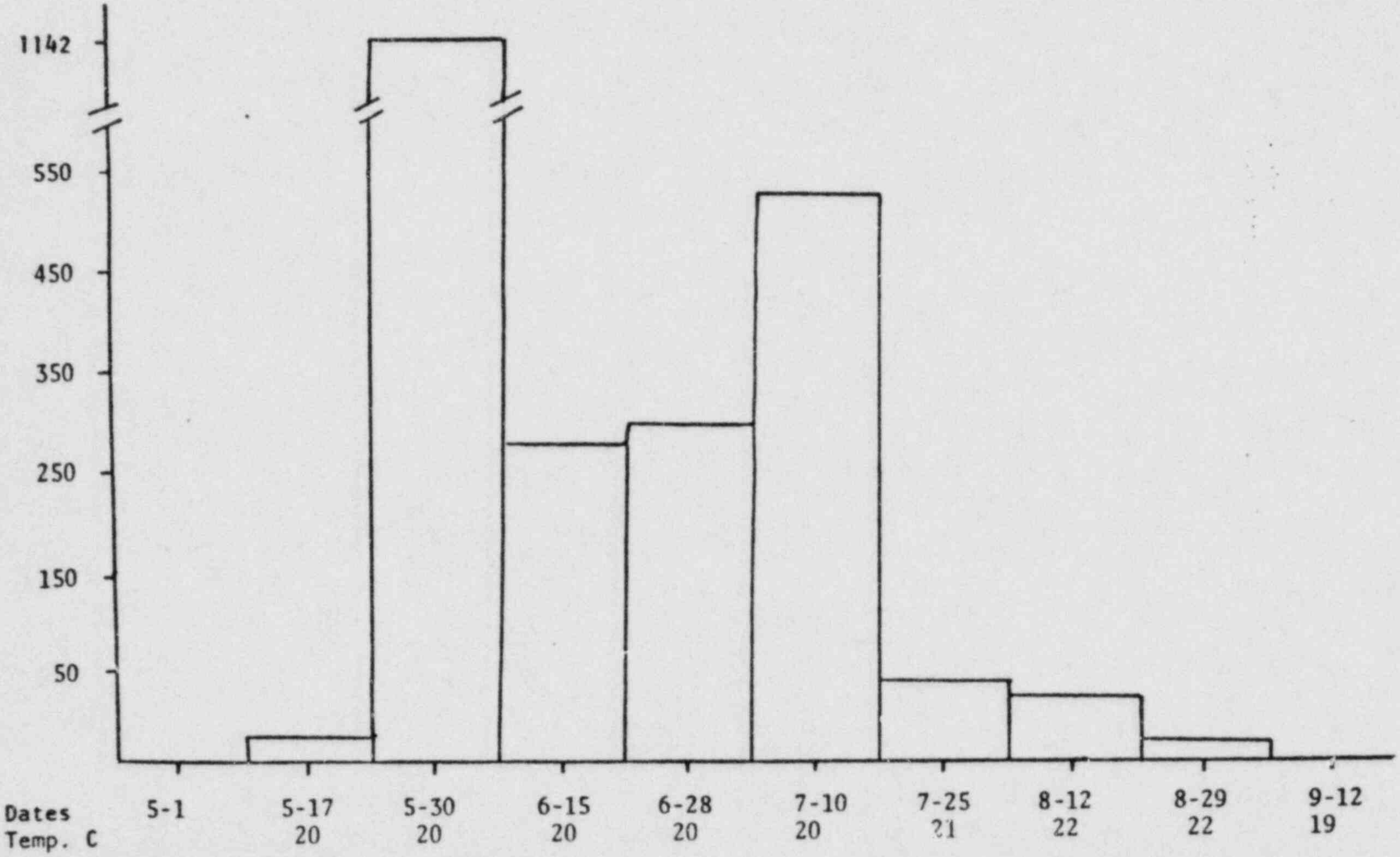


Figure 7. Catch Distribution of Larval Fish Collections in the Clinch River below Melton Hill Dam, May through September, 1975

families from near the Kingston Steam Plant (TVA, 1976c). Clupeidae was the dominant family of larval fish found by these studies with density values ranging from 77% near the Bull Run Steam Plant in the upper reaches of Melton Hill Reservoir (TVA, 1976b) to 92% in the Kingston Steam Plant area of Watts Bar Reservoir (TVA, 1976c). Larval fish taken during the 1975 season appeared at peak densities in Melton Hill, May 29 (TVA, 1976b); the present research (NFRRC), CRM 12-15, May 30; and in the Kingston Steam Plant area, June 4 (TVA, 1976c).

One of the principal concerns of larval fish research is that of hydraulic entrainment. The NFRRC water intake structure to be built at CRM 14.4 is not expected to adversely affect the fisheries of the study area as a result of larval fish entrainment. The degree of entrainment is proportional to the volume of water withdrawn and the concentration of the larvae within this volume. The normal operational withdraw of water from the Clinch River will be approximately 5.9 m^3/minute which amounts to about 0.07% of the annual average flow of the Clinch River at 8,600 m^3/minute (Exxon Nuclear Co., 1976). Utilizing push, vertical, and yoyo larval tows, TVA (1976a) found that the average, 1975, larval fish concentration at CRM 16 was 427.21/1000m^3. Assuming uniform distribution of the larval fish in the water column, entrainment would equal the volume of water withdrawn from the Clinch River, 0.07%. Larval fish that are entrained would be subject to 100% mortality due to the stresses of filtration, thermal and pressure changes, abrasion, biocides, and corrosion inhibitors they would encounter (Exxon Nuclear Co., 1976).

FISHES OF GRASSY AND BEAR CREEKS

The NFRRC study of Grassy and Bear Creeks in 1975 was the first intensive study conducted on these creeks. Cumulative lists of the fish found in Grassy and Bear Creeks are presented in Tables 12 and 13 respectively. Information concerning the numbers and relative abundance of the fish collected from Grassy and Bear Creeks may be found in Tables 6 through 10 in Appendix A.

Fifteen species from six families were found in Grassy Creek. The bluegill was the most abundant game fish in Grassy Creek; the bluntnose minnow was the dominant forage fish; and the white sucker was the most abundant rough fish. Seventeen species from six families were collected in Bear Creek. Among the eight cyprinids found in Bear Creek, one is an undescribed subspecies of Phoxinus oreas, the mountain redbelly dace (Starnes, personal communication, 1977). According to Etnier (1973), this fish has a limited distribution within the state of Tennessee. The dominant game fish in Bear Creek was the rock bass; the common shiner was the most abundant forage fish; and the white sucker was the dominant rough fish. In assessing changes which may occur in the fish populations of these two creeks, the appearance or abundance of the members of the Cyprinidae, Percidae, and Cottidae families should be monitored.

Table 12. A List of the Fishes Collected in Grassy Creek October, 1975, through April, 1976

Common Name	Scientific Name
	Family - Cyprinidae
Stoneroller	Campostoma anomalum (Rafinesque)
Common shiner	Notropis cornutus (Mitchill)
Spotfin shiner	Notropis spilopterus (Cope)
Bluntnose minnow	Pimephales notatus (Rafinesque)
Blacknose dace	Rhinichthys atratulas (Hermann)
Creek chub	Semotilus atromaculatus (Mitchill)
	Family - Catostomidae
White sucker	Catostomus commersoni (Lacepede)
	Family - Ictaluridae
Yellow bullhead	Ictalurus natalis (LeSueur)
	Family - Centrarchidae
Redbreast sunfish	Lepomis auritus (Linnaeus)
Bluegill	Lepomis macrochirus Rafinesque
Longear sunfish	Lepomis megalotis (Rafinesque)
Spotted bass	Micropterus punctulatus (Rafinesque)
	Family - Percidae
Tennessee snubnose darter	Etheostoma simoterum (Cope)
Logperch	Percina caprodes (Rafinesque)
	Family - Cottidae
Banded sculpin	Cottus carolinae (Gill)

Table 13. A List of the Fishes Collected in Bear Creek September, 1975, through April, 1976

Common Name	Scientific Name
	Family - Cyprinidae
Stoneroller	Campostoma anomalum (Rafinesque)
Rosefin shiner	Notropis ardens (Cope)
Emerald shiner	Notropis atherinoides Rafinesque
Common shiner	Notropis cornutus (Mitchill)
Bluntnose minnow	Pimephales notatus (Rafinesque)
Redbelly dace	Phoxinus oreas sp.
Blacknose dace	Rhinichthys atratulas (Hermann)
Creek chub	Semotilus atromaculatus (Mitchill)
	Family - Catostomidae
White sucker	Catostomus commersoni (Lacepede)
Northern hog sucker	Hypentelium nigricans (LeSueur)
Golden redhorse	Moxostrom erythrurum (Rafinesque)
	Family - Poeciliidae
Mosquitofish	Gambusia affinis (Baird and Girard)
	Family - Centrarchidae
Rock bass	Ambloplites rupestris (Rafinesque)
Bluegill	Lepomis macrochirus Rafinesque
	Family - Percidae
Stripetail darter	Etheostoma kennicotti (Putnam)
Tennessee snubnose darter	Etheostoma simoterum (Cope)
	Family - Cottidae
Banded sculpin	Cottus carolinae (Gill)

Chapter 5

SUMMARY AND CONCLUSIONS

1. Fifty species of fish and two hybrids from 14 families were collected from the Clinch River, mile 12-15.

2. The community was dominated by 21 species of rough (42%); 16 species of game fish (32%); and 13 species of forage fish (26%).

3. The bulk of the catch was comprised of six species: gizzard shad, threadfin shad, carp, skipjack herring, bluegill, and sauger.

4. Generally, it appears that forage fish dominated the community in terms of numbers while rough fish contributed the greatest percentage of biomass.

5. Threadfin shad were the most numerous of the total number of fish; carp accounted for the greatest total weight; and bluegill were the most abundant game fish.

6. Sauger was the second most abundant game fish, and represented the second highest percentage of the total biomass taken.

7. Sauger in the present study ranged in length from 214 mm to 535 mm and in weight from 78 g to 1860 g.

8. Growth rates of sauger in the Clinch River were faster than those found in northern waters; generally, similar to growth rates in the Tennessee Valley; and initially faster but slower by age classes 3-5 than those of western sauger.

9. The largest sauger, a female, weighed 4.1 pounds (1860 g);

the largest male weighed 2.7 pounds (1220 g).

10. The length-weight relationships of 278 sauger (combined sexes) yielded the equation:

$$\text{Log } W = -6.249 + 3.479 \log L.$$

The weight of sauger in the present study increased faster than the cube of the length.

11. Threadfin shad was the dominant food item of Clinch River sauger. Dorosoma sp., logperch, and a mayfly also contributed to the diet.

12. Fecundity estimates were made on eight sauger. An average of 69,625 eggs per fish and 27,300 eggs per 454 g of fish weight was found.

13. Eight gravid and two spent sauger females were taken in collections made on April 17, 1976 (water temperature averaged 14.5 C). Milt was easily extracted from males collected on this date. A number of males was found clustered in the nets around two of the gravid females indicating capture during the act of spawning.

14. One postlarval Stizostedion sp., 8.8 mm in length, was taken on April 9, 1976, at CRM 12.0 in the supplementary tows of the present study (water temperature, 15 C).

15. It is probable that the spawning period extends from mid-March until early May for the Clinch River sauger; and that the headwaters of Watts Bar, Melton Hill, and Norris Reservoirs are utilized by sauger for spawning sites.

16. Nine genera of larval fish from six families were taken in collections from May through September, 1975.

17. Clupeidae were the dominant larvae at 90% of the total number.

18. Peak larval fish densities occurred on May 30, 1975, when 1172 fish were taken.

19. The NFRRC water intake structure to be built at CRM 14.4 is not expected to adversely affect the fisheries of the study area as a result of larval fish entrainment. An entrainment value of 0.07% was arrived at based on the average NFRRC withdrawal and average annual flow of the Clinch River.

20. Fifteen species from six families were found in Grassy Creek. The bluntnose minnow was the dominant species.

21. Seventeen species from six families were collected in Bear Creek. The common shiner was the most abundant species. Among the cyprinids found, one is an undescribed subspecies of Phoxinus oreas, the mountain redbelly dace (Starnes, personal communication, 1977).

22. The appearance or abundance of members of the Cyprinidae, Percidae, and Cottidae families should be monitored in assessing any changes which may occur in the fish populations of these creeks.

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APPENDIX A

Table 1. Number, Weights and Relative Abundance of Fish Collected at CRM 12.0 in 1975 and 1976

	May				June-August				September-November				December-February				March-April			
	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.
GAME																				
Rock bass									2	0.75	33	0.05	1	0.69	7	0.02				
Redbreast sunfish	1	1.37	197	0.51																
Bluegill					5	4.90	295	0.76	54	20.45	841	1.66	6	4.17	84	0.24	5	4.13	97	0.20
Spotted bass									1	0.38	9	0.02								
Largemouth bass									6	2.27	3607	7.12	2	1.39	270	0.81	3	2.48	337	0.78
White crappie									1	0.38	259	0.50	1	0.69	158	0.46				
Black crappie									1	0.38	30	0.06								
White bass	4	5.48	1015	2.64	2	1.96	300	0.77	6	2.27	1171	7.61	8	5.56	1979	5.75	1	0.83	548	1.27
Yellow bass	1	1.37	120	0.31	1	0.98	125	0.32	1	0.38	130	0.26					2	1.65	131	0.35
Striped bass					2	1.96	556	1.43												
Sauger	5	6.85	3143	8.16	4	3.92	2506	6.46	6	2.27	3523	6.96	28	19.44	19025	55.25	15	12.40	12180	28.22
Walleye	1	1.37	1060	2.75																
FORAGE																				
Gizzard shad	14	19.18	3177	8.25	20	19.61	2603	6.71	22	8.33	4876	9.63	12	8.33	2287	6.64	4	3.31	990	2.29
Threadfin shad	10	13.70	1082	2.81	18	17.65	1402	3.61	19	7.20	375	0.74	23	15.97	403	1.17	5	4.13	194	0.45
Banded sculpin									2	0.76	25	0.05					2	1.65	16	0.04
Silver chub									6	2.27	84	0.17	1	0.69	20	0.06	1	0.83	4	0.01
Golden shiner													2	1.39	2	0.01				
Emerald shiner									21	7.95	114	0.23	9	6.25	61	0.18	10	8.26	33	0.08
Spotfin shiner									1	0.38	4	0.01								
Bluntnose minnow					2	1.96	--	--	17	6.44	20	0.04	6	4.17	13	0.04				
Bullhead minnow									50	18.94	95	0.19	29	20.14	75	0.22	41	33.88	77	0.18
ROUGH																				
River carpsucker									2	0.76	2590	5.11								
Quillback carpsucker	1	1.37	600	1.56	2	1.96	1142	2.94	1	0.38	480	0.95								
Hog sucker																	1	0.83	138	0.32
Smallmouth buffalo					4	3.92	4840	12.47	4	1.52	6215	12.27					2	1.65	5100	11.82
Bigmouth buffalo	1	1.37	1500	3.90																
Black buffalo					1	0.98	1380	3.55												
Spotted sucker									2	0.76	440	0.87								
River redhorse									1	0.38	646	1.28								
Golden redhorse	12	16.44	7600	19.74					3	1.14	1444	2.85	1	0.69	827	2.40				
Skipjack herring	6	8.22	2870	7.45	11	1.08	2840	7.32	17	6.44	6974	13.77	8	5.56	4760	13.82	25	20.66	19190	47.15
Carp	8	10.96	11305	29.36	17	16.67	15367	39.64	4	1.52	3860	7.62	1	0.69	920	2.67	3	2.48	4200	9.73
Mirror carp	1	1.37	620	1.61																
Mooneye	1	1.37	205	0.53	8	7.84	2075	5.35	5	1.89	1305	2.58								
Channel catfish	3	4.11	931	2.42	1	0.98	1000	2.58	7	2.65	8320	16.43	6	4.17	3537	10.27				
Spotted gar	1	1.37	1120	2.91																
Longnose gar	2	2.74	1860	4.83	1	0.98	1940	5.00	1	0.38	450	0.89					1	0.83	930	2.16
Paddlefish									1	0.38	2540	5.02								
Freshwater drum	1	1.37	103	0.27	3	2.94	420	1.08												

Relative Abundance in Number, CRM 12.0, 1975-76: 25.71% rough, 25.00% game, 49.29% forage.
Relative Abundance in Weight CRM 12.0, 1975-76: 65.00% rough, 26.23% game, 8.77% forage.
Relative Abundance in Species CRM 12.0, 1975-76: 46.15% rough, 30.77% game, 23.08% forage.

Values	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.
Rough	37	50.68	28715	74.57	48	47.06	31024	79.97	48	18.18	35261	69.64	16	11.11	10044	29.17	32	26.45	28554	66.18
Game	12	16.44	5535	14.37	14	13.73	3790	9.76	78	29.55	9782	19.31	46	31.94	21532	62.53	26	21.49	13283	30.78
Forage	24	32.88	4259	11.06	40	39.22	4005	10.27	138	51.14	5594	11.05	82	56.94	2861	8.31	63	52.07	1314	3.04
	73		38510		102		38819		264		50637		144		34437		121		43155	

Values	Total No. of Species	% Total No. of Species	Total No. of Species	% Total No. of Species	Total No. of Species	% Total No. of Species	Total No. of Species	% Total No. of Species	Total No. of Species	% Total No. of Species
Rough	11	61.11	9	52.94	12	41.38	4	23.53	5	31.25
Game	5	27.78	5	29.41	9	31.03	6	35.29	5	31.25
Forage	2	11.11	3	17.65	8	27.59	7	41.18	6	37.50

* Weights expressed in grams, abundance expressed in percentages.

Table 2. Number, Weights and Relative Abundance of Fish Collected at CRM 14.4 in 1975 and 1976

	May				June-August				September-November				December-February				March-April			
	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.
GAME																				
Rock bass					8	4.59	312	0.69	5	1.85	126	0.29	1	0.17	35	0.07				
Redbreast sunfish					6	5.17	501	1.11	2	0.74	24	0.06								
Warmouth													1	0.17	23	0.05				
Bluegill					11	9.48	782	1.73	23	8.49	682	1.57	56	9.55	998	1.99	18	6.92	341	0.47
Longear sunfish													1	0.17	67	0.13				
Redear sunfish					1	0.86	318	0.06												
Spotted bass									6	2.21	184	0.42	4	0.67	96	0.19	2	0.77	49	0.07
Largemouth bass	1	1.41	720	2.36					1	0.37	53	0.21	9	1.52	2173	4.36	9	3.46	1560	2.13
White crappie					2	1.72	271	0.60	5	1.85	353	0.71	3	0.51	155	0.31				
Black crappie									1	0.37	219	0.50								
White bass	2	2.82	203	0.66	1	0.86	132	0.29	7	2.58	2112	4.91	3	0.51	977	1.96	5	1.92	969	1.33
Yellow bass					1	0.86	162	0.36	3	1.11	160	0.37					3	1.15	400	0.55
Striped bass					1	0.86	800	1.77									2	0.77	4250	5.81
Sauger	3	4.23	1800	5.92	2	1.72	1538	3.40	7	2.58	4583	10.38	19	3.20	15405	30.91	39	15.00	23465	32.10
Sauger X Walleye					1	0.86	2809	6.17												
FORAGE																				
Brook Silverside					3	2.59	-	-	6	2.21	8	0.02	4	0.67	10	0.02				
Gizzard shad	21	29.58	5127	16.77	34	29.31	7881	17.45	35	12.92	5647	13.02	27	4.55	3760	7.54	26	10.00	3618	4.98
Threadfin shad	5	7.04	440	1.44	5	4.31	419	0.93	95	35.06	2917	6.77	414	69.70	5547	11.13	73	28.08	2616	3.58
Banded sculpin									2	0.74	25	0.06								
Emerald shiner					2	1.72	8	0.02	12	4.43	93	0.21	20	3.37	160	0.32	25	9.62	139	0.19
Spotfin shiner					1	0.86	4	0.01									1	0.38	4	0.01
Bluntnose minnow					1	0.86	-	-	2	0.74	1	-					2	0.77	4	0.01
Bullhead minnow									3	1.11	4	-	9	1.52	19	0.04	2	0.77	4	0.01
Logperch									3	1.11	40	0.11					1	0.38	12	0.02
ROUGH																				
River carpsucker					1	0.86	1000	2.39	1	0.37	2750	6.38								
Quillback carpsucker	3	6.23	2127	6.96	5	4.31	5249	11.63	3	1.11	2505	5.77	1	0.17	990	1.99				
White sucker													1	0.17	448	0.90				
Smallmouth buffalo					3	2.59	4310	9.56									1	0.38	1588	2.16
Black buffalo									1	0.37	1860	4.29								
Spotted sucker																	1	0.38	178	0.24
Silver redhorse					2	1.72	3430	7.59	1	0.37	1800	4.15								
Black redhorse					1	0.86	618	1.37												
Golden redhorse	5	7.04	2971	9.73	3	2.59	1810	4.01	3	1.11	2136	4.92	1	0.17	1670	3.35	1	0.38	735	1.01
Skipjack herring	9	12.68	6289	20.58	3	2.59	695	1.54	20	7.38	6496	14.97	16	2.69	8928	17.93	38	14.62	29152	39.89
Carp	19	26.76	9480	31.01	13	11.21	10006	22.32	7	2.58	5752	13.26	7	1.18	7940	15.93	5	1.92	3010	4.12
Mirror carp	1	1.41	159	0.52													1	0.38	580	0.79
[illegible]					3	2.59	770	1.70	6	2.21	1495	3.45								
Channel catfish	2	2.82	1240	4.06	2	1.72	1224	2.71					2	0.34	435	0.87				
Freshwater drum									11	4.06	1396	3.22					5	1.92	625	0.86

Relative Abundance in Number, CRM 14.4, 1975-76: 15.85% rough, 20.58% game, 63.58% forage.
Relative Abundance in Weight, CRM 14.4, 1975-76: 55.17% rough, 29.20% game, 15.04% forage.
Relative Abundance in Species, CRM 14.4, 1975-76: 39.47% rough, 36.84% game, 23.68% forage.

Value	May				June-August				September-November				December-February				March-April			
	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.
Rough	38	54.93	22268	72.65	36	31.03	29290	61.80	53	19.56	26141	60.37	28	4.71	20421	40.97	52	20.00	35860	49.06
Game	6	8.45	2731	8.33	34	29.31	7588	16.78	60	22.14	8429	19.43	92	15.49	19923	39.97	78	30.00	31032	42.46
Forage	26	36.62	5567	16.21	46	39.66	8314	18.40	158	58.30	8763	20.20	474	79.80	9496	19.05	130	50.00	6197	8.48
	71		30566		116		45102		271		43383		594		49840		260		73089	

Value	Total No. of Species	% Total No. of Species	Total No. of Species	% Total No. of Species	Total No. of Species	% Total No. of Species	Total No. of Species	% Total No. of Species	Total No. of Species	% Total No. of Species
Rough	6	54.54	10	38.46	9	33.33	6	30.00	7	33.33
Game	3	27.27	10	38.46	10	37.04	9	45.00	7	33.33
Forage	2	18.18	6	23.08	8	29.63	5	25.00	7	33.33

* Weights expressed in grams; abundances expressed in percentages.

Table 3. Number, Weights and Relative Abundance of Fish Collected at Grassy Creek Embayment in 1975 and 1976

	[illegible]				[illegible]				September-November				December-February				March-April			
	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.
GAME																				
Rock bass																	1	0.51	11	0.12
Redbreast sunfish									1	0.27	1	-								
Warmouth									1	0.27	79	0.22					2	1.01	91	0.??
Bluegill	5	17.86	171	2.69					152	41.76	1724	4.72	44	7.60	899	1.69	32	16.16	541	5.[illegible]
Redear sunfish									4	1.10	144	0.50								
Spotted bass									12	3.30	124	0.34	11	1.93	106	0.25	3	1.52	72	0.69
Largemouth bass	5	17.86	1516	23.75					5	1.37	444	1.22					5	2.53	78	0.75
White crappie									17	4.67	1152	3.16	30	5.24	1034	1.95	2	1.01	136	1.30
Black crappie									6	1.65	352	0.96								
White bass									1	0.27	35	0.10	1	0.17	23	0.04				
Yellow bass									2	0.55	330	0.90								
Sauger	1	3.57	330	5.17					3	0.82	983	2.69					1	0.51	960	9.20
FORAGE																				
Brook silverside									30	8.24	34	0.09	43	7.50	56	0.11	13	6.57	16	0.15
Gizzard shad	11	39.29	710	11.13					17	4.67	2744	7.52	53	9.25	4447	8.38	13	6.57	2124	20.36
Threadfin shad	1	3.57	26	0.41					25	6.87	806	2.21	250	43.63	2563	4.83	52	26.26	753	7.43
Golden shiner																	2	1.01	7	0.[illegible]
Emerald shiner									8	2.20	65	0.18	28	4.89	155	0.29	8	4.04	40	0.38
Spotfin shiner									4	1.10	5	0.01	8	1.40	4	-	7	3.54	10	0.10
Bluntnose minnow													12	2.09	32	0.06	19	9.60	53	0.51
Bullhead minnow									25	6.87	36	0.10	[illegible]	0.73	81	0.15	32	16.16	78	0.[illegible]
Logperch									5	1.37	36	0.10								
ROUGH																				
Smallmouth buffalo													1	0.17	362	0.68				
Spotted sucker									1	0.27	287	0.79								
Silver redhorse													2	0.35	26	0.05				
Golden redhorse									4	1.10	1066	2.92	1	0.17	643	1.21	1	0.51	710	6.80
Skipjack herring									2	0.55	409	1.12								
Carp	5	17.86	3630	56.86					20	5.49	18860	51.68	33	5.76	34722	65.46	3	1.52	2800	26.84
Channel catfish									1	0.27	300	0.82					1	0.51	1060	10.16
Spotted gar									7	1.92	4290	11.76	6	1.05	7810	14.72	1	0.51	860	8.24
Longnose gar									2	0.55	660	1.81								
Freshwater drum									9	2.47	1478	4.05								

Relative Abundance in Numbers, Grassy Creek 0.4, 1975-76: 8.60 rough, 29.84 game, 61.56 forage.
Relative Abundance in Weight, Grassy Creek 0.4, 1975-76: 75.20 rough, 10.77 game, 14.03 forage.
Relative Abundance in Species, Grassy Creek 0.4, 1975-76: 32.26 rough, 38.71 game, 29.03 forage.

Value	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.
Rough	5	17.86	3630	56.86					46	12.64	27358	74.97	43	7.50	43560	82.13	6	3.03	5430	52.04
Game	11	39.29	2018	31.61					204	56.04	5408	14.82	86	15.01	2142	4.04	46	23.23	1883	18.05
Forage	12	42.86	736	11.53					114	31.32	3726	10.21	444	77.49	7339	13.83	146	73.74	3121	29.91
	28		6384						364		36492		573		53040		198		10434	

	Total No. of species	% Total No. of species	Total No. of species	% Total No. of species	Total No. of species	% Total No. of species	Total No. of species	% Total No. of species	Total No. of species	% Total No. of species
Rough	1	16.66			8	30.77	5	31.25	4	21.05
Game	3	50.00			11	42.31	4	25.00	7	36.84
Forage	2	33.33			7	26.92	7	43.75	8	42.11

* Weights expressed in grams; abundances expressed in percentages.

Table 4. Number, Weights and Relative Abundance of Fish Collected at CRM 15.0 East in 1975 and 1976

	May				[illegible]				[illegible]				[illegible]				March-April			
	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.
GAME																				
Rock bass					1	0.81	40	0.15	3	0.78	191	0.36					1	0.50	14	0.03
Bluegill	3	3.80	450	1.45	7	5.65	678	2.41	25	6.45	1170	1.95	11	6.25	242	0.43	6	2.99	314	0.37
Smallmouth bass					1	0.81	31	0.09	2	0.52	61	0.17								
Spotted bass													3	1.70	1041	1.26	1	0.50	3	-
Largemouth bass					2	1.61	898	1.97	1	0.26	368	1.20	3	1.70	121	0.21	3	1.49	300	0.36
White crappie					2	1.61	237	0.55	1	0.26	230	0.76								
White bass	2	2.53	630	2.06	1	0.81	676	2.41	5	1.29	2212	7.46					1	0.50	290	0.31
Yellow bass					1	0.81	70	0.20	1	0.26	93	0.31					3	1.49	460	0.64
Striped bass																	1	0.50	6360	7.49
Striped bass x white bass					1	0.81	132	0.52												
Sauger	21	26.58	11215	36.06	2	1.61	355	1.41	6	1.55	3365	11.25	20	11.36	15781	27.91	39	19.40	26018	30.90
FORAGE																				
Brook silverside									2	0.52	3	0.01	3	1.70	3	0.01	1	0.50	1	-
Gizzard shad	12	15.19	3070	9.87	29	23.38	5602	21.01	9	2.33	2010	6.70	8	4.55	1392	2.46	9	4.48	1751	2.08
Threadfin shad	14	17.72	940	3.02	49	39.51	3487	13.83	270	69.77	5090	16.87	30	17.05	1186	2.10	26	12.94	1017	1.21
Banded sculpin									2	0.52	12	0.04								
Silver chub									1	0.26	10	0.06	4	2.27	33	0.06	4	1.99	14	0.02
Emerald shiner					1	0.81	3	0.01	12	3.10	85	0.29	38	21.59	251	0.44	17	8.46	117	0.14
Spotfin shiner					1	0.81	5	0.02					2	1.14	3	0.01				
Bluntnose minnow					2	1.61	-	-	2	0.52	3	0.01	1	0.57	1	-				
Bullhead minnow									8	2.07	10	0.03	17	9.66	43	0.08	35	17.41	74	0.09
Logperch									3	0.78	45	0.15								
ROUGH																				
Quillback carpsucker	4	5.06	3632	11.68	1	0.81	940	3.73	1	0.26	1300	4.39	3	1.70	3680	6.51	3	1.49	3662	4.35
Hog sucker																	1	0.50	332	0.39
Smallmouth buffalo																	1	0.50	5300	6.39
Black buffalo									1	0.26	1300	4.38								
Spotted sucker					[illegible]	0.81	359	1.42												
Silver redhorse	1	1.27	530	1.70	1	0.81	1320	5.24												
River redhorse					1	0.81	720	2.85	4	1.03	2265	7.64								
Black redhorse					1	0.81	228	0.90									1	0.50	648	0.77
Golden redhorse	4	5.06	1646	5.29	5	4.03	2600	10.31												
Skipjack herring	13	16.46	6140	19.74	3	2.41	725	2.88	13	3.36	3261	11.00	13	7.39	7696	13.61	45	22.39	34954	41.58
Carp	1	1.27	908	2.92	4	3.22	3380	13.41	6	1.55	5697	19.21	18	10.23	22647	40.05	3	1.49	2630	3.12
Mirror carp													1	0.57	1300	2.30				
[illegible]					4	3.22	961	3.73												
Channel catfish	2	2.53	1310	4.21	1	0.81	1120	4.44	1	0.26	631	2.13	1	0.57	320	0.57				
Flathead catfish	1	1.27	520	1.67																
Spotted gar					1	0.81	850	3.37												
Freshwater drum	1	1.27	110	0.35	1	0.81	94	0.37	5	1.29	475	1.60								

Relative Abundance in Numbers, CRM 15.0 East, 1975-76: 17.79% rough, 18.92% game, 63.29% forage.
Relative Abundance in Weights, CRM 15.0 East, 1975-76: 55.70% rough, 32.66% game, 11.64% forage.
Relative Abundance in Species, CRM 15.0 East, 1975-76: 44.74% rough, 28.95% game, 26.32% forage.

Value	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.
Rough	27	34.18	14796	47.57	24	19.36	13286	52.71	31	8.01	14869	50.15	36	20.45	35643	63.04	54	26.87	47646	56.61
Game	26	32.91	12295	39.53	18	14.51	2624	10.41	47	12.15	7580	25.58	37	21.02	17984	31.81	55	27.36	33541	39.85
Forage	26	32.91	4010	12.89	82	66.13	9297	36.88	309	79.85	7186	24.24	103	58.52	2912	5.15	92	45.77	2976	3.54
	79		31101		124		25207		387		29643		176		56540		201		84163	

Value	Total No. of Species	% Total No. of Species	Total No. of Species	% Total No. of Species	Total No. of Species	% Total No. of Species	Total No. of Species	% Total No. of Species	Total No. of Species	% Total No. of Species
Rough	8	61.54	12	46.15	7	29.17	5	29.41	6	30.00
Game	3	23.08	9	34.62	8	33.33	4	23.53	8	40.00
Forage	2	15.38	5	19.23	9	37.50	8	47.06	6	30.00

* Weights expressed in grams; abundances expressed in percentages.

Table 5. Number, Weights and Relative Abundance of Fish Collected at CRM 15.0 West in 1975 and 1976

	May				June-August				September-November				December-February				March-April			
	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.
GAME																				
Rock bass									4	0.89	73	0.24	3	0.56	38	0.12	1	0.95	178	0.41
Redbreast sunfish									1	0.22	32	0.10								
Bluegill									23	5.11	1410	4.62	24	4.47	889	2.82	14	13.33	592	1.37
Spotted bass									3	0.67	61	0.20	1	0.19	2	0.01				
Largemouth bass									1	0.22	1620	5.30	4	0.74	1281	4.08	2	1.90	1750	4.04
White crappie	No samples taken.								2	0.45	222	0.73	2	0.37	534	1.70				
White bass													2	0.37	1155	3.68	2	1.90	142	0.33
Yellow bass									2	0.45	254	0.83					3	2.86	329	0.76
Striped bass																	1	0.95	2100	5.03
Sauger									5	1.12	2319	7.59	6	1.12	3836	12.21	23	21.90	18001	41.51
FORAGE																				
Brook silverside									3	0.67	3	0.01	2	0.37	3	0.01				
Gizzard shad									5	1.12	1160	3.80	5	0.93	1180	3.75	3	2.86	750	1.73
Threadfin shad									188	41.96	4571	14.96	455	84.71	5839	18.58	23	21.90	1130	2.61
Silver chub									12	2.68	242	0.79					2	1.90	26	0.06
Emerald shiner					3	60.00	--	--	155	34.60	1118	3.66	13	2.42	93	0.30	4	3.81	27	0.06
Spotfin shiner					1	20.00	--	--	3	0.67	11	0.04								
Bluntnose minnow													2	0.37	4	0.01				
Bullhead minnow									15	3.35	34	0.11	6	1.12	15	0.05	7	6.67	19	0.04
Tennessee snubnose darter													1	0.19	2	0.01				
Logperch									3	0.67	40	0.13								
ROUGH																				
River carpsucker									1	0.22	1120	3.67								
Quillback carpsucker																	1	0.95	700	1.60
Smallmouth buffalo									2	0.45	3085	10.16	2	0.37	6970	22.18				
Black buffalo									1	0.22	1540	5.04								
Silver redhorse									2	0.45	3460	11.33								
Black redhorse									2	0.45	1250	4.09								
Golden redhorse									2	0.45	1236	4.05	2	0.37	1260	4.01				
Skipjack herring									8	1.79	2710	8.87	1	0.19	1270	3.88	18	17.14	15460	35.65
Carp									3	0.67	2470	8.09	5	0.93	6660	21.19	1	0.95	1200	2.77
Channel catfish									1	0.22	300	1.34	1	0.19	450	1.43				
Freshwater drum					1	20.00	61	100.00	1	0.22	127	0.42								

Relative Abundance in Numbers, CRM 15.0 West, 1975-76: 5.02% rough, 11.78% game, 83.30% forage.
Relative Abundance in Weight, CRM 15.0 West, 1975-76: 48.80% rough, 35.76% game, 15.43% forage.
Relative Abundance in Species, CRM 15.0 West, 1975-76: 35.48% rough, 32.26% game, 32.26% forage.

Value	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.	No.	%No.	Wt.	%Wt.
Rough					1	20.00	61	100.00	23	5.13	17378	56.85	11	2.05	16560	52.69	20	19.05	17440	40.22
Game					0	--	0	--	41	9.15	5991	19.61	42	7.82	7732	24.60	46	43.81	23972	55.28
Forage					4	80.00	--	--	384	85.71	7179	23.50	484	90.11	7136	22.71	39	37.14	1952	4.50
					5		61		448		30548		537		31428		105		43364	

Value	Total No. of Species	%Total No. of Species	Total No. of Species	%Total No. of Species	Total No. of Species	%Total No. of Species	Total No. of Species	%Total No. of Species
Rough	1	33.33	10	38.46	5	26.32	3	20.00
Game	0		8	30.77	7	36.84	7	46.67
Forage	2	66.66	8	30.77	7	36.84	5	33.33

* Weights expressed in grams; abundances expressed in percentages.

Table 6. Number, Weights and Relative Abundance of Fish Collected at Grassy Creek 1.0 in 1975 and 1976

Mile 1.0	Fall Quarter (October and November) No.	% No.	Wt.	% Wt.	Winter Quarter (December and February) No.	% No.	Wt.	% Wt.	Spring Quarter (April) No.	% No.	Wt.	% Wt.
GAME												
Redbreast sunfish	1	1.56	4	2.61	1	0.65	1	0.15	2	3.57	4	0.77
Bluegill	11	17.19	14	9.15	5	3.23	149	22.82	1	1.79	23	4.45
Longear sunfish					1	0.65	9	1.38	2	3.57	12	2.32
Spotted bass	4	6.25	30	19.61								
FORAGE												
Stoneroller	2	3.13	4	2.61	3	1.94	10	1.53	5	8.93	50	9.67
Common shiner	1	1.56	42	27.45	2	1.29	12	1.84	6	10.71	65	12.57
Spotfin shiner	8	12.50	8	5.23	28	18.06	33	5.05	2	3.57	2	0.39
Bluntnose minnow	32	50.00	42	27.45	67	43.23	78	11.94				
Blacknose dace					9	5.81	26	3.98	1	1.79	2	0.39
Creek chub	1	1.56	1	0.65	1	0.65	11	1.68	6	10.71	68	13.15
Tennessee snubnose darter	2	3.13	2	1.31	10	6.45	12	1.84	2	3.57	2	0.39
Logperch					2	1.29	14	2.14	9	16.07	114	22.05
Banded sculpin	2	3.13	6	3.92	24	15.48	98	15.01	19	33.93	145	28.05
SUCKER												
White sucker					2	1.29	200	30.63				
Yellow bullhead									1	1.79	30	5.80

* Weights expressed in grams

Table 7. Number, Weights and Relative Abundance of Fish Collected at Grassy Creek 2.2 in 1975 and 1976

Mile 2.2	(October and November) Fall Quarter				(December and February) Winter Quarter				(April) Spring Quarter			
	No.	% No	Wt.	% Wt.	No.	% No.	Wt.	% Wt.	No.	% No.	Wt.	% Wt.
GAME												
	0	-	0	-	0	-	0	-	0	-	0	-
FORAGE												
Blacknose dace					24	34.29	33	27.73	6	40.00	6	20.00
Creek chub	4	100.00	12	100.00	46	65.71	86	72.27	9	60.00	24	80.00
ROUGH												
	0	-	0	-	0	-	0	-	0	-	0	-

* Weights expressed in grams

Table 8. Number, Weights and Relative Abundance of Fish Collected at Bear Creek 0.5 in 1975 and 1976

	Fall Quarter (October and November)				Winter Quarter (December and February)				Spring Quarter (April)			
Mile 0.5	No.	% No.	Wt.	% Wt.	No.	% No.	Wt.	% Wt.	No.	% No.	Wt.	% Wt.
GAME												
Rock bass	2	1.98	9	6.43	3	1.27	147	18.87	3	3.75	154	37.11
FORAGE												
Stoneroller	11	10.89	17	12.14	52	22.03	145	18.61	22	27.50	117	28.19
Rosefin shiner	2	1.98	4	2.86	12	5.08	15	1.93				
Emerald shiner					1	0.42	1	0.13				
Common shiner	54	53.47	76	54.29	110	46.61	166	21.31	7	8.75	37	8.92
Bluntnose minnow									1	1.25	1	0.24
Blacknose dace	3	2.97	5	3.57	19	8.05	34	4.36	21	26.25	55	13.25
Creek chub	6	5.94	6	4.29	5	2.12	61	7.83				
Mosquito fish					2	0.85	-					
Stripetail darter	2	1.98	4	2.86	10	4.24	14	1,80	9	11.25	11	2.65
Tennessee snubnose darter	17	16.83	13	9.29	14	5.93	8	1.03	11	13.75	9	2.17
Banded sculpin	4	3.96	6	4.29	2	0.85	11	1.41	3	3.75	10	2.41
ROUGH												
White sucker					4	1.69	86	11,04	3	3.75	21	5.06
Northern hog sucker					2	0.85	91	11,68				

* Weights expressed in grams

Table 9. Number, Weights and Relative Abundance of Fish Collected at Bear Creek 1.2 in 1975 and 1976

	Fall Quarter (October and November)				Winter Quarter (December and February)				Spring Quarter (April)			
SITE 1.2	No.	% No.	Wt.	% Wt.	No.	% No.	Wt.	% Wt.	No.	%No.	Wt.	% Wt.
GAME												
Rock bass	1	0.68	4	1.35	3	2.04	279	47.77				
FORAGE												
Stoneroller	13	8.84	48	16.22	21	14.29	106	18.15	14	31.82	157	5.68
Rosyfin shiner	13	12.24	17	5.74	4	2.72	2	0.34	1	2.27	-	-
Common shiner	74	50.34	139	46.96	62	42.18	102	17.47	4	9.09	16	0.58
Bluntnose minnow					1	0.68	1	0.17				
Phoxinus sp.									1	2.27	1	0.04
Blacknose dace	21	14.29	25	8.45	23	15.65	55	9.42	10	22.73	31	1.12
Creek chub	5	3.40	46	15.54	3	2.04	5	0.86	4	9.09	119	[illegible]
Stripetail darter					3	2.04	5	0.86				
Tennessee snubnose darter	12	8.16	10	3.38	24	16.33	17	2.91	4	9.09	3	0.11
Banded sculpin	2	1.36	5	1.69	1	0.68	3	0.51				
ROUGH												
White sucker					2	1.36	9	1.54	4	9.09	737	26.67
Northern hog sucker	1	0.68	2	0.58								
Golden redhorse									2	4.55	1700	61.51

* Weights expressed in grams

Table 10. Number, Weights and Relative Abundance of Fish Collected in Bear Creek 3.0 in 1975 and 1976

Mile 3.0	(October and Novneber) Fall Quarter				(December and February) Winter Quarter				(April) Spring Quarter			
	No.	% No.	Wt.	% Wt.	No.	% No.	Wt.	% Wt.	No.	% No.	Wt	% Wt.
GAME												
Rock bass	5	4.85	579	65.28								
Bluegill	2	1.94	20	2.25								
FORAGE												
Stoneroller	16	15.53	45	5.07	15	20.55	18	19.78	11	47.83	46	41.44
Rosefin shiner	12	11.65	21	2.37	26	35.62	25	27.47	1	4.35	1	0.90
Common shiner	16	15.53	33	3.72	14	19.18	18	19.78				
Phoxinus sp.	2	1.94	4	0.45	1	1.37	3	3.30				
Bluntnose minnow	1	0.97	2	0.23								
Blacknose dace	9	8.74	15	1.69	5	6.85	3	3.30	3	13.04	4	3.60
Creek chub	30	29.13	87	9.81	2	2.74	8	8.79				
Stripetail darter	1	0.97	1	0.11								
Tennessee snubnose darter	5	4.85	8	0.90	9	12.33	9	9.89	7	30.43	6	5.41
ROUGH												
White sucker	4	3.88	72	8.12	1	1.37	7	7.69	1	4.35	54	48.65

* Weights expressed in grams

Table 11. Date and Effort of Electrofishing Collections in the Clinch River, May, 1975, through April, 1976*

Date	Location and Effort
5-02-75	Grassy Creek embayment - 1 hr.
6-28-75	CRM 12, 14.4, and 15 east - 30 min./station. (Day light)
8-30-75	CRM 12, 14.4, 15 east and west - 30 min./station. (Day light)
9-27-75	CRM 12, 14.4, 15 east and west, and Grassy Creek embayment - 30 min./station.
11-1-75	As sampled on 9-27-75
11-16-75	CRM 12, 15 east and west and Grassy Creek embayment - 30 min./station. CRM 14.4 - 1 hr. (Day light)
12-16-75	As sampled on 9-27-75
1-17-76	As sampled on 9-27-75
2-20-76	As sampled on 9-27-75
3-17-76	As sampled on 9-27-75
4-9-76	As sampled on 9-27-75

*Unless otherwise indicated, collections were made at night.

Table 12. Date and Effort of Gill Net Collections in the Clinch River, May, 1975, through April, 1976

Date	Location and Effort
5-02-75	CRM 12, 14.4, 15 east - 3 nets/station
6-28-75	As sampled on 5-02-75
7-26-75	As sampled on 5-02-75
8-30-75	As sampled on 5-02-75
9-27-75	CRM 12, 14.4, 15 east and west - 2 nets/station. Grassy Creek embayment - 1 net
10-31-75	CRM 12, 14.4, 15 east and west and Grassy Creek embayment - 2 nets/station
11-15-75	As sampled on 10-31-75
12-15-75	CRM 12, 14.4, 15 east and west - 3 nets/station
1-16-76	CRM 12, 14.4, 15 east and west and Grassy Creek embayment - 3 nets/station
2-13-76	As sampled on 12-15-75
3-14-76	As sampled on 12-15-75
4-17-76	As sampled on 1-16-76

Table 13. Date and Effort of Larval Fish Collections on the Clinch River May, 1975, through September, 1975

Date	Location and Effort
5-01-75	CRM 12, 14.4, 15 east. Each station - tows taken - 0 m shore, 0 m and 2 m at 25% of river width
5-17-75	CRM 12, 14.4, 15 east and west. Each station - tows taken - 0 m shore, 0 m and 5 m at 25% of river width. Grassy Creek embayment - 1 tow taken - 0 m mid-channel
5-30-75	CRM 12, 14.4, 15 east and west. Each station - tows taken - 0 m shore, 0 m and 5 m at 25% of river width. Grassy Creek embayment - 2 tows - 0 m mid-channel
6-15-75	As sampled on 5-30-75
6-28-75	As sampled on 5-30-75
7-10-75	As sampled on 5-30-75
7-25-75	CRM 12, 14.4, 15 east and west. Each station - tows taken - 0 m shore, 0 m and 5 m at 25% of river width
8-12-75	CRM 12, 14.4. Each station - tows taken - 0 m shore, 0 m and 5 m at 25% of river width. CRM 15 east and west bank - 0 m shore only. Grassy Creek embayment - 2 tows - 0 m mid-channel
8-29-75	As sampled on 5-30-75
9-12-75	As sampled on 5-30-75

Table 14. Date and Effort of Collection in Grassy Creek, October, 1975 through April, 1976

Date	Location and Effort
10-11-75	Grassy Creek 1.0 and 2.2 - 30 min./station seining
11-16-75	As sampled on 10-11-75
12-16-75	Grassy Creek 1.0 - 30 min. of electrofishing and seining. Grassy Creek 2.2 - 30 min. seining
2-14-76	Grassy Creek 1.0 and 2.2 - 30 min./station electrofishing
4-18-76	As sampled on 2-14-76

Table 15. Date and Effort of Collections in Bear Creek, September, 1975, through April, 1976

Date	Location and Effort
9-27-75	Bear Creek 3.0 - 30 min. seining
10-11-75	Bear Creek 0.5 and 1.2 - 30 min./station seining
11-16-75	Bear Creek 0.5, 1.2, and 3.0 - 30 min./station seining
12-15-75	As sampled on 11-16-75
2-14-76	Bear Creek 0.5, 1.2, and 3.0 - 30 min./station electrofishing
4-16-76	As sampled on 2-14-76

APPENDIX B

Table 1. Temperature (C) in the Clinch River, Grassy Creek, and Bear Creek from June, 1975, to May, 1976*

	Clinch River				Grassy Creek		Bear Creek		
Month	12.0	14.4	15.0E	15.0W	1.0	2.2	0.5	2	3.0
June	-	-	-	-	-	23.0	22.0	22.0	20.0
July	20.0	18.5	19.0	19.5	25.0	21.0	-	18.0	19.5
Aug.	19.5	20.0	20.0	20.0	25.0	22.5	23.0	23.0	19.0
Sept.	21.0	21.0	21.0	21.0	23.0	19.5	21.0	20.0	20.3
Oct.	19.1	19.0	18.9	18.9	18.8	18.5	17.3	17.1	17.2
Nov.	15.4	15.5	15.5	15.5	11.4	9.5	8.9	10.5	12.0
Dec.	10.5	11.0	10.9	10.7	10.5	11.5	11.0	11.1	11.2
Jan.	7.3	7.2	7.3	7.3	5.0	4.0	4.7	5.3	6.0
Feb.	8.2	6.5	8.2	8.0	12.5	12.6	13.0	13.0	12.0
March	12.5	12.0	10.5	10.3	11.0	8.5	10.0	10.0	10.6
April	14.8	14.6	14.5	14.0	12.7	15.2	15.0	15.3	14.0
May	17.1	16.6	16.6	-	18.6	15.6	16.0	15.9	15.5
AVERAGE	15.0	14.9	14.8	14.5	15.8	15.1	14.7	15.1	14.8

*Civil Engineering Department, Tennessee Technological University, personal communication, 1977

Table 2. pH in the Clinch River, Grassy Creek, and Bear Creek from July, 1975, to May, 1976*

Month	Clinch River 12.0	Clinch River 14.4	Clinch River 15.0E	Clinch River 15.0W	Grassy Creek 1.0	Grassy Creek 2.2	Bear Creek 0.5	Bear Creek 1.2	Bear Creek 3.0
July	7.2	7.1	7.0	7.1	7.4	7.8	-	7.8	7.3
Aug.	7.0	7.3	6.8	6.8	7.1	7.9	7.3	7.4	7.0
Sept.	7.1	7.1	7.1	7.2	7.3	7.5	7.4	7.3	7.3
Oct.	7.9	7.9	7.7	7.8	7.8	7.2	7.5	7.4	7.3
Nov.	7.8	7.8	7.8	7.9	7.9	8.0	8.1	7.8	7.5
Dec.	8.4	8.4	8.4	8.4	8.2	8.4	7.9	8.3	8.4
Jan.	7.8	7.9	7.9	7.9	7.8	7.9	7.8	7.6	7.5
Feb.	8.4	8.6	8.6	8.5	8.2	8.3	8.1	8.0	7.9
March	8.6	8.6	8.2	8.3	8.2	8.5	8.2	8.0	7.8
April	8.2	8.1	8.1	8.0	8.4	8.3	8.2	8.0	7.9
May	8.5	8.4	8.4	-	8.4	8.2	8.0	7.9	7.7
AVERAGE	7.9	7.9	7.8	7.8	7.8	8.0	7.8	7.8	7.6

*Civil Engineering Department, Tennessee Technological University, personal communication, 1977

Table 3. Discharge (m^3/sec) of the Clinch River, Grassy Creek, and Bear Creek from June, 1975, to May, 1976

Month	Clinch River[1]	Grassy Creek[2]	Bear Creek[2]
June	202.64	0.02	0.13
July	201.21	-	0.16
Aug.	188.08	-	-
Sept.	136.36	-	-
Oct.	87.36	0.06	0.48
Nov.	87.50	0.03	0.24
Dec.	126.76	0.05	0.39
Jan.	180.85	0.06	0.47
Feb.	135.27	0.02	0.20
March	111.97	0.07	0.64
April	118.97	0.04	0.27
May	-	0.02	0.12

[1]TVA Department of River Management, personal communication, 1977

[2]Randall Morton, personal communication, 1977

Sec. 2.7.2, ref. 120 5.1 8a Rec'd from: REFERENCE 2-55

Clinch River Sauger Study

Introduction

Sauger in the Tennessee River system instinctively migrate upstream out of the reservoirs each winter as the spawning season approaches. Their migrations are impeded by TVA dams, except during lock operations (Cobb 1960), and it follows that sauger would become concentrated in tailwater areas at this time. These concentrations have led to the assumption that spawning occurs along the rip-rap shorelines of the tailrace during January and February. The "spawning" congregations have been sampled for various reasons in the past, but have yielded inconclusive evidence of spawning activity in the immediate vicinity of dams.

The present study investigates the hypothesis that sauger do not utilize the tailwater areas for spawning purposes. Concentrating on the lower Clinch River below Melton Hill Dam, this study is aimed at identifying areas in which sauger actually do spawn, classifying the spawning habitat in detail, and applying that knowledge to other areas of the Tennessee River system to determine additional areas of suitable sauger spawning habitat in efforts to minimize impacts upon this species by power plant construction or industrial development.

Methods

Preliminary data were gathered during a seven-week period beginning March 29, 1979. Adult sauger were captured in gill nets (mostly 1-1/2", bar measure) in the Clinch River set between Gallaher Bridge (CRM 14.1) and the mouth of Caney Creek (CRM 17.0) and at the lock walls of Melton Hill (CRM 23.1). In the area from Gallaher Bridge to Caney Creek, the nets were set at dusk and pulled the next morning. At the dam, the nets were only fished approximately one hour shortly after dusk. In addition to sampling adults, attempts were made to collect sauger eggs by pumping the substrate at depths of one to six meters at the dam and the downstream areas.

Results of 1979 Study

At the outset of the study, it was hoped that spawning locations could be determined by clusters of spawning saugers captured in gill nets, as observed at CRM 14.7 by Fletcher (1977), and by fertilized sauger eggs collected from the river. Although no actual "clusters" of spawning saugers were collected, hundreds of males in spawning condition and several females, some flowing and some partially spent, were observed in an area six to eight miles below Melton Hill Dam. On two occasions, flowing females were captured in close proximity (less than one foot apart in the gill net) to solitary mature males. According to Nelson (1968) and Scott and Crossman (1973) as few as one male sauger may accompany a spawning female. One egg from the pump samples has been identified as a sauger egg; it was collected in the downstream area near CRM 14.7 where the substrate was composed of sand and silt.

The study site above Gallaher Bridge was divided into four areas for presentation of catch data (Tables 1-4): (1) CRM 14.1 to 14.9, (2) CRM 15.0 to 15.5, (3) CRM 15.6 to 16.0, and (4) CRM 16.1 to 17.0. A total of 550 sauger captured during this study and 38 collected by Oak Ridge National Laboratory (ORNL) personnel is included in the following discussion.

With regard to the possibility that sauger do not spawn immediately below the dam, spawning instead six to eight miles downstream, the following observations were made. Gill nets were first set near Gallaher Bridge on the night of March 30 when surface water temperature was 50° F. Only 13 sauger were captured in three nets. Of these, 10 were males, and their milt was thick and slow-running, indicating that they had not commenced spawning. Two of the three females appeared to be gravid due to their size and robustness, but dissection revealed large amounts of visceral fat and immature ovaries (i.e., pinkish, transparent without developing ova). The other female was also immature.

The next week (April 3) three nets were fished for approximately one hour below Melton Hill Dam when surface water temperature was 53° F. A total of 95 sauger was caught, nearly 32 fish/net-hour. Twenty-eight of these fish were males, and the milt again was thick. Since milt can usually be obtained from males with slight pressure during late winter and early spring, if no milt appeared when pressure was applied to the abdomen of the fish, that fish was presumed to be a female. Maturity of the ovaries could not be positively determined in most cases without sacrificing the fish. Of the 67 females captured, at least 7 were gravid. One female had already spawned and was very gaunt in appearance. Most of the fish were released in good condition, although some were retained for brood stock for propagation studies.

On April 10, seven nets were set in the downstream area when surface water temperature was 53° F. A total of 180 sauger was caught. Most of these were males in running ripe spawning condition, i.e., milt freely flowing. There were also 22 gravid females, at least 1 of which was flowing (extruding eggs freely). The majority of the sauger caught on this date (53 and 61 in two nets) were captured in Areas 3 and 4 (Table 4). The high catch/net-night suggested that a submerged island or sand bar of Area 3 deserved special attention.

Efforts were concentrated at the downstream site for the next two weeks. Many mature males and occasional females in spawning condition were captured. The occurrence of flowing females was not limited to any particular area, although the greatest number, four, were taken in Area 3. Therefore, if presence of flowing females is an indication, it appears that spawning is not localized in a small area. Nelson (1968) reported the major spawning ground of Missouri River sauger (above Lewis and Clark Reservoir) to be a four-mile stretch of river, six miles below Fort Randall Dam.

On the night of May 2, three nets were set below Melton Hill Dam and fished for one hour in the same manner as on April 4. The surface water temperature was 62° F. A total of nine sauger was collected, and all were dissected for sex and maturity information. All were found to be immature females. The large numbers of sauger present four weeks earlier had apparently left the area. On this same date five nets set overnight at the downstream areas collected 64 sauger, the majority of which were sexually mature (41 flowing males, 2 flowing females, 8 gravid females, and 4 spent females). The results of this night's effort lend credence to the hypothesis that the area immediately below the dam is not used for sauger spawning, but rather that spawning occurs six to eight miles downstream.

In addition to TVA's netting on May 2, ORNL fished one experimental gill net at the lower end of Jones Island, CRM 19.7 on this date. Of the 38 sauger caught, 36 were mature males, and 1 was a female from which eggs would flow upon slight pressure to the abdomen. By the criteria previously discussed, this area may also qualify as a sauger spawning locality.

Discussion

Regarding the length of the spawning season, this series of data shows a sauger spawning period of at least six weeks duration. The first spent female was captured on April 4, and gravid females were still present May 10, the last sampling date. These latter fish showed no indication of ovary resorption. Surface water temperatures during this period ranged from 53° to 62° F. These temperatures are roughly 10° higher than those recorded in the literature for more northern areas (Nelson 1968, Priegel 1969, Graham and Penkal 1978). Eschmeyer and Smith (1943) found that sauger below Norris Dam failed to spawn and resorbed their ovaries at water temperatures below 50° F. Fletcher (1977) reported Clinch River sauger spawning at 58° F. Cool discharges from Norris Dam even after flowing through Melton Hill Reservoir may have prolonged the sauger spawning season in the particular study area. Nelson (1968) and Priegel (1969) reported spawning seasons lasting only two weeks.

Peak spawning activity, based on catch/net-night and the number of flowing females, in the downstream areas (Table 7) occurred from April 10 to April 25. The April 10 samples resulted in nearly 26 sauger captured per net-night. The vast majority were males, but 22 gravid females were captured. None of the females were spent, and only 1 of the 22 gravid females was recorded as flowing on this date. The predominance of males in spawning condition agrees with Nelson's observations (1968) in that they arrive at spawning grounds before the females.

The catch per net-night dropped the following week, but five of the six gravid females collected were flowing and another had spawned. The catch rate increased slightly during the week of April 25, and 11 gravid females plus 2 spent females were captured. Samples taken after April 25 produced higher ratios of spent to gravid females, and the catch rate declined to 4.33 sauger per net-night. During this three-week peak period, surface water temperatures increased from 53° to 58° F. Sex ratios strongly favored males over mature females during these weeks with males being at least five times more abundant (Table 8). Immature females are intentionally omitted from sex ratios since their importance in assigning spawning characteristics is nil. Males were more numerous than females on all occasions except the April 3 sample below Melton Hill Dam (Table 5). Predominance of males during the peak spawning period does not agree with available literature for northern populations, although Fletcher (1977) found similar results on the date he reported spawning activity in the Clinch. For sauger populations as a whole, females are more abundant (Priegel 1969, pp. 26-27). Hassler (1958) reported larger percentages of females than males in Norris Reservoir.

Few sauger were collected near the shore or in shallow water. Most of the fish were taken in the deeper half of the net with many at the end. Even the flowing females were taken in water 15-20 feet deep. If flowing females indicate spawning, these observations are inconsistent with available literature which reports sauger spawning in 2'-4' depths (Nelson 1968, Graham and Penkal 1978). Substrates do not seem to agree either, since the literature describes the spawning substrates as gravel and rubble. The fish in the present study were taken over sand and silt substrates.

Concentrating on the data collected in the vicinity of Gallaher Bridge, alleged spawning fish (i.e., flowing females) were captured in all four areas (Tables 1-4). Catch rates of sauger were highest at Area 3, near the submerged island. Although gravid females constituted higher proportions of the catch in Areas 1, 2, and 4, half of the eight flowing females were captured in Area 3. The two flowing females collected from Area 4 were taken only 0.2 mile upstream of Area 3. While the low number of females limits the conclusions that may be drawn, on the basis of flowing females as indicators of spawning activity, the area surrounding the submerged island in Area 3 appears to be a major spawning area. The percentage of spent females increased progressively downstream, indicating their return to Watts Bar Reservoir following spawning.

Spawning activity was apparently not localized since high yielding locations one week were not so the next. The large numbers of males captured is probably not representative of their abundance because yearlings males (i.e., fish completing one year's growth) were not vulnerable to the 1-1/2" nets used in this study. However, most of the sauger sampled by an experimental net by ORNL on May 2 were yearling, mature males.

Suggestions for Further Study

The time frame for additional study during the 1980 spawning season spans approximately two months beginning in mid-March. Necessary equipment includes ultrasonic transmitters, receiving apparatus, shocker boat, tracking boat, pumping boat, gill nets, larval fish drift nets, and a sled-type attachment for the bottom pump intake (Manz 1964). The transmitters are available from Smith-Root, Inc., and the receiver and hydrophone may possibly be borrowed from the biothermal unit at Browns Ferry. The drift net frames and pump attachment will have to be fabricated. The other materials are maintained at the Walnut Orchard.

During mid-March prespawning sauger are abundant below Melton Hill Dam. Plans are to capture several fish for tagging purposes at this time. Ten transmitters (five for males, five for gravid females) will be attached externally using a harness similar to that described by Carr and Chaney (1976).

Other sauger would receive a pelvic fin clip before being released. Each transmitter has a different pulse rate, allowing the ability to monitor the movements of individual fish. Fin-clipped fish would show gross movement from the dam site.

Recalling that the 1979 data showed that mature sauger vacated the area immediately below the dam while concentrations of mature fish occurred six to eight miles downstream, tracking the telemetered sauger released at the dam should reveal significant information about their spawning locations and activity. It is believed that tagged males will illustrate nightly movements onto the spawning grounds while occupying deeper stretches during the day. According to Nelson (1968) few sauger were captured on the spawning grounds during the day, but their numbers peaked rapidly during the first two hours of darkness. Occasionally males will be recaptured in the areas inhabited at night to determine if they are accompanied by a school of sauger and, more importantly, if flowing females are present. If the fish are in shallow water (less than four feet) at night, electrofishing would be the best sampling method because groups of spawning fish could be collected as described by Nelson (1968). Otherwise gill nets could be set, but only for short periods in order to minimize the injury to the tagged fish. The tracking crew will carry several readied gill nets for spot-checking areas frequented by the tagged fish.

Nelson (1968) reported that male sauger precede the females to the spawning grounds. The females tagged in the present study would presumably remain apart from the concentrations of males until their eggs matured. Attempts would be made to capture a telemetered female entering areas of males in order to examine her sexual readiness. A female sauger probably sheds all her eggs in one night, as does a female walleye (Priegel 1970), and may return to the reservoir downstream after spawning. If a tagged female continues downstream out of the primary study area toward Watts Bar Reservoir, attempts would be made to capture her to verify that she had spawned.

The information gained from the movements of adult sauger would be used to search for sauger eggs. If male sauger show a tendency to frequent particular areas at night, those areas would be intensively sampled for eggs using the modified pump and larval fish drift nets. According to Nelson (1968) sauger eggs are strongly adhesive and can best be sampled by pumping, although some viable eggs may be collected in drift nets. The present study intends to determine whether the eggs, if spawned over sand and silt, retain their adhesiveness and are collected more often by pumping, or if they cease to adhere to the loose, fine substrate and are collected in drift nets as they are swept downstream.

The amount of manpower required to pursue the study as proposed would be substantial. Several man-days would be expended during the initial evening of collection to ensure adequate numbers of minimally injured adult sauger to carry the transmitters. Thereafter and throughout the rated 30-day life of the tags, the movements of the telemetered fish should be monitored during day and night periods several times weekly. Perhaps 10 man-weeks would be required to track the fish. However, if sufficient information to describe the spawning localities is gained before the transmitter batteries fail, the tracking could be halted and attention focussed on the collection of eggs. The drift nets could easily be set day or night and allowed to fish during tracking or pumping operations. Weekly pump samples would be taken during the day at areas indicated by the telemetered adults.

Following the spawning season, processing of the egg samples, and analysis of the data, scuba divers will explore the more likely spawning grounds to describe in detail the various substrates preferred by sauger for spawning purposes.

CLINCH RIVER SAUGER STUDY

GILL NET CAPTURE BREAKDOWN BY AREA, SEX, MATURITY

TABLE 1, AREA 1. GALLAHER BRIDGE UPSTREAM TO CRM 14.9.

Date	Net-Nights	Total	M	F(im)	F(gr)	F(sp)	F(flo)	Catch/Net-Night
3-30-79	1	2	2	-	-	-	-	2
4-10-79	2	27	18	4	5	-	-	13.5
4-19-79	2	4	1	-	2	1	2	2
5- 2-79	1	17	15	-	-	2	-	17
5-10-79	3	21	12	4	2	3	-	7
TOTALS	9	71	48	8	9	6	2	7.89

TABLE 2, AREA 2. CRM 15.0 to 15.5 - DOWNSTREAM OF SUBMERGED ISLAND

Date	Net-Nights	Total	M	F(im)	F(gr)	F(sp)	F(flo)	Catch/Net-Night
3-30-79	1	4	2	2	-	-	-	4
4-10-79	2	34	26	1	7	-	1	17
4-25-79	1	22	17	2	3	-	-	22
5- 2-79	1	18	8	2	5	2	1	18
5-10-79	2	13	9	3	-	1	-	6.5
TOTALS	7	91	62	10	15	3	2	13.0

TABLE 3, AREA 3. CRM 15.6 to 16.0 - ALONG SUBMERGED ISLAND

Date	Net-Nights	Total	M	F(im)	F(gr)	F(sp)	F(flo)	Catch Net-Night
4-10-79	1	53	47	1	5	-	-	53
4-19-79	2	53	49	-	4	-	3	26.5
4-25-79	3	40	31	2	6	1	-	13.3
5- 2-79	2	12	7	2	2	-	1	6
5-10-79	3	3	2	-	-	1	-	1
TOTALS	11	161	136	5	17	2	4	14.64

TABLE 4, AREA 4. CRM 16.1 to 17.0.

Date	Net-Nights	Total	M	F(im)	F(gr)	F(sp)	F(flo)	Catch Net-Night
3-30-79	1	7	6	1	-	-	-	7
4-10-79	2	66	60	1	5	-	-	33
4-25-79	1	16	13	-	2	1	-	16
5- 2-79	1	17	11	3	3	-	-	17
5-10-79	4	17	11	1	5	-	2	4.3
TOTALS	9	123	101	6	15	1	2	13.6

TABLE 5. GRAND TOTALS BY DATE FOR AREAS 1-4 COMBINED AND CATCH PER NET-NIGHT.

Date	Net-Nights	Total	M	F(im)	F(gr)	F(sp)	F(flo)	Catch Net-Night
3-30-79	3	13	10	3	-	-	-	4.33
4-10-79	7	180	151	7	22	-	1	25.71
4-19-79	5	57	50	-	6	1	5	11.40
4-25-79	5	78	61	4	11	2	-	15.60
5- 2-79	5	64	41	7	10	4	2	12.80
5-10-79	12	52	33	8	6	5	2	4.33
OVERALL	36	444	346	29	55	12	10	12.33

TABLE 6. MELTON HILL DAM LOCK WALLS, CRM 23.1 APPROXIMATELY ONE-HOUR SETS.

4- 3-79	3	95	28	?	7+	1	(59 females maturity unknown)
5- 2-79	3	9	-	9	-	-	-
TOTALS	6-1-hr. sets	104	28	9+	7+	1	

(17.33 sauger/net hour) (none flowing)

Table 7. SEX RATIOS OF MALES TO MATURE FEMALES, AREAS 1-4 COMBINED AND SURFACE WATER TEMPERATURE ACTUAL NUMBERS IN PARENTHESIS.

Date	Males:Females	Actual Number	Temperature
3-30-79	10:0	(10,0)	50°
4-10-79	1:0.15	(151,22)	53°
4-19-79	1:0.14	(50,7)	54°
4-25-79	1:0.21	(61,13)	58°
5- 2-79	1:0.34	(41,14)	62°
5-10-79	1:0.33	(33,11)	64

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CRRF 4.1-3

REFERENCE 4-1

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NTID300.1

NOISE FROM CONSTRUCTION EQUIPMENT AND OPERATIONS, BUILDING EQUIPMENT, AND HOME APPLIANCES

DECEMBER 31, 1971

U.S. Environmental Protection Agency
Washington, D.C. 20460

NTID300.1

NOISE FROM CONSTRUCTION EQUIPMENT AND OPERATIONS, BUILDING EQUIPMENT, AND HOME APPLIANCES

DECEMBER 31, 1971

Prepared by

BOLT, BERANEK AND NEWMAN
under
CONTRACT 68-04-0047

for the

U.S. Environmental Protection Agency
Office of Noise Abatement and Control
Washington, D.C. 20460

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402 - Price $2.50

2. SOURCE CHARACTERIZATION

2.1 Construction Equipment and Operation

Construction has become a major noise problem in many cities and towns. The trend toward urban renewal and more high-rise structures has created an almost perpetual din on city streets. Equipment associated with construction projects is more numerous, and the time span for construction at a given site has lengthened. Residents very near a construction site may well plan on two years of intolerable noise levels as a high-rise structure is being built.

In this section, we consider the construction noise problem as it relates to residential and nonresidential buildings, city streets, and public works, because these kinds of project usually take place in areas where the number of people likely to be exposed is very high. Heavy construction, such as highways and civil works, has been omitted from our study because the vast bulk of this activity occurs in thinly populated areas where the noise affects very few people. We view construction as a process that can be categorized according to type and that consists of separate and distinct phases.

2.1.1 The construction process

The basic unit of construction activity is the construction site, which exists in both space and time. The temporal dimension consists of various sequential phases which change the character of the site's noise output as work progresses. These phases are discussed further below. In the case of building construction, the spatial character of the site is self-evident; in the case of sewers and roads, the extent of a site is taken, for reasons explained in Sec. 3.2, to be one standard city block or about 1/8 of a mile. (That is, if a city reports 40 miles of sewer construction, we consider that project as consisting of 320 separate sites.)

Construction sites are typically classified in the fifteen categories in which construction data is reported by the U.S. Bureau of Census and various state and municipal bodies. The categories are:

- Residential buildings:

  one- to four-family
  Five-family and larger

- Nonresidential buildings:

  Office, bank, professional
  Hotel, motel, etc.
  Hospitals and other institutions
  Schools
  Public works buildings
  Industrial
  Parking garages
  Religious
  Recreational
  Store, mercantile
  Service, repair station

- Municipal streets

- Public works (e.g., sewers, water mains).

For purposes of allocating construction effort among the different types of sites, it it possible to group the nonresidential sites into four larger categories which are differentiated by the cost of the average building in each category, as well as by the distribution of effort among the various construction phases. These four groups, in order of decreasing average cost per building, are:

- Office buildings, hospitals, hotels
- Schools, public works buildings
- Industrial buildings, parking garages
- Stores, service stations, recreational buildings, and religious buildings.

Construction is carried out in several reasonably discrete steps, each of which has its own mix of equipment and consequently its own noise characteristics. The phases (some of which can be subdivided) are:

- *Building Construction*
  1. a. Clearing
     b. Demolition
     c. Site preparation
  2. Excavation
  3. Placing foundations
  4. a. Frame erection
     b. Floors and roof
     c. Skin and windows
  5. a. Finishing
     b. Cleanup

- *City Streets*
  1. Clearing
  2. Removing old roadbed
  3. Reconditioning old roadbed
  4. Laying new subbase, paving
  5. Finishing and cleanup

· *Public Works*

1. Clearing
2. Excavation
3. Compacting trench floor
4. Pipe installation, filling trench
5. Finishing and cleanup.

Defining the construction phases as above allows us to account for the variation in site noise output with time. By inventorying the equipment which is to be found at each site in each phase, we can derive a representative source level for each phase by the process described below.

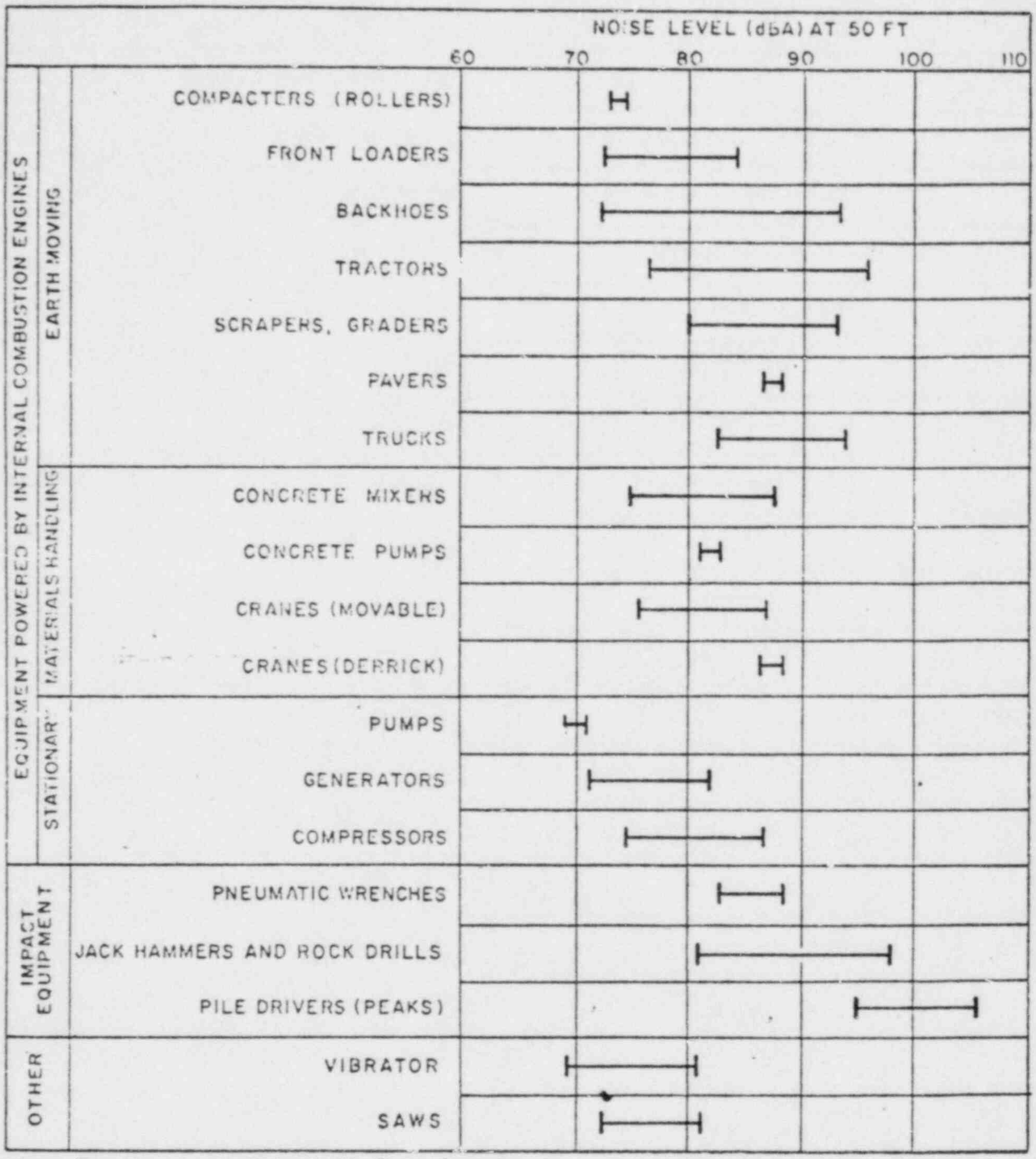
2.1.2 Equipment noise characteristics

Despite the variety in type and size of construction equipment, similarities in the dominant noise sources and in patterns of operation permit one to assign all equipment to a very limited number of categories. These categories are described below and are indicated in Fig. 1, together with corresponding noise level data. Corresponding spectra and the sources of this data are given in Appendix A.

Equipment Powered by Internal Combustion Engines

The most prevalent noise source in construction equipment is the prime mover, i.e., the internal combustion engine (usually of the diesel type) used to provide motive and/or operating power. Engine-powered equipment may be categorized according to its mobility and operating characteristics, as (1) earthmoving equipment (highly mobile), (2) handling equipment (partly mobile), and (3) stationary equipment.

Earthmoving equipment includes excavating machinery (backhoes, bulldozers, shovels, front loaders, etc.) and highway



Note: Based on Limited Available Data Samples

FIG. 1. CONSTRUCTION EQUIPMENT NOISE RANGES.

building equipment (compactors, scrapers, graders, pavers, etc.). Internal combustion engines are used for propulsion (either on wheels or tracks) and for powering working mechanisms (buckets, arms, trenchers, etc.). Engine power varies from about 50 hp to over 600 hp. Engine noise typically predominates, with exhaust noise usually being most significant and with inlet noise and structural noise being of secondary importance. Other sources of noise in this equipment include the mechanical and hydraulic transmission and actuation systems, and cooling fans (often very significant). Typical operating cycles may involve one or two minutes of full-power operation, followed by three or four minutes at lower power.

Noise levels at 50 ft from earthmoving equipment range from about 73 to 96 dB(A). The greatest and most direct potential for noise abatement here lies in quieting the engine by use of improved mufflers.

Engine-powered materials-handling equipment such as cranes, derricks, concrete mixers, and concrete pumps, is used in a more-or-less fixed location; mobility of this equipment over the ground is not part of its major work cycle. Although noise from the working process (such as the clanking of aggregate in the concrete mixing bin) often is the most "identifiable" noise component, the dominant source of noise generally is the prime mover. Noise levels at 50 ft range from about 75 to 90 dB(A). The greatest potential abatement for noise again lies in engine quieting, with treatment of power transmission and working mechanisms being of secondary importance.

Stationary equipment, such as pumps, electric power generators and air compressors, generally runs continuously at relatively constant power and speed. Noise levels at 50 ft range from about 70 to 80 dB(A), with pumps typically at the low end of this range. Stationary equipment, because of its fixed location and constant speed and/or load operation, may be quieted more easily than mobile equipment; engine mufflers can be more effective, and use of enclosures becomes feasible. [In fact, noise from some air compressors, has already been reduced by about 10 dB(A) by use of appropriate enclosures.]

The greatest near-term abatement potential for all current equipment powered by internal combustion engines lies in the use of better exhaust mufflers, intake silencers, and engine enclosures (in conjunction with appropriate cooling system and fan design). Reductions of 5 to 10 dB(A) appear to be achievable, usually without great difficulty. Practical long-term abatement [of about 15 to 20 dB(A)] can probably be achieved by basic engine design changes. Of course, replacement of the internal combustion engine by a quieter prime mover, such as a gas turbine or electric motor, would eliminate the reciprocating-engine noise source altogether.

Impact Equipment and Tools

Conventional pile drivers are either steam-powered or diesel-powered; in both types, the impact of the hammer dropping onto the pile is the dominant noise component. With steam drivers, noise is also generated by the power supply (a boiler) and the release of steam at the head; with diesel drivers, noise is also generated by the combustion explosion that actuates the hammer. Noise levels are difficult to measure or standardize, because they are affected by pile type and length, but peak levels tend to be about 100 dB(A) (or higher) at 50 ft.

Impact-noise is absent in the so-called "sonic" (or vibratory) pile drivers. These do not use a drop hammer, but vibrate the pile at resonance. The noise associated with pile vibrations typically occurs around 150 Hz and is barely audible. The power source, which generally consists of two gasoline engines, is the primary noise source.

Abatement can be accomplished best by substituting use of a sonic pile driver for an impact machine where possible. (Unfortunately, sonic pile drivers are useful only for some soils.) Impact noise reduction at the source generally is very difficult. Substitution of nonimpact tools offers the best practical abatement potential; otherwise, reductions of perhaps 5 dB(A) may be obtained by use of enclosures.

Most impact tools, such as jack hammers, pavement breakers, and rock drills are pneumatically powered, but there are also hydraulic and electric models. The dominant sources of noise in pneumatic tools are the high-pressure exhaust and the impact of the tool bit against the work. Noise levels at 50 ft typically range from 80 to 97 dB(A).

An exhaust muffler on the compressed air exhaust can lower noise levels from the exhaust by up to about 10 dB(A). Pneumatic exhaust noise, of course, is absent in hydraulic or electric impact tools. Reduction of the impact noise from within a tool can be accomplished by means of an external jacket, which can contribute perhaps a 5 dB(A) reduction. Reduction of the noise due to impact between the tool and material being worked upon generally is difficult and requires coustic barriers enclosing the work area and its immediate vicinity. Depending on the impacted structures, such barriers may reduce noise by 3 to 10 dB(A).

Small hand-held pneumatic tools, such as pneumatic wrenches, generate noise of levels between 84 and 88 dB(A) at 50 ft. The exhaust and the impact are the dominant noise sources. Because of the obvious weight and size limitations to which hand tools are subject, only small and light mufflers can be used with them, limiting the achievable noise reduction to 5 dB(A) at best. The best practical means for reducing the noise from impact tools consists of using other types of tools to accomplish the same functions.

2.1.3 Site noise characteristics

To characterize the noisiness – i.e., the average noise annoyance potential – of the various types of construction sites during each phase of construction, a Noise Pollution Level (NPL) was calculated for each type of site and each construction phase. The NPL used here was taken as the same measure that was used for similar evaluation of traffic noise [2]. The NPL (in dB) is defined as the sum of the A-weighted average sound pressure level and 2.56 times the standard deviation of the A-weighted sound pressure level*; thus, NPL accounts for the effect of steady noise, plus the annoyance due to fluctuations.

Although a thorough study relating NPL to subjective descriptors of annoyance (e.g., acceptable, unacceptable) has not been accomplished, a provisional interpretation of NPL in such terms can be suggested. On the basis of an evaluation of domestic and

---

*A-weighting refers to a standard weighting of the various frequency components, approximating the behavior of human hearing. The average sound pressure level is computed on the basis of the time-average root-mean-square sound pressure, whereas the standard deviation is calculated from the time-variation of the dB(A) values.

foreign social surveys and psycho-acoustic studies, the Department of Housing and Urban Development has adopted a set of "guideline criteria" [3] for outdoor noise levels in residential areas as shown in Fig. 2 [4]. According to this chart, the community noise situation is evaluated by comparing a measured distribution of A-weighted levels with the criteria curves. The situation is categorized by the region of least desirability penetrated by the actual noise distribution. Since this criterian is based on level distributions, the boundaries between regions of acceptability may be defined in terms of the NPL. Thus, the following descriptors of NPL values may be used in interpreting the site noise NPL levels used in the remainder of this report.

Clearly Acceptable: The noise exposure is such that both the indoor and outdoor environments are pleasant.	NPL less than 62 dB
Normally Acceptable: The noise exposure is great enough to be of some concern but common building constructions will make the indoor environment acceptable, even for sleeping quarters, and the outdoor environment will be reasonably pleasant for recreation and play.	NPL between 62 and 74 dB
Normally Unacceptable: The noise exposure is significantly more severe so that unusual and costly building constructions are necessary to ensure some tranquility indoors, and barriers must be erected between the site and prominent noise sources to make the outdoor environment tolerable.	NPL between 74 and 88 dB
Clearly Unacceptable: The noise exposure at the site is so severe that the construction costs to make the indoor environment acceptable would be prohibitive and the outdoor environment would still be intolerable.	NPL greater than 88 dB

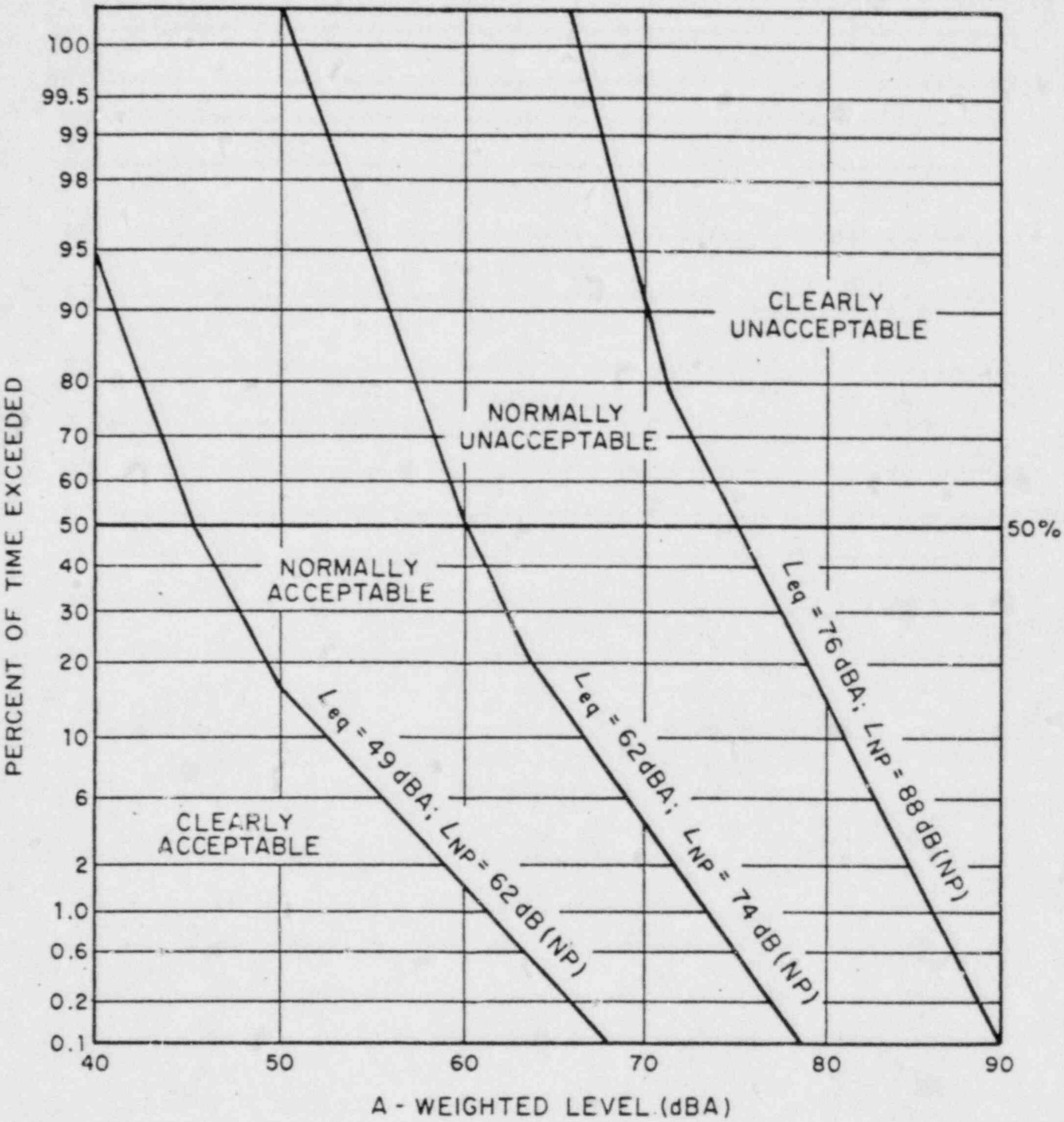


FIG. 2 PROVISIONAL CRITERIA RELATING NPL TO COMMUNITY NOISE ACCEPTABILITY

We must emphasize that these criteria have not been officially or unofficially adopted by HUD or any other government agency. They are presented here solely to enable the reader to interpret NPL values computed in this report.

The aforementioned averages of noise annoyance potential were calculated on the basis of information obtained on (1) the number of each item of equipment typically present at a site (in a given phase), (2) the length of the duty cycles of this equipment, and (3) the average noise levels during operation. For purposes of site characterization, the noisiest piece of equipment was assumed to be located at 50 ft from an observer, and all other equipment was assumed to be located at 200 ft from the observer; ambient noise, of levels depending on the surroundings of the site, was taken to be present in addition to the equipment noise. (Note that pile driver noise was not included in the NPL calculations, because its repetitive impact character makes its intrusion characteristics different from the more continuous noises for which the NPL concept was developed.) Clearly, this construction noise model is not entirely realistic; however, it may be expected to fulfill its intended purposes — that of yielding at least a relative measure of the noise annoyance associated with each type of site and phase for the most adverse conditions likely to be associated with each phase.

Table I shows NPLs calculated for each of five phases for each of four types of construction. For residential housing and public works construction, two NPL values are given in the table; one pertains to a noisy [70 dB(A)] background characteristic of urban conditions, the other to relatively quiet [50 dB(A)] ambient conditions found in suburban environments. As one may expect, the values indicated in the table reflect the fact that a given intruding noise is more annoying if it occurs in a quieter environment.

TABLE I-a. TYPICAL RANGES OF NOISE LEVELS AT CONSTRUCTION SITES WITH A 50 dB(A) AMBIENT TYPICAL OF SUBURBAN RESIDENTIAL AREAS

	Domestic Housing I	Domestic Housing II	Office Building, Hotel, Hospital School, Public Works I	Office Building, Hotel, Hospital School, Public Works II	Industrial Parking Garage, Religious, Amusement & Recreations, Store, Service Station I	Industrial Parking Garage, Religious, Amusement & Recreations, Store, Service Station II	Public Works Roads & Highways, Sewers, and Trenches I	Public Works Roads & Highways, Sewers, and Trenches II	
Ground Clearing	83	83	84	84	84	83	84	84	Energy Average dB(A)
	8	15	7	16	9	16	8	8	Standard Deviation
	103	122	101	123	106	124	103	104	NPL
Excavation	88	75	89	79	89	71	88	78	Energy Average dB(A)
	8	14	6	2	6	2	7	3	Standard Deviation
	109	111	105	85	105	77	106	86	NPL
Foundations	81	81	78	78	77	77	88	88	Energy Average dB(A)
	10	17	3	3	4	5	8	8	Standard Deviation
	107	124	84	86	87	90	108	108	NPL
Erection	81	65	87	75	84	72	79	78	Energy Average dB(A)
	10	9	6	2	9	7	9	11	Standard Deviation
	107	87	99	79	107	91	103	108	NPL
Finishing	88	72	89	75	89	74	84	84	Energy Average dB(A)
	7	12	7	8	7	10	7	8	Standard Deviation
	106	104	107	97	105	100	101	104	NPL

I – All pertinent equipment present at site.

II – Minimum required equipment present at site.

TABLE 1-b. TYPICAL RANGES OF NOISE LEVELS AT CONSTRUCTION SITES WITH A 70 dB(A) AMBIENT TYPICAL OF URBAN AREAS

	Domestic Housing		Office Building, Hotel, Hospital School, Public Works		Industrial, Parking Garage, Religious, Amusement & Recreations, Store, Service Station		Public Works Roads & Highways, Sewers, and Trenches		
	I	II	I	II	I	II	I	II	
Ground Clearing	84	83	84	84	84	87	84	84	Energy Average dB(A)
	6	8	6	8	6	8	6	7	Standard Deviation
	100	103	99	103	101	103	100	101	NPL
Excavation	88	76	89	79	89	74	89	79	Energy Average dB(A)
	7	5	6	2	7	1	6	2	Standard Deviation
	106	88	104	85	106	77	105	85	NPL
Foundations	81	81	78	78	78	78	88	88	Energy Average dB(A)
	7	7	3	2	3	3	8	8	Standard Deviation
	99	100	85	85	85	85	108	108	NPL
Erection	82	71	85	76	85	74	79	79	Energy Average dB(A)
	6	1	5	1	7	2	3	4	Standard Deviation
	97	75	97	79	103	80	88	88	NPL
Finishing	88	74	89	76	89	75	84	84	Energy Average dB(A)
	7	4	6	4	6	3	6	6	Standard Deviation
	106	84	104	86	104	84	100	100	NPL

I – All pertinent equipment present at site.

II – Minimum required equipment present at site.

The NPL values shown in Table I obviously depend on the previously described model of site noise. For this model, the average sound pressure level depends strongly on the one or two noisiest pieces of equipment, whereas the standard deviation depends largely on the numbers and duty cycles of the less noisy equipment and on the ambient noise level.

As evident from Table I, in building construction, the initial ground clearing and excavation phases tend to be the noisiest, the subsequent foundation and erection phases tend to be somewhat less noisy, and the final finishing phase again tends to be relatively noisy. In public works construction, on the other hand, NPLs are more nearly the same for all phases, except that the erection phase tends to be less noisy.

Table II lists the two noisiest types of equipment for each site type and phase, together with the average A-weighted noise levels (at 50 ft) for this equipment. Inspection of this table indicates that rock drills, which typically are the noisiest equipment, are prevalent in the excavation and finishing phases; trucks, on the other hand, are somewhat less noisy than rock drills or similar equipment but are present in nearly all phases.

Effect of Equipment Quieting

To assess the effect of some quieting strategies on the previously described site noise model, we recalculated the NPL for three "strategies" for each type of site and each phase:

Strategy 1:

- Only the noisiest piece of equipment being quieted by 10 dB(A), with this equipment remaining at the previously specified 50 ft distance from the observer.

TABLE II. NOISIEST EQUIPMENT TYPES OPERATING AT CONSTRUCTION SITES*

Construction Phase	Construction Type: Domestic Housing	Office Bldgs.	Industrial	Public Works
Ground Clearing	Truck (91)	Truck (91)	Truck (91)	Truck (91)
	Scraper (88)	Scraper (88)	Scraper (88)	Scraper (88)
Excavation	Rock Drill (98)	Rock Drill (98)	Rock Drill (98)	Rock Drill (98)
	Truck (91)	Truck (91)	Truck (91)	Truck (91)
Foundations	Concrete Mixer (85)	Jack Hammer (88)	Jack Hammer (88)	Truck (91)
	Pneumatic Tools (85)	Concrete Mixer (85)	Concrete Mixer (85)	Scraper (88)
Erection	Concrete Mixer (85)	Derrick Crane (88)	Derrick Crane (88)	Paver (89)
	Pneumatic Tools (85)	Jack Hammer (88)	Jack Hammer (88)	Scraper (88)
Finishing	Rock Drill (98)	Rock Drill (98)	Rock Drill (98)	Truck (91)
	Truck (91)	Truck (91)	Truck (91)	Paver (89)

*Numbers in parentheses represent typical dB(A) levels at 50 ft. See Table I for definition of construction types.

4.2 SAME AS 2.18

REFERENCE 4-3

4-3

STONE & WEBSTER ENGINEERING CORPORATION
FILE COPY

R. A. Chidlaw-2/enc. PO

LSSSmith, 245/
DTKillilea
WIClifford
SJStratis, enc.
JMShivley
DHArmstrong
AEKing Jr., enc.
RHTownsend
WCDennis, enc.
JPDunhamIII, enc.
CEGay, enc.
Job Files - 2, enc.
FMMansbach, enc.

NOTED MAY 31 1977 F.Mansbach
NOTED MAY 31 1977
NOTED MAY 31 1977 S.J.Stratis
NOTED MAY 31 1977 W.Clifford

ACTION ITEM

Mr. Richard A. Chidlaw
Assistant Director for Construction
CRBRP Project Office
P. O. Box U
Oak Ridge, Tennessee 37830

MAY 31 1977

J.O. No. 12720
File No. 98.32
SWS 296

Dear Sir

CONSTRUCTION ENVIRONMENTAL MONITORING PROGRAM
CRBRP

References:

1. S&W Letter SWB-16, JR Chapman to BL Trawicky, "Draft Environmental Statement, CRBRP," dated March 10, 1976.

2. S&W Letter SWB-137, JR Chapman to BL Trawicky, "Draft Environmental Statement Applicants' Commitments, CRBRP," dated June 18, 1976.

3. ERDA Letter CN 76-152, BL Trawicky to JR Chapman, "Draft Environmental Statement," dated June 22, 1976.

4. S&W Letter SWS-200, WI Clifford to RA Chidlaw, "Final Environmental Statement, CRBRP," dated March 14, 1977.

Enclosed is a copy of Stone & Webster's Construction Environmental Monitoring Program for your approval.

Please note that in some cases our Program has deviated from the commitments of the Final Environmental Statement. These items have been previously addressed in References 1 through 4.

The specific FES commitments which are not strictly adhered to in the Stone & Webster program are itemized as follows:

a)	FES 4.6.1.1 (2) and (7)	We have modified these commitments to indicate our intention to conform to Tennessee regulations.
b)	FES 4.6.1.1. (3)	We have deleted the phrase "over a 4-month period," since we cannot adhere to this commitment.
c)	FES 4.6.1.1 (6)	We have modified this commitment to indicate our intention to conform to state and federal regulations.
d)	FES 4.6.1.1 (10)	We have modified the statement restricting on-site truck traffic to "paved roads."
e)	FES 4.6.1.1 (18)	We have provided our interpretation of how this commitment can be satisfied.
f)	FES 4.6.1.2 (1)	We have identified the responsible organization for part of this commitment.
g)	FES 4.6.2 (c)	We have modified the wording of this commitment.

I 163 S We would appreciate receiving your approval of the Construction Environmental Monitoring Program by July 1, 1977.

Very truly yours,

W. I. Clifford
Resident Manager

FMM/my
Enclosure
Standard Distribution (without enclosure)

NOTED MAY 31 1977 R.M. Smith

J.O. No. 12720
DATE: May 31, 1977

STONE & WEBSTER ENGINEERING CORPORATION

CLINCH RIVER BREEDER REACTOR PLANT PROJECT

CONSTRUCTION ENVIRONMENTAL MONITORING PROGRAM

Approved by

Senior Construction Site Representative W. J. Clifford 5/31/77

SWS296

Clinch River Breeder Reactor Plant Project

CONSTRUCTION ENVIRONMENTAL MONITORING PROGRAM

1.0 Scope

The Construction Environmental Monitoring Program (CEMP) defines the administrative procedures to be used to assure that Stone & Webster's portion of the construction effort for the Clinch River Breeder Reactor Plant (CRBRP) conforms to the applicable commitments of the US Nuclear Regulatory Commission Environmental Statement (NRC Docket No. 50-537). This program is the means by which the Construction Department will monitor its activities with regard to environmental protection. Not included in this program are the baseline meteorological and ecological monitoring programs and the construction of transmission lines which are the responsibilities of the Tennessee Valley Authority.

2.0 References

2.1 NRC Final Environmental Statement

2.2 Environmental Report

2.3 Limited Work Authorization (Later)

2.4 Construction Permit (Later)

2.5 Permit to Discharge under the National Pollutant Discharge Elimination System (Draft)

2.6 Corps of Engineers Permits (Later)

2.7 State of Tennessee Permits

.1 Open Burning

3.0 Responsibility

3.1 The overall responsibility for the implementation of the CEMP will reside with the Senior Construction Site Representative.

3.2 The Resident Engineer will have direct responsibility for assuring that all subcontractors are familiar with and that their construction activities conform to the CEMP.

3.3 The Construction Environmental Representative (CER) designated by the Senior Site Representative shall be responsible for surveillance, coordination, inspection, and report preparation as delineated in Section 4.0. He shall be familiar with the commitments of the documents referenced in Section 2.0. The CER will be responsible for routine liaison between the Engineering and Construction groups and Project Office (ERDA). He will ensure that records, notes, reports, laboratory results, administrative actions, and engineering procedures are maintained on a current basis.

3.4. A Construction Environmental Committee (CEC) shall be formed consisting of the following members:

Senior Construction Site Representative (or designee)
Resident Engineer (or designee)
Construction Environmental Representative
Safety Engineer

The CEC shall be responsible for overall evaluation and review as delineated in Section 4.0.

3.5 The procedures employed in this program (CEMP) will be subject to periodic audits by Stone & Webster's Project Quality Assurance Organization.

4.0 Implementation and Documentation

4.1 Prior to the commencement of any operation subject to the environmental limitations of Section 2.0, the Construction Environmental Representative will review these applicable environmental requirements with the responsible Construction Supervisor or subcontractor's representative to ensure that adequate precautions will be taken to minimize potential adverse effects.

4.2 The Construction Environmental Representative will conduct site inspections on a monthly basis. An inpection plan consisting of a written checklist of items will be prepared by the CER and reviewed by the Senior Site Representative (or designee) prior to the date of the inspection. Items to be checked shall be drawn from but are not necessarily limited to the commitments referenced in Section 5.0. Items may be added and related areas investigated as necessary. The CER may utilize the services of members at the Construction Environmental Committee or other S&W personnel at his option, with the approval of the Senior Site Representative.

A post inspection conference of the Construction Environmental Committee shall be held to summarize any deficiencies, unexpected effects, or evidences of damage which are detected. Necessary corrective actions shall be determined and a timetable for initiating these actions established. If necessary, a schedule of follow up inspections shall be determined to be performed by the CER prior to the next monthly inspection.

4.3 After the monthly inspection is completed, a report shall be issued to the Senior Construction Site Representative stating:

Inspection date

Names of participants

Findings, including a list of items checked, and details of any deficiencies in systems or procedures that require supervisory or management corrective or preventive action

Names of supervisors to whom action is assigned

The date by which corrective action is expected

Schedule of follow up inspections

Copies of inspection reports shall be sent to all committee members for their files. Additional copies shall be sent to Construction Supervisors and subcontractor's representative responsible for the areas inspected.

4.4 Should there be any significant construction activity in progress not meeting the commitments established in this manual, the CER shall discuss the problem with the responsible Construction Supervisor or subcontractor's representative. This discussion shall include a detailed explanation of the nonconformance, the corrective action to be taken, and the timetable for initiating that action.

4.5 Surveillance of the routine implementation and progress of the CEMP requires the use of the Construction Inspection Report form illustrated in Fig. 1. The Construction Inspection Report (CIR) forms will be completed as necessary by the CER to record program progress, special activities, and nonconformances. The necessity for additional inspections shall be determined by the results of the monthly CEC conferences. Copies of all CIR's shall be forwarded to all members of the Construction Environmental Committee and cognizant Construction Supervisors or subcontractor's representatives.

4.6 All deficiencies will be held as "open" items until satisfactory completion of corrective action has been verified. The status of open items will be determined and reported in the next monthly inspection and the CIR shall be signed off in the appropriate block.

4.7 A copy of all lab and outside reports required to prove conformance with the commitments required by the documents listed in Section 2.0 will be forwarded to the CER who will maintain an up-to-date file of the records and data.

4.8 Should a problem develop in meeting the commitments of Section 5.0, the matter shall be brought to the immediate attention of a member of the CEC. Any member of the CEC may convene the committee at any time.

4.9 The Senior Construction Site Representative shall issue Construction Environmental Monitoring Guidelines as necessary to further clarify the requirements of Section 2.0. CEMG's shall be distributed when applicable to Construction Supervisors and subcontractor's representatives and shall be addenda to this program (CEMP).

The Construction Environmental Representative shall maintain copies of all CEMG's and any other documents referenced by this program in his file.

4.10 If it becomes necessary to engage in a construction activity which may result in a significant adverse environmental impact that was not previously evaluated, or if unexpected harmful effects are detected, the Senior Construction Site Representative will notify ERDA and provide an analysis of the problem and a plan of action to eliminate or significantly reduce the harmful effects for submittal to the Director of Licensing of the Nuclear Regulatory Commission as required by the Final Environmental Statement, Summary and Conclusions, Paragraphs 7(e) and 7(f).

5.0 Commitments

The following summarizes the commitments made to limit adverse effects during plant construction activities. Portions have been quoted from the Final Environmental Statement (FES). Other statements describe Stone & Webster's intentions regarding the FES commitment.

Where applicable, reference is made to Specifications, Construction Methods Procedures (CMP), and Construction Environmental Monitoring Guidelines (CEMG) or other documents which give more detailed information on the subject.

From FES 4.6.1.1

1. "Open burning will conform to State and Federal air pollution requirements."

   Reference CEMG 1.0

2&7. Disposal of wastes will conform to Tennessee Solid Waste Management Regulations.

   Reference CEMG 5.0

3. "Blasting will be restricted to small multiple charges..."

   Reference B&R Spec. 3066-19-2A

   CMP 2.1

4. "Depth of the borrow pit will not exceed 25 feet and the sides, a 2 to 1 slope. Encroachment upon the Hensley Cemetary and the Indian Mound will be avoided. Reclamation will consist of grading, returning topsoil and seeding native grasses and forbs."

   Reference B&R Spec. 3066-19-1

   B&R Spec. 3066-19-2A

5. "In constructing the barge-unloading facility, river siltation will be controlled by doing major construction elements in sequence."

   Reference CEMG 4.0

6. Disposal of hazardous wastes and pollutants will conform to State and Federal regulations.

8. "Treated sanitary wastewater discharged to the river will meet standards of the Tennessee Department of Public Health. Chemical toilets will be used in remote areas, with approved disposal of wastes."

Reference CEMG 3.0

9. "General erosion control will consist of leveling rutted areas, maintaining contours where possible, leaving tree stands where possible in the plant construction area, constructing drainage ditches at the base of stockpiles and excavation slopes, rip-rapping major diversion channels where erosive velocities are indicated, holding up drainage water in settling basins before discharge to the river, developing a storm drainage system for site access roads and spoil laydown areas, landscaping as soon as construction schedules permit, providing burlap protection to seeding on slopes, and planting trees or other appropriate vegetation."

10. The site access road will be paved. On site traffic will be controlled by Stone & Webster.

Reference B&R Spec. 3066-19-2A

CMP 2.2

11. "Dust will be controlled by sprinkling roads and construction areas."

13. "Chemicals will not be used in clearing land..."

18. Construction will be limited to those areas shown on approved drawings.

19. "A fire prevention and control plan will be developed and applied."

Reference S&W Safety and Health Program (Safety Manual)

20. "Siltation impacts will be reduced by dredging and constructing behind temporary dams all such structures as intake channels that require disturbing the soil-water interface."

Reference CEMG 4.0

From FES 4.6.1.2

1. "Prior to construction, the construction plant manager will be provided with locations of critical ecological elements..." Inspections of these species will be performed by Westinghouse Environmental Systems Division.

   Reference CEMG 2.0

2. "Construction of the intake, discharge, and barge facilities will be scheduled so as to mitigate environmental impacts."

   Reference CEMG 4.0

From FES 4.6.2

a. "The applicant shall set aside an appropriate buffer zone upslope of cover type vegetation 32 and 33 on the north edge of the site to ensure their preservation and protection during the construction period. (Reference Environmental Report Figure 2.7-6)" There is no construction planned in this area. (See response to Item 18 of FES 4.6.1.1.)

b. "Water discharged from settling basins shall meet the effluent limitations which are promulgated by EPA in the National Pollutant Discharge Elimination System Permit."

   Reference CEMG 3.0

c. If possible, work schedules will be staggered with those of nearby plants to avoid unreasonable congestion on State Road 58 in Roane County.

d. "Installation and removal of the cofferdams for the intake and the barge unloading facilities shall be conducted during the August to March period unless there is evidence showing that those activities at other times would not adversely affect fish spawning."

   Reference CEMG 4.0

Figure 1

STONE & WEBSTER ENGINEERING CORPORATION	DATE	REPORT NO.
CONSTRUCTION INSPECTION REPORT	INSPECTOR'S NAME	
CLIENT		J.O. NO.
LOCATION		UNIT NO.
ITEM INSPECTED: (DESCRIBE)		
VENDOR / CONTRACTOR:		
PURCHASE ORDERS / CONTRACT NO.		
INSPECTION REFERENCES:		
INSPECTIONS PERFORMED:		
NONCONFORMANCES OBSERVED:		
INSPECTED BY (SIGNATURE)	NONCONFORMANCES RESOLVED: (SIGNATURE)	DATE

Appendix A

Construction Environmental Monitoring Guidelines

Index

Construction Environmental Monitoring Guideline No. 1.0

Open Burning

Date: May 31, 1977

1. Waste material to be burned shall consist only of wood products, trees, brush, etc., cleared from the site only. No tires, heavy oils or products of similar combustion characteristics are to be included in material burned or used to kindle the fire. No. 2 fuel oil or similar may be used.

   Burning of lumber, dunnage, paper products, and other items of comparable combustion characteristics excluding garbage is allowed.

2. Burning shall be done between the hours of 9:00 a.m. and 4:00 p.m. six days per week.

3. Burning shall be done in small piles, and in such a manner that no visible emission shall be evident after 5:00 p.m.

4. Burning shall be done within the approved areas shown on S&W Dwg. YSK-12720-007.

5. On each day that open burning is done, the following persons shall be notified.

   1. The Oak Ridge Fire Department (483-5671)

   2. the Plant Shift Supervisor at X-10 (483-8611, ext. 36606)
Y-12 (483-8611, ext. 37172)
K-25 (483-8611, ext. 33282)

   3. the State Forest Service (354-0258)

Construction Environmental Monitoring Guideline No. 2.0

Threatened and Unusual Plant Species

Date: May 31, 1977

1. Prior to commencing construction activities beyond the clearing and grubbing limits shown on the drawings, the responsible construction supervisor or contractor's representative shall be issued a copy of the following attached documents:

   a. "Threatened and Unusual Plant Species on the CRBRP Site."

   b. S&W Dwg. 12720-YSK-010.

STONE & WEBSTER ENGINEERING CORPORATION

February 10, 1977

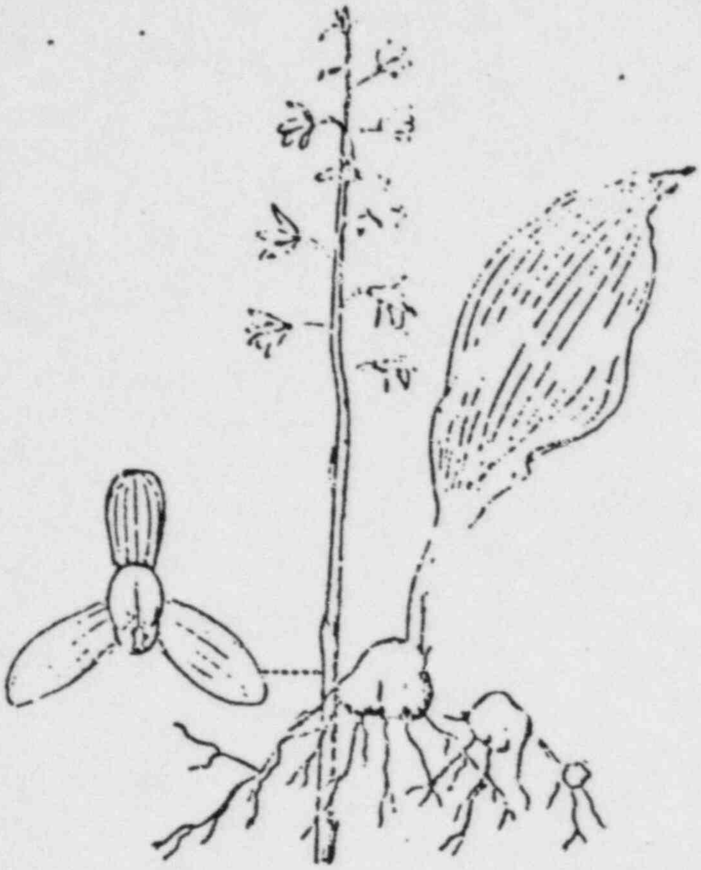
Threatened and Unusual Plant Species on the CRBRP Site

The forest surrounding the CRBRP site supports a variety of threatened and unusual plant species. Within a mile of the Nuclear Island, the following species have been identified as unusual or rare:

Carey's Saxifrage (Saxifraga Careyana)
Adam and Eve Orchid (Aplectrum hyemale)
Lizard's Tail (Saururus cernuus)
Wister's Coral - Root (Corallorhiza Wisteriana)
Southern Buckthorn (Bumelia lycioides)
Common Adder's Tongue (Ophioglossum vulgatum)

Of these species, only Carey's Saxifrage appears on the 1975 Smithsonian Institution endangered and threatened plant species list. Adam and Eve Orchid, Lizard's Tail, and Wister's Coral - Root are unusual but not rare. Southern Buckthorn and Common Adder's Tongue are widespread species but are uncommon in the site area. All of these plants are fragile and care should be taken not to disturb them or the area within 50 ft. of them.

Local habitats are shown on S & W Dwg. 12720-YSK-010. They can be located in the field by looking for the signs labeled "OFF LIMITS - FRAGILE ECOSYSTEM", at the borders of their habitats.



Aplectrum hyemale (Adam and Eve Orchid). Putty-root. Leaf basal, its blade elliptic, 10-15 cm. long. Scape 3-6 dm. tall, with a few linear-oblong sheathing bracts; raceme 7-15-flowered. Sepals and petals 10-15 mm. long, purplish toward the base, brown toward the summit. Lip white, marked with violet, 10-15 mm. long.

Located on a south facing slope approximately 0.8 mile north of CRBRP.

Saururus cernuus (Lizard's Tail). Stem branched, 5-12 dm. tall. Leaves with long petioles sheathing at base, the blades cordate-ovate, 6-15 cm. long, about half as wide. Spikes 1 or 2, peduncled, terminal but often surpassed by axillary branches, 6-15 cm. long, nodding at the tip before anthesis. Filaments white, 3-4 mm. long, much surpassing the pistils. Fruit 2-3 mm. in diameter. Swamps and marshes.

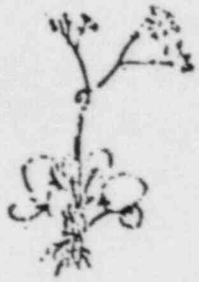
Located on a small inlet approximately 0.3 mile west-southwest of CRBRP.

Ophioglossum vulgatum (Common Adder's Tongue). Plant 7-36 cm. long. Stipe 1.5-19 cm., usually 6-13 cm. long. Sterile blade oblong-elliptic to ovate, 1-10 cm., usually 4-8 cm. long. 0.8-4 cm., usually 2-3 cm. wide, rounded, obtuse, or subacute at the apex but not apiculate, sessile or distinctly stalked: venation regularly areolate, the areoles all small, not enclosing secondary areoles. Stalk of the fertile blade 3-17 cm., usually 7-14 cm. long, the blade 1-4 cm. long, 2.5-4 mm. wide. Sporangia 0.6-1.2 mm. in diameter.

Located approximately 0.3 mile southeast of the CRBRP.

Corallorhiza Wisteriana (Wister's Coral-Root) Stem purple reddish, 1-4 dm. tall. Raceme 3-7 cm. long, 10-flowered. Sepals and lateral petals extending forward over the column, scarely spreading, narrowly lanceolate, 7-8 mm. long, greenish yellowish, tinged with purple and marked with short purple lines. Lip deflexed, about as long as the sepals, narrowed below into a slender claw more than half as long as the blade, the latter broadly oval, crenulate, notched at the rounded summit, white, dotted with purple.

Located on a north-facing slope approximately 0.3 mile northeast of CRBRP.



Saxifraga Careyana (Carey's Saxifrage). Plant 1-5 dm. tall. Leaves ovate to slightly obovate, to 14 cm. long and 4 cm. wide, glabrous above, pubescent to glabrate beneath, obtuse or acute, coarsely serrate or dentate, base cuneate to attenuate; petioles pubescent. Calyx tube campanulate, 0.5-1 mm long, lobes 1-1.5 mm long, reflexed in fruit; petals clawed or not clawed, 1.5-4 mm long; stamens exserted, filaments filiform. Capsules usually 2.5-3 mm long; seeds longitudinally striate, cristate, 0.6-0.7 mm long. May-June. Moist rocks and seepage slopes, rare; mts. of NC, VA, and Tenn.

Located on a steep sloping hillside facing the Clinch River approximately 0.8 northeast of the CRBRP.

Bumelia lycioides (Southern Buckthorn). Shrub or small tree, up to 10 m tall. Leaves elliptic to elliptic-oblanceolate, commonly 5-12 cm. long, a fourth to a third as wide, acuminate to obtuse, nearly or quite glabrous, prominently reticulately veined. Flowers 10-60 in a cluster, the pedicels 5-12 mm. long, glabrous or with a few scattered hairs.

Located on a small hilltop 0.2 mile east of the CRBRP.

Descriptions and sketches have been extracted from the following references:

1.) "Manual of the Vascular Flora of the Carolinas", Radford et.al., University of North Carolina Press, Chapel Hill, NC.

2.) "Illustrated Flora of the Northeastern United States and Adjacent Canada", Henry A. Gleason, Hafner Press, New York, NY.

Construction Environmental Monitoring Guideline No. 3.0

Monitoring, Recording, and Reporting Discharges

Date: May 31, 1977
(Draft)

1. Monitoring, recording, and reporting shall be performed for the following discharge serial numbers shown on Fig. 3.1:

   002 CRBRP Construction Period Sanitary Discharge
   003 CRBRP Construction Period Discharge Impounding Pond "A"
   004 CRBRP Construction Period Discharge Impounding Pond "B"
   005 CRBRP Construction Period Discharge Impounding Pond "C"
   006 CRBRP Construction Period Discharge Impounding Pond "D"

2. Sampling frequency shall be:

   Sewage Treatment Plant Effluent - 5 grab samples per week.

   Sewage Treatment Plant Influent - 3 grab samples per week.

   Impounding Pond Effluent - 3 grab samples per week during periods of actual discharge (each pond).

   Samples shall be of sufficient volume to allow performance of all required tests.

   The CER shall also take monthly readings of the flow recorder at the waste treatment plant.

3. Measurement frequencies and acceptance criteria are:

	Effluent Characteristic	DISCHARGE LIMITATIONS kg. 1 day (lbs./day) Daily Average	kg. 1 day (lbs./day) 7-Day Average	mg./l. Daily Average	mg./l. 7-Day Average	Measurement Frequency
WASTE TREATMENT PLANT	BOD_5	6.96 (15.3)	10.4 (23.0)	30	45	3/week *
	TOTAL SUSPENDED SOLIDS	6.96 (15.3)	10.4 (23.0)	30	45	3/week *
	SETTLEABLE SOLIDS (ml/l)	NA	NA	1.0	1.0	5/week
	DISSOLVED OXYGEN (mg/l)	NA	NA	NA	NA	5/week
	AMMONIA (as N)	1.16 (2.56)	1.85 (4.09)	5.0	8.0	1/week
	TOTAL CHLORINE RESIDUAL	NA	NA	NA	NA	5/week
	FECAL COLIFORM (number/100 ml.)	NA	NA	200	400	3/week *
	PH (standard units)	NA	NA	6.0-9.0	NA	1/week
		INSTANTANEOUS MAXIMUM				
IMPOUNDING PONDS	TOTAL SUSPENDED SOLIDS (mg./l)	NA				1/week
	SETTLEABLE SOLIDS (ml/l)	NA				3/week
	PH (standard units)	6.0 - 9.0				3/week

* - Reduced to one/two weeks during periods when flow is less than 50,000 gpd.

The CER shall send samples to the testing lab as required for the performance of the above tests.

4. For all samples or measurements taken, the CER shall maintain a log of:

   a. The exact place, date, and time of sampling.

   b. The dates the analyses were performed.

   c. The person(s) who performed the analyses.

   d. The analytical techniques or methods used.

   e. The results of all required analyses.

5. Monitoring results for the previous three months shall be summarized for each month by the CER on an EPA Discharge Monitoring Report Form (Attachment 1). This report shall be forwarded to ERDA Construction Division and Public Safety no later than the 21st day of the month following the reporting period. A copy shall be maintained in the CER's files.

6. If, for any reason, discharges do not comply or will be unable to comply with any daily maximum effluent limitation, the CER will notify the ERDA Construction Division within two days and provide them with the following information in writing:

   a. A description of the discharge and cause of noncompliance; and

   b. The period of noncompliance, including exact dates and times; or, if not corrected, the anticipated time the noncompliance is expected to continue, and steps being taken to reduce, eliminate and prevent recurrence of the noncomplying discharge.

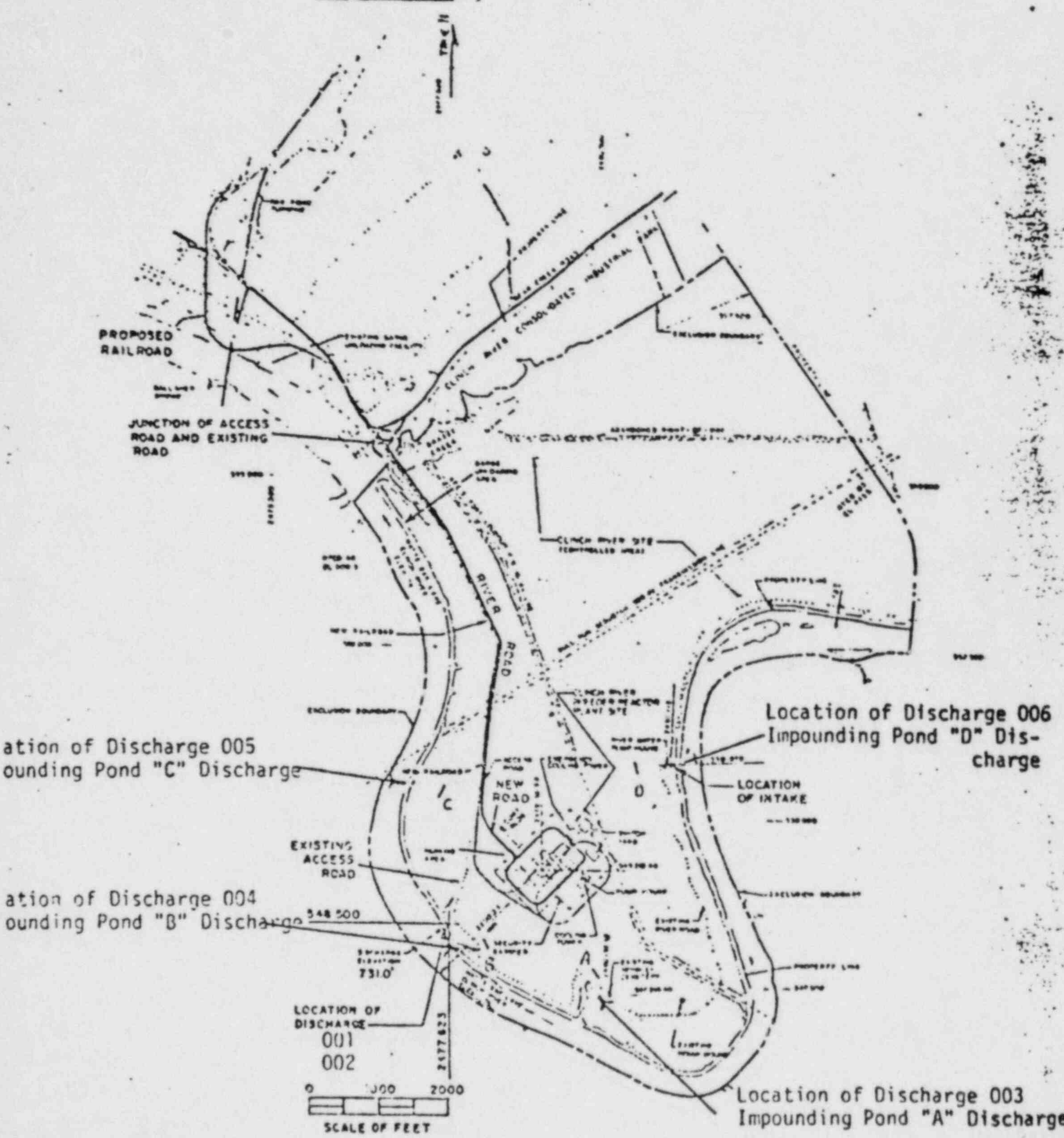
7. Any diversion from or bypass of facilities is prohibited, except (1) where unavoidable to prevent loss of life or severe property damage, or (2) where excessive storm drainage or runoff would damage facility.

   The CER shall promptly notify the ERDA Construction Department in writing of each diversion or bypass.

8. Should monitoring be carried out more frequently than required, using approved analytical methods, the results of such monitoring shall be included in the calculation and reporting of the values required in the Discharge Monitoring Report Form (EPA No. 3320-1). Such increased frequency shall also be indicated.

9. All records and information resulting from the monitoring activities required, including all records of analyses performed and calibration and maintenance of instrumentation and recordings from continuous monitoring instrumentation shall be retained for a minimum of three (3) years by the CER.

Figure 3.1



LOCATION MAP
FROM CRBRP ENVIRONMENTAL REPORT
CLINCH RIVER BREEDER REACTOR PLANT
OAK RIDGE, ROANE COUNTY, TENNESSEE
APRIL 1976 Revised August 1976

Attachment 1

Sample EPA Discharge Monitoring Report Forms for Construction Period Discharges.

Serial Number 004 Impounding Pond "B"

0028801	004		35°53'13"N / 84°23'09"W
PERMIT NUMBER	DIS	SIC	LATITUDE / LONGITUDE

REPORTING PERIOD: FROM YEAR | MO | DAY TO YEAR | MO | DAY

INSTRUCTIONS

1. Provide dates for period covered by this report in spaces marked "REPORTING PERIOD".
2. Enter reported minimum, average and maximum values under "QUANTITY" and "CONCENTRATION" in the units specified for each parameter as appropriate. Do not enter values in boxes containing asterisks. "AVERAGE" is average computed over actual time discharge is operating. "MAXIMUM" and "MINIMUM" are extreme values observed during the reporting period.
3. Specify the number of analyzed samples that exceed the maximum *(and/or minimum as appropriate)* permit conditions in the columns labeled "No. Ex." If none, enter "O".
4. Specify frequency of analysis for each parameter as No. analyses/No. days. *(e.g., "3/7" is equivalent to 3 analyses performed every 7 days.)* If continuous enter "CONT."
5. Specify sample type ("grab" or "__ hr. composite") as applicable. If frequency was continuous, enter "NA".
6. Appropriate signature is required on bottom of this form.
7. Remove carbon and retain copy for your records.
8. Fold along dotted lines, staple and mail Original to office specified in permit.

PARAMETER		QUANTITY (3 card only) MINIMUM	AVERAGE	MAXIMUM	UNITS	NO. EX	CONCENTRATION (4 card only) MINIMUM	AVERAGE	MAXIMUM	UNITS	NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
FLOW	REPORTED				MGD (m³/day)							1/7	NA
	PERMIT CONDITION												
TOTAL SUSPENDED SOLIDS	REPORTED									mg/1		1/7	Grab
	PERMIT CONDITION							NA					
SETTLEABLE SOLIDS	REPORTED									ml/1		3/7	Grab
	PERMIT CONDITION							NA					
PH	REPORTED									standard units		3/7	Grab
	PERMIT CONDITION						6.0		9.0				
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												

NAME OF PRINCIPAL EXECUTIVE OFFICER | TITLE OF THE OFFICER | DATE

Serial Number 003 Impounding Pond "A"

ST (2-3)	PERMIT NUMBER (4-15)	DIS (17-19)	SIC	LATITUDE	LONGITUDE
TN	0028801	003		35°53'08"N	84°22'49"W

REPORTING PERIOD: FROM (20-21) YEAR (22-23) MO (24-25) DAY TO (26-27) YEAR (28-29) MO (30-31) DAY

INSTRUCTIONS

1. Provide dates for period covered by this report in spaces marked "REPORTING PERIOD".
2. Enter reported minimum, average and maximum values under "QUANTITY" and "CONCENTRATION" in the units specified for each parameter as appropriate. Do not enter values in boxes containing asterisks. "AVERAGE" is average computed over actual time discharge is operating. "MAXIMUM" and "MINIMUM" are extreme values observed during the reporting period.
3. Specify the number of analyzed samples that exceed the maximum *(and/or minimum as appropriate)* permit conditions in the columns labeled "No. Ex." If none, enter "O".
4. Specify frequency of analysis for each parameter as No. analyses/No. days. *(e.g., "3/7" is equivalent to 3 analyses performed every 7 days.)* If continuous enter "CONT."
5. Specify sample type ("*grab*" or "___ *hr. composite*") as applicable. If frequency was continuous enter "NA".
6. Appropriate signature is required on bottom of this form.
7. Remove carbon and retain copy *for your records.*
8. Fold along dotted lines, staple and mail Original to office specified in permit.

PARAMETER (32-37)		QUANTITY (3 card only) MINIMUM (38-45)	AVERAGE (46-53)	MAXIMUM (54-61)	UNITS	NO. EX (62-63)	CONCENTRATION (4 card only) MINIMUM (38-45)	AVERAGE (46-53)	MAXIMUM (54-61)	UNITS	NO. EX (62-63)	FREQUENCY OF ANALYSIS (64-68)	SAMPLE TYPE (69-75)
FLOW	REPORTED				MGD (m^3/day)							1/7	NA
	PERMIT CONDITION												
TOTAL SUSPENDED SOLIDS	REPORTED									mg/l		1/7	Grab
	PERMIT CONDITION							NA					
SETTLEABLE SOLIDS	REPORTED									ml/l		3/7	Grab
	PERMIT CONDITION							NA					
PH	REPORTED									standard units		3/7	Grab
	PERMIT CONDITION						6.0		9.0				
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												

Serial Number 002 Sanitary Discharge

PERMIT NUMBER	DIS	SIC	LATITUDE	LONGITUDE
0028801	002	4952	35°53'17"N	84°23'12"W

REPORTING PERIOD: FROM YEAR MO DAY TO YEAR MO DAY

INSTRUCTIONS

1. Provide dates for period covered by this report in spaces marked "REPORTING PERIOD".
2. Enter reported minimum, average and maximum values under "QUANTITY" and "CONCENTRATION" in the units specified for each parameter as appropriate. Do not enter values in boxes containing asterisks. "AVERAGE" is average computed over actual time discharge is operating. "MAXIMUM" and "MINIMUM" are extreme values observed during the reporting period.
3. Specify the number of analyzed samples that exceed the maximum *(and/or minimum as appropriate)* permit conditions in the columns labeled "No. Ex." If none, enter "O".
4. Specify frequency of analysis for each parameter as No. analyses/No. days. *(e.g., "3/7" is equivalent to 3 analyses performed every 7 days.)* If continuous enter "CONT."
5. Specify sample type ("grab" or "___ hr. composite") as applicable. If frequency was continuous, enter "NA".
6. Appropriate signature is required on bottom of this form.
7. Remove carbon and retain copy for your records.
8. Fold along dotted lines, staple and mail Original to office specified in permit.

PARAMETER		QUANTITY (3 card only) MINIMUM	QUANTITY AVERAGE	QUANTITY MAXIMUM	UNITS	NO. EX	CONCENTRATION (4 card only) MINIMUM	CONCENTRATION AVERAGE	CONCENTRATION MAXIMUM	UNITS	NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
PH	REPORTED				NA					standard units		1/7	Grab
	PERMIT CONDITION		NA				6.0		9.0				
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
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	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												

NAME OF PRINCIPAL EXECUTIVE OFFICER	TITLE OF THE OFFICER	DATE

Serial Number 002 Sanitary Discharge

(2-3) ST	(4-10) PERMIT NUMBER	(17-19) DIS	SIC	LATITUDE	LONGITUDE
TN	0028801	002	4952	35°53'17"N	84°23'12"W

REPORTING PERIOD: FROM (20-21) YEAR (22-23) MO (24-25) DAY TO (26-27) YEAR (28-29) MO (30-31) DAY

INSTRUCTIONS

1. Provide dates for period covered by this report in spaces marked "REPORTING PERIOD".
2. Enter reported minimum, average and maximum values under "QUANTITY" and "CONCENTRATION" in the units specified for each parameter as appropriate. Do not enter values in boxes containing asterisks. "AVERAGE" is average computed over actual time discharge is operating. "MAXIMUM" and "MINIMUM" are extreme values observed during the reporting period.
3. Specify the number of analyzed samples that exceed the maximum (and/or minimum as appropriate) permit conditions in the columns labeled "No. Ex." If none, enter "O".
4. Specify frequency of analysis for each parameter as No. analyses/No. days. (e.g., "3/7" is equivalent to 3 analyses performed every 7 days.) If continuous enter "CONT."
5. Specify sample type ("grab" or "___ hr. composite") as applicable. If frequency was continuous, enter "NA".
6. Appropriate signature is required on bottom of this form.
7. Remove carbon and retain copy for your records.
8. Fold along dotted lines, staple and mail Original to office specified in permit.

(32-37) PARAMETER		QUANTITY (3 card only) MINIMUM (38-45)	AVERAGE (46-53)	MAXIMUM (54-61)	UNITS	(62-63) NO. EX	CONCENTRATION (4 card only) MINIMUM (38-45)	AVERAGE (46-53)	MAXIMUM (54-61)	UNITS	(62-63) NO. EX	(64-68) FREQUENCY OF ANALYSIS	(69-70) SAMPLE TYPE
FLOW	REPORTED				MGD (m^3/day)					NA		CONT.	NA
	PERMIT CONDITION							NA					
BOD_5	REPORTED				Kg/day (lbs/day)					mg/1		3/7	Grab
	PERMIT CONDITION												
TOTAL SUSPENDED SOLIDS	REPORTED				Kg/day (lbs/day)					mg/1		3/7	Grab
	PERMIT CONDITION												
SETTLEABLE SOLIDS	REPORTED				NA					ml/1		5/7	Grab
	PERMIT CONDITION							1.0					
DISSOLVED OXYGEN	REPORTED				NA					mg/1		5/7	Grab
	PERMIT CONDITION		NA					NA					
AMMONIA	REPORTED				Kg/day (lbs/day)					mg/1		1/7	Grab
	PERMIT CONDITION												
TOTAL CHLORINE RESIDUAL	REPORTED				NA					ppm		5/7	Grab
	PERMIT CONDITION		NA					NA					
FECAL COLIFORM	REPORTED				NA					number/100ml		3/7	Grab
	PERMIT CONDITION		NA										

NAME OF PRINCIPAL EXECUTIVE OFFICER | TITLE OF THE OFFICER | DATE

Serial Number 005 Impounding Pond "C"

ST	PERMIT NUMBER	DIS	SIC	LATITUDE	LONGITUDE
TN	0028801	005		35°53'36"N	84°23'19"W

REPORTING PERIOD: FROM | YEAR | MO | DAY | TO | YEAR | MO | DAY |

INSTRUCTIONS

1. Provide dates for period covered by this report in spaces marked "REPORTING PERIOD".
2. Enter reported minimum, average and maximum values under "QUANTITY" and "CONCENTRATION" in the units specified for each parameter as appropriate. Do not enter values in boxes containing asterisks. "AVERAGE" is average computed over actual time discharge is operating. "MAXIMUM" and "MINIMUM" are extreme values observed during the reporting period.
3. Specify the number of analyzed samples that exceed the maximum (and/or minimum as appropriate) permit conditions in the columns labeled "No. Ex." If none, enter "O".
4. Specify frequency of analysis for each parameter as No. analyses/No. days. (e.g., "3/7" is equivalent to 3 analyses performed every 7 days.) If continuous enter "CONT."
5. Specify sample type ("grab" or "__ hr. composite") as applicable. If frequency was continuous, enter "NA".
6. Appropriate signature is required on bottom of this form.
7. Remove carbon and retain copy for your records.
8. Fold along dotted lines, staple and mail Original to office specified in permit.

PARAMETER		QUANTITY (3 card only) MINIMUM	AVERAGE	MAXIMUM	UNITS	NO. EX	CONCENTRATION (4 card only) MINIMUM	AVERAGE	MAXIMUM	UNITS	NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
FLOW	REPORTED				MGD (m^3/day)							1/7	NA
	PERMIT CONDITION												
TOTAL SUSPENDED SOLIDS	REPORTED									mg/1		1/7	Grab
	PERMIT CONDITION							NA					
SETTLEABLE SOLIDS	REPORTED									ml/1		3/7	Grab
	PERMIT CONDITION							NA					
PH	REPORTED									standard units		3/7	Grab
	PERMIT CONDITION						6.0		9.0				
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												

Serial Number 006 Impounding Pond "D"

TN	0028801	006		35°53'39"N	84°22'33"W
ST	PERMIT NUMBER	DIS	SIC	LATITUDE	LONGITUDE

REPORTING PERIOD: FROM YEAR MO DAY TO YEAR MO DAY

INSTRUCTIONS

1. Provide dates for period covered by this report in spaces marked "REPORTING PERIOD".
2. Enter reported minimum, average and maximum values under "QUANTITY" and "CONCENTRATION" in the units specified for each parameter as appropriate. Do not enter values in boxes containing asterisks. "AVERAGE" is average computed over actual time discharge is operating. "MAXIMUM" and "MINIMUM" are extreme values observed during the reporting period.
3. Specify the number of analyzed samples that exceed the maximum *(and/or minimum as appropriate)* permit conditions in the columns labeled "No. Ex." If none, enter "O".
4. Specify frequency of analysis for each parameter as No. analyses/No. days. *(e.g., "3/7" is equivalent to 3 analyses performed every 7 days.)* If continuous enter "CONT."
5. Specify sample type ("grab" or "— hr. composite") as applicable. If frequency was continuous enter "NA".
6. Appropriate signature is required on bottom of this form.
7. Remove carbon and retain copy for your records.
8. Fold along dotted lines, staple and mail Original to office specified in permit.

PARAMETER		QUANTITY (3 card only) MINIMUM	AVERAGE	MAXIMUM	UNITS	NO. EX	CONCENTRATION (4 card only) MINIMUM	AVERAGE	MAXIMUM	UNITS	NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
FLOW	REPORTED				MGD (m³/day)							1/7	NA
	PERMIT CONDITION												
TOTAL SUSPENDED SOLIDS	REPORTED									mg/l		1/7	Grab
	PERMIT CONDITION							NA					
SETTLEABLE SOLIDS	REPORTED									ml/l		3/7	Grab
	PERMIT CONDITION							NA					
PH	REPORTED									standard units		3/7	Grab
	PERMIT CONDITION						6.0		9.0				
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												
	REPORTED												
	PERMIT CONDITION												

NAME OF PRINCIPAL EXECUTIVE OFFICER | TITLE OF THE OFFICER | DATE

THE WHITE HOUSE

Office of the Press Secretary

For Immediate Release

STATEMENT BY THE PRESIDENT

A more abundant, affordable, and secure energy future for all Americans is a critical element of this Administration's economic recovery program. While homeowners and business firms have shown remarkable ingenuity and resourcefulness in meeting their energy needs at lower cost through conservation, it is evident that sustained economic growth over the decades ahead will require additional energy supplies. This is particularly true of electricity, which will supply an increasing share of our energy.

If we are to meet this need for new energy supplies, we must move rapidly to eliminate unnecessary government barriers to efficient utilization of our abundant, economical resources of coal and uranium. It is equally vital that the utilities -- investor-owned, public, and co-ops -- be able to develop new generating capacity that will permit them to supply their customers at the lowest cost, be it coal, nuclear, hydro, or new technologies such as fuel cells.

One of the best potential sources of new electrical energy supplies in the coming decades is nuclear power. The U.S. has developed a strong technological base in the production of electricity from nuclear energy. Unfortunately, the Federal Government has created a regulatory environment that is forcing many utilities to rule out nuclear power as a source of new generating capacity, even when their consumers may face unnecessarily high electric rates as a result. Nuclear power has become entangled in a morass of regulations that do not enhance safety but that do cause extensive licensing delays and economic uncertainty. Government has also failed in meeting its responsibility to work with industry to develop an acceptable system for commercial waste disposal, which has further hampered nuclear power development.

To correct present government deficiencies and to enable nuclear power to make its essential contribution to our future energy needs, I am announcing today a series of policy initiatives:

(1) I am directing the Secretary of Energy to give immediate priority attention to recommending improvements in the nuclear regulatory and licensing process. I anticipate that the Chairman of the Nuclear Regulatory Commission will take steps to facilitate the licensing of plants under construction and those awaiting licenses. Consistent with public health and safety, we must remove unnecessary obstacles to deployment of the current generation of nuclear power reactors. The time involved to proceed from the planning stage to an operating license for new nuclear power plants has more than doubled since the mid-1970s and is presently some 10-14 years. This process must be streamlined, with the objective of shortening the time involved to 6-8 years, as is typical in some other countries.

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(2) I am directing that government agencies proceed with the demonstration of breeder reactor technology, including completion of the Clinch River Breeder Reactor. This is essential to ensure our preparedness for longer-term nuclear power needs.

(3) I am lifting the indefinite ban which previous Administrations placed on commercial reprocessing activities in the United States. In addition, we will pursue consistent, long-term policies concerning reprocessing of spent fuel from nuclear power reactors and eliminate regulatory impediments to commercial interest in this technology, while ensuring adequate safeguards.

It is important that the private sector take the lead in developing commercial reprocessing services. Thus I am also requesting the Director of the Office of Science and Technology Policy, working with the Secretary of Energy, to undertake a study of the feasibility of obtaining economical plutonium supplies for the Department of Energy by means of a competitive procurement. By encouraging private firms to supply fuel for the breeder program at a cost that does not exceed that of government-produced plutonium, we may be able to provide a stable market for private sector reprocessing, and simultaneously reduce the funding needs of the U.S. breeder demonstration program.

(4) I am instructing the Secretary of Energy, working closely with industry and state governments, to proceed swiftly toward deployment of means of storing and disposing of commercial high-level radioactive waste. We must take steps now to accomplish this objective and demonstrate to the public that problems associated with management of nuclear waste can be resolved.

(5) I recognize that some of the problems besetting the nuclear option are of a deep-seated nature and may not be quickly resolved. Therefore, I am directing the Secretary of Energy and the Director of the Office of Science and Technology Policy to meet with representatives from the universities, private industry and the utilities and requesting them to report to me on the obstacles which stand in the way of increased use of nuclear energy and the steps needed to overcome them in order to assure the continued availability of nuclear power to meet America's future energy needs not later than September 30, 1982.

Eliminating the regulatory problems that have burdened nuclear power will be of little use if the utility sector cannot raise the capital necessary to fund construction of new generating facilities. We have already taken significant steps to improve the climate for capital formation with the passage of my program for economic recovery. The tax bill contains substantial incentives designed to attract new capital into industry.

Safe, commercial nuclear power can help meet America's future energy needs. The policies and actions that I am announcing today will permit a revitalization of the U.S. industry's efforts to develop nuclear power. In this way, native American genius -- not arbitrary federal policy -- will be free to provide for our energy future.

# # # #

ATTACHMENT