THE EFFECTS OF IMPOUNDMENT ON THE CARP, _CYPRINUS CARPIO_ AND THE RIVER CARPSUCKER, _CARPIODES CARPIO_ IN THE CEDAR BLUFF RESERVOIR, WESTERN KANSAS

by

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TABLE OF CONTENTS

INTRODUCTION 1

Natural History of the Carp 3

Natural History of the River Carpsucker 6

DESCRIPTION OF THE STUDY AREA 9

MATERIALS AND METHODS 14

Age and Growth Determination 14

Condition Factor 16

Fat Content Determination 17

Methods of Analyses 18

RESULTS 20

Condition Factor

Carp 20

Carpsucker 25

Fat Content Analysis

Carp 29

Carpsucker 32

Growth Rate

Carp 33

Carpsucker 44

DISCUSSION 55

SUMMARY 60

ACKNOWLEDGMENTS 62

LITERATURE CITED 63

TABLE OF FIGURES

FIGURE

1. Reservoirs in Kansas and Enlarged Study Area 12

2. Carp from the Cedar Bluff Reservoir 21

3. Carp from the Smoky Hill River 21

4. Carp from the Cedar Bluff Reservoir 22

5. Carp from the Smoky Hill River 22

6. River Carpsucker from the Cedar Bluff Reservoir 23

7. River Carpsucker from the Smoky Hill River 23

8. Distribution, by Length Group, of Carp from the Cedar Bluff Reservoir 35

9. Distribution, by Length Group, of Carp from the Smoky Hill River 37

10. Body Length-Scale Radius Relationship of Carp from the Smoky Hill River and Cedar Bluff Reservoir 39

11. Distribution, by Length Group, of Carpsucker from the Smoky Hill River 46

12. Distribution, by Length Group, of Carpsucker from the Cedar Bluff Reservoir 48

13. Body Length-Scale Radius Relationship of Carpsucker from the Smoky Hill River and Cedar Bluff Reservoir 50

TABLE OF TABLES

TABLE

1. Physical and Chemical Characteristics of Sampling Stations Located on the Smoky Hill River 13

2. Carp Data. Two-way Means (Environment, Sex) of the Condition Coefficient (K_{TL}) 24

3. Carp Data. Two-way Means (Environment, Length Group) of the Condition Coefficient (K_{TL}) 24

4. Carp Data. Analysis of Variance of the Condition Coefficient (K_{TL}) 25

5. Comparison of Carp Length Group (Condition Coefficient) Means Using Fisher's LSD Procedure 26

6. Comparison of Carp Environment/Length Group (Condition Coefficient) Means Using Fisher's LSD Procedure 26

7. Carpsucker Data. Two-way Means (Environment, Sex) of the Condition Coefficient (K_{TL}) 27

8. Carpsucker Data. Two-way Means (Environment, Length Group) of the Condition Coefficient (K_{TL}) 27

9. Carpsucker Data. Analysis of Variance of the Condition Coefficient (K_{TL}) 28

10. Comparison of Carpsucker Sex (Condition Coefficient) Means Using Fisher's LSD Procedure 29

11. Comparison of Carpsucker Length Group (Condition Coefficient) Means Using Fisher's LSD Procedure 29

12. Comparison of Carpsucker Environment/Sex (Condition Coefficient) Means Using Fisher's LSD Procedure 30

13. Comparison of Carpsucker Environment/Length Group (Condition Coefficient) Means Using Fisher's LSD Procedure 30

14. Carp Fat Content Data. Two-way (Environment, Sex) Means of the Percentage Fat Content 31

15. Carp Data. Two-way Analysis of Variance of Percentage Fat Content 31

TABLE

16. Carpsucker Fat Content Data. Two-way (Environment, Sex) Means of the Percentage Fat Content 32

17. Carpsucker Data. Two-way Analysis of Variance of Percentage Fat Content 33

18. Calculated Lengths (mm) of Carp Collected from the Smoky Hill River 41

19. Calculated Lengths (mm) of Carp Collected from the Cedar Bluff Reservoir 42

20. Comparison of Mean Calculated Lengths (mm) of Carp Using Fisher's LSD Procedure 43

21. Calculated Lengths (mm) of Carpsucker Collected from the Smoky Hill River 52

22. Calculated Lengths (mm) of Carpsucker Collected from the Cedar Bluff Reservoir 53

23. Comparison of Mean Calculated Lengths (mm) of Carpsucker Using Fisher's LSD Procedure 54

INTRODUCTION

Reservoir construction had its beginning in the United States early in the 1920's when they were constructed primarily for the purpose of flood control and hydro-electric power (Jenkins, 1961). During the 1930's, reservoir construction gained momentum and today the U. S. Army Corps of Engineers has created reservoirs or has plans for impoundments on nearly every stream in the United States with any record of primary or secondary flood damage (Bennett, 1962). In Kansas, numerous multipurpose reservoirs have been constructed during the past two decades which have created aquatic environments completely new to the state.

Although reservoirs have been constructed primarily for the purpose of water management; i.e. flood control, irrigation, municipal water supply, and hydro-electric power, significant side benefits have developed so that now many reservoirs are considered to have multipurpose values. Among the significant benefits are the fisheries, both sport and commercial, which have developed in these impoundments.

The potential of the fisheries created by these impoundments was realized early in the 1930's and immediately biologists began studying and investigating this newly created fisheries resource. Early studies of these new impoundments consisted primarily of inventories of plankton, bottom fauna, and fishes (Jenkins, 1965; Moore, 1931; Wickliff, 1933). However, in the latter part of the 1930's, it became apparent that the fish populations went through similar successional patterns in the majority of new reservoirs: immediately after impoundment, fishing was outstanding but in a matter of a few years, it declined and became poor (Bennett, 1962). This led to the assumption that after an initial high productivity brought about by the decay and utilization of the organic matter present at impoundment, reservoirs virtually become aquatic deserts (Cahn, 1937; Ellis, 1937; Stroud, 1967). Biologists investigating the Tennessee Valley Authority reservoirs (Eschmeyer, 1941; Tarzwell, 1942), replaced this assumption with the following successional pattern described by Bennett (1962), primarily in reference to reservoirs in the southeast. During the first few years following impoundment, fishes of catchable size are numerous, producing excellent fishing. This is a direct result of the expanding habitat which provides an increased amount of food per fish. As numbers of fishes increase and the carrying capacity of the impoundment is approached, the feeding activity of rough fishes begins to have a detrimental effect on the game fishes by altering their habitat. Eventually this leads to changes in the relative abundance of certain species: rough fishes outnumbering game fishes. Because the primary function of the reservoir is water management and not recreation, little can be done to bring back conditions that were obtained in the early years of impoundment.

In recent years a considerable amount of research has been aimed at estimating the effects of water management operations on impounded fish populations. Game fish like the northern pike, Esox lucius, and the walleye, Stizostedion vitreum, two species introduced into reservoirs for the specific purpose of utilizing the abundance of forage species, have benefited from impoundment (Bennett, 1962). On the contrary, the study conducted by Walburg (1964) showed that the carp, Cyprinus carpio, the river carpsucker, Carpiodes carpio, the smallmouth buffalo, Ictiobus bubalus, and the bigmouth buffalo, Ictiobus cyprinellus, in the Lewis and Clark Lake located on the mainstem Missouri River near Yankton, South Dakota, had experienced slow growth and irregular year-class survival as a result of impoundment. Sigler (1958) studying impounded carp, Cyprinus carpio, in Utah came to very similar conclusions. Schoonover and Thompson (1954), made an early post-impoundment study of fishes in the Fall River Reservoir, Kansas, and concluded that the reproductive rate of carp was lowered as a result of impoundment.

Preliminary observations of two of the dominant species of rough fish, the carp, Cyprinus carpio, and the river carpsucker, Carpiodes carpio, in the Cedar Bluff Reservoir located on the Smoky Hill River in west central Kansas, revealed that a noticeable difference in relative condition (plumpness or robustness) existed between fish in the reservoir and those below the reservoir in the river.

The purpose of this study was to test the hypothesis that impoundment has affected the carp, Cyprinus carpio, and the river carpsucker, Carpiodes carpio, in the Cedar Bluff Reservoir. If acceptable, one would expect to find a significant difference between variables studied for respective reservoir and river fishes.

The following variables studied for each species in the reservoir and those in the river below the reservoir were: the length and age composition and calculated growth. In addition, a condition index (measure of body robustness or plumpness) was derived and comparisons were made between reservoir and river fishes. Finally, samples of each species of river and reservoir fishes were analyzed for per cent fat content.

Natural History of the Carp (Cyprinus carpio)

Cyprinus carpio, commonly called the European carp, German carp, or simply, carp, is perhaps the most celebrated of the minnow family, Cyprinidae. The carp is generally described as having a back of brassy-olive and sides and belly of yellowish-white. The lower fins are often tinged with red. Two fleshy barbels grow from each side of the upper jaw, one pair hanging from the edge of the snout; the other pair, from slightly farther back. The head is scaleless and contains a small, tender, toothless mouth with thin lips. Located on each gill arch are three rows of broad pharyngeal teeth with molar surfaces.

Both the elongated dorsal fin and the anal fin have a strong, hard, serrated spine (actually ossified soft fin rays). No spines occur in either the pelvic or the pectoral fin, and the caudal fin is strongly forked (Cross, 1967; Sigler, 1958; Slastenenko, 1958).

The carp is subject to considerable genetic variation; some individuals have a lean and low body, while others are shorter and correspondingly deeper bodied. Some have no trace of scales and are called "leather carp." Others have scales only along the lateral line and on the back. These are referred to as "mirror-carp" (Gunther, 1880).

The word "ubiquitous" describes the range of the carp quite well as they are established throughout the warm waters of the world. Originally the carp was a native of Asia, and it still abounds in a wild state in China where it was domesticated centuries ago (Jordon, 1905). From Asia, it was transported to Germany and Sweden, and the year 1614 is assigned as the date of its first introduction into England (Gunther, 1880).

Exactly when the first carp were brought to America is unknown, but most authors agree that it was around 1877 (Forbes and Richardson, 1920: Bulletin of U. S. Bureau of Fisheries, 1927). They became adapted to the new environment rapidly and soon spread into, and became established in 48 states (Sigler, 1958). At present, the carp is probably more abundant than any other freshwater fish in the United States. It is noteworthy that the carp is continuing to expand the boundaries of its range. Though generally thought to be a warm-water fish, in the last decade, the carp has migrated north and invaded many of the cold lakes and river systems of Canada and British Columbia (Atton, 1959; Slastenenko, 1958).

The carp inhabits almost any moderately warm water that supports fish life. Being a dull and sluggish fish, it prefers shaded, tranquil, and weedy waters with muddy bottoms (Jordan, 1905). Deep water is not a habitat requirement for the carp as they thrive in water three feet deep or even less if sufficient cover exists. Crowded conditions, resulting from dense growths of water plants, are not detrimental either, as they exist in waterfowl areas which may have a covering of over eighty per cent emergent plants.

An important factor which aids in the remarkable adaptability of the carp is their feeding habits. Carp are obviously omnivorous as they will consume everything from detritus to other fishes. The principle foods however, are bottom organisms such as aquatic insect larvae, worms, crustaceans, small snails, molluscs and aquatic vegetation (Slastenenko, 1958; Moen, 1953; Cross, 1967; King and Hunt, 1967).

Apparently the location and type of environment determine the age at which carp reach maturity. Professer Shelton (Call, 1961:32), working with carp at Kansas State University reported, "At one year old, our carp bred." English (1952) and Sigler (1958), from Iowa and Utah respectively, found that carp are usually mature when they are two years old. In Canada, according to Swee and McCrimmon (1966), males mature at ages three and four and females at ages four and five. In general, maturity is reached when they are two or three years old and around 315 to 380 mm in length.

Carp reproduce intermittently over a lengthy period each year, beginning in late March and continuing through July or even later (Cross, 1967).

The fecundity of carp is high as over 2,000,000 eggs have been found in the ovaries of a single female (Jordon, 1905). The adhesive eggs are scattered freely over vegetation and debris where they adhere, completely disregarded by both parents.

"When carp were first introduced into this country, they were received with excitement and optimism. The early enthusiasm for carp waned gradually, and the species now has few advocates, even among commercial fishermen" (Cross, 1967).

Natural History of the River Carpsucker (Carpiodes carpio)

In spite of its abundance, little is known of the river carpsucker, Carpiodes carpio. Four species of carpsuckers are included in the genus Carpiodes which is a subdivision of the sucker family Catostomidae. In general, carpsuckers are bright, silvery fishes having relatively deep bodies and long, curved dorsal fins. The widest part of the subopercle is slightly anterior to the middle of its length. The mouth is small and horizontal, with thin, weakly grooved lips (Cross, 1967). The river carpsucker, Carpiodes carpio, is distinguished from other carpsuckers by its small head; short-rounded snout, and a characteristic nipple-like projection on its lower lip. In addition, the anterior rays of the dorsal fin are shorter than the basal length of the fin (Cross, 1967).

The river carpsucker may reach a length of 63.5 cm (25 inches) and weigh up to 4.65 kg (10.25 pounds); in Kansas, however, they seldom reach a length of more than 40.1 cm (16 inches) and a weight of more than 1.36 kg (3.0 pounds) (Cross, 1967).

The river carpsucker, which is the dominant species of carpsucker in midwest and central United States, has apparently been around for a long time. Lundberg (1967), reports that fossil remains of the river carpsucker have been found from the Wisconsin era. According to Eddy (1957), the river carpsucker can be found today in the north from Montana to Pennsylvania and south to Tennessee and Texas. In Kansas, its range is essentially statewide, in small and large streams regardless of gradient, turbidity, or bottom type (Cross, 1967).

Because of its virtually ubiquitous occurrence, defining the specific habitat of the river carpsucker is quite difficult. It does seem evident however, that this species prefers calm pools, backwaters, or eddies where sediments accumulate, rather than the main currents of moving streams.

There is general agreement that the river carpsucker is primarily a detritus feeder (Walburg and Nelson, 1965; Harlan and Speaker, 1951; Buchholz, 1957). The sand and silt found in carpsucker stomachs, along with the wide variety of organic detritus indicates that this fish is primarily a bottom browser.

Attainment of sexual maturity in the river carpsucker is apparently related to both length and age. Morris (1965) found that both males and females were mature at 34.2 cm (12 inches) in the Missouri river. This length generally corresponded to an age of four or five years. Walburg and Nelson (1965) investigating the river carpsuckers in Louis and Clark Lake, South Dakota, found that only 50% of the males and females were mature at age five, and 100% mature at age eight.

Associated with male spawning behavior, Huntsman (1967) noted specific patterns of nuptial tubercles occurring on the heads of male river carpsuckers during spawning season.

There is general agreement that the river carpsucker is an intermittent spawner (Walburg and Nelson, 1965; Buchholz, 1957; Cross, 1967). The spawning period generally begins in May and extends until the middle of July. Peak spawning is reached when the water temperature ranges from 21° C to 24° C (70–76° F). Harlan and Speaker (1951) describe the river carpsucker as a shallow water, random spawner. Walburg and Nelson (1966) observed many eggs floating freely on the water surface, which would indicate that eggs are broadcast loosely into the water. Buchholz (1957), reported the average number of eggs produced by a normal female river carpsucker was approximately 103,000. This high reproductive potential indicates the river carpsucker is indeed a random spawner showing little or no parental care.

STUDY AREA

Cedar Bluff Dam and Reservoir is a Bureau of Reclamation project located on the Smoky Hill River in Trego County, west central Kansas. The area is in the Great Plains Region, with flat to rolling topography and occasional breaks and canyons. The dam itself is located approximately 24 kilometers (15 miles) south of Wakeeney and 32 kilometers (20 miles) southwest of Ellis; more specifically: Trego County, west $\frac{1}{2}$ of sec. 36, T. 14 S., R. 22 W..

Closure of the dam was in July, 1951. It is an earthfill structure with a maximum height of 66.3 meters (217.5 feet) above the river bed and a length of 4,060 meters (13,316.8 feet) (U. S. Dept. of Interior, 1963). At conservation level, 702.3 meters (2,194 feet) above sea level, an area of 2,780.9 surface hectares (6,869 acres) of water is impounded. This creates a shoreline of approximately 80.5 kilometers (50 miles) (Information Bulletin, Number 279). The reservoir reaches a maximum depth of approximately 20 meters (65.6 feet) a short distance west of the dam in what was formerly the main channel of the Smoky Hill River (Koch, 1968).

This area has a continental climate with an average annual precipitation of 54.4 centimeters (21.4 inches) (U. S. Dept. of Interior, 1963).

According to the land capacity survey conducted by the Soil Conservation Service (U. S. Dept. of Interior, 1963), there are three major soils in this area. The upland soils of loessial parent materials are dark and have moderately heavy clay subsoils. The terrace soils have parent materials of stream deposits which are very dark with dominant surface textures of silt loam. The lowland soils have parent materials of old alluvium, loess, caliche, and chalky shale. It is estimated that approximately seventy per cent of the Smoky Hill River drainage basin is native grassland (U. S. Dept. of Interior, 1963).

Cedar Bluff Reservoir was constructed primarily as an irrigation, municipal water supply and flood-control reservoir. At conservation level, the main stem of the reservoir lies generally straight west and extends approximately 15 kilometers (9.3 miles) upstream from the dam (Koch, 1968). A limnological study of the reservoir by Koch (1968), revealed the principle factor limiting transparency is the density of phytoplankton. He reported that transparency, determined with a Secchi disc, ranged from 0.5 to 2.5 meters. Koch further reported that total alkalinity remained relatively constant, ranging from 105 to 120 ppm.

The entire reservoir and upstream from the reservoir was referred to as Station I. Fishes were collected from three general locations (Fig. 1). Fishes were collected at the location upstream from the reservoir on only one occasion after a heavy rainfall. Under normal conditions, the Smoky Hill River upstream from the reservoir is only one or two meters wide and several centimeters deep.

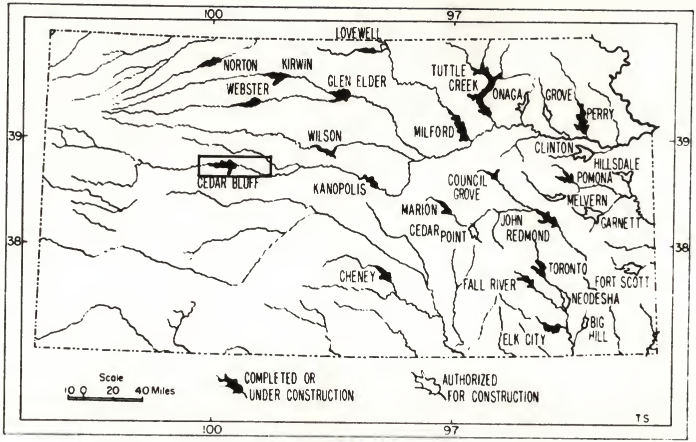
The reservoir is used so extensively for irrigation that water is seldom released into the river below the dam. This creates a relatively stable situation as these two aquatic environments (reservoir and river) are distinct and thus conclusions can be reached regarding the effects of impoundment on the two species under study by comparing and contrasting fishes from the two environments.

Because water is seldom released into the river from the reservoir, the entire volume of the river is the result of springs, seepage, precipitation, and irrigation runoff below the dam. Thus the stream volume is quite low upstream near the dam but becomes progressively greater as one travels

EXPLANATION OF FIG. 1

Reservoirs in Kansas and enlarged study area.

Numbers correspond to sampling sites.


100
97
39
38
LOVEWELL
NORTON
KIRWIN
WEBSTER
GLEN ELDER
TUTTLE CREEK
ONAGA
GROVE
PERRY
MILFORD
WILSON
CLINTON
HILLSDALE
POMONA
CEDAR BLUFF
KANOPOLIS
COUNCIL GROVE
MELVERN
MARION
GARNETT
JOHN REDMOND
CEDAR POINT
TORONTO
FORT SCOTT
CHENEY
FALL RIVER
NEODESHA
BIG HILL
ELK CITY
Scale
10 0 20 40 Miles
COMPLETED OR UNDER CONSTRUCTION
AUTHORIZED FOR CONSTRUCTION
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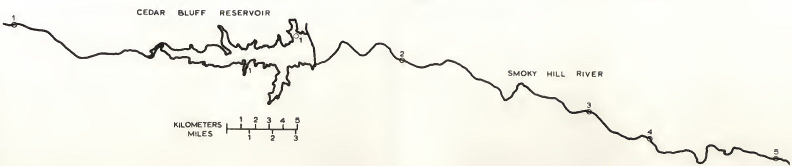

CEDAR BLUFF RESERVOIR
SMOKY HILL RIVER
KILOMETERS 1 2 3 4 5
MILES 1 2 3

downstream from the dam.

All fishes collected from the river were taken at four specific locations (Fig. 1), or stations. Table 1 shows some physical and chemical characteristics of these stations. Values are averages of the 16 observations made during the course of this two-year study. Notice that a difference in stream flow of 0.357 cms (12.6 cfs) exists between Station II and Station V

Table 1. Physical and chemical characteristics of sampling stations located on the Smoky Hill River.

Station	Distance downstream from the dam (km)	Normal stream flow (cms)	(cfs)	Ave. Width (m)	Ave. Depth (m)	Total alkalinity (ppm $CaCo_3$)
II	9.65	0.306	10.8	6.18	0.162	164
III	30.70	0.595	21.0	10.03	0.185	168
IV	36.85	0.660	23.3	9.65	0.165	170
V	70.60	0.663	23.4	9.95	0.172	157

which are 9.65 and 70.60 stream kilometers respectively downstream from the dam. It is also significant that the average depth at all stations was less than .2 meters. As a result, both carp and river carpsucker were generally taken from the deeper, washed-out holes in the river.

MATERIALS AND METHODS

Collection of the fishes began in the spring of 1967 and was terminated in the fall of 1968. All fishes in the river were collected with the aid of a 230-volt, 3,000-watt, 60-cycle, alternating current electroshocker. The electroshocker was also used to collect fishes upstream from the reservoir. Fishes taken from the reservoir coves nearer the dam were collected with the aid of frame traps having a one inch bar mesh size. In addition, a sample of reservoir fishes were collected in the summer of 1968 when the Kansas Forestry, Fish and Game Commission poisoned a cove in an attempt to analyze the existing reservoir fish populations.

In the field, the following data were obtained from each fish: a scale sample, total length (millimeters), weight (grams), and, when possible, sex. In addition, a number of river and reservoir fishes of both species were taken back to the lab to be analyzed for per cent fat content.

Age and Growth Determination

Scale samples were taken from the general area anterior to the dorsal fin, immediately above the lateral line. Because of the large number of regenerate scales present on both species, large scale samples were taken.

As discussed by Van Oosten (1929:272), the following may be determined from scales: (1) the age of a fish in years; (2) the approximate length attained by it at the end of each year of life; and (3) its rate of growth for each year of life. Scales can be used to age fish, because they, like other bony structures, show seasonal changes in rate of growth (Lagler, 1956). Any natural or artificial phenomenon that will stop feeding and growth of a fish for about fourteen days or longer will be followed, once growth is resumed, by the appearance of an "annulus", on the margin of the scales (Bennett, 1962). The soundness of the scale method for determining the length of a fish at previous, successive years of its life depends on the validity of the following assumptions (Van Oosten, 1929: 278): (1) that the scales remain constant in number and retain their identity throughout the life of the fish; (2) that the annual increment in length of the scale maintains, throughout the life of the fish, a predictable ratio to the annual increment in body length; and (3) that the annuli are formed yearly and at the same time each year.

A roller press (Smith, 1954; Lanbou, 1963) was used to make a plastic impression of two or three scales (depending on size) from each fish. Depending on the thickness and size, impressions of scales were made on 20, 40, or 60 mil cellulose acetate plastic slides. The age of the fishes was determined by reading the scale impressions with a modified microfilm viewer at a magnification of 28.6 X. Each impression was aged independently on two different occasions. Disagreements were re-examined and the differences reconciled. Because annuli were close together near the outer edge, scales from fish over four years old were difficult to read. Determining the age of carp scales proved to be quite subjective as carp are notorious for laying down extra or false annuli (Bennett, 1962). Thus another method of aging fish was performed to verify the ages as determined by the scale method. The method, derived by Peterson (1891) and described by Lagler (1956), is based on the expectency that frequency analysis of the individuals of a species of any one age-group collected on the same date will show variation around the mean length according to a normal distribution; it is based further on the expectation that when data for a sample of the entire population are plotted, there will be clumping of fish of successive ages about successive given lengths, making possible a separation by age-groups.

After the age of each scale was determined, the length of the total radius (from the focus to anterior edge of the scale) and the lengths from the focus to each respective annulus, magnified 28.6 X, were recorded in millimeters. All values were later changed to actual size by multiplying times a factor of .0349.

The Lee method (Lagler, 1956) was used to calculate the growth at various ages of the fishes from the scale measurements. This method assumes that the mathematical relationship between body length and scale radius is expressed by the equation:

$$L = a + cS$$

where L = body length, S = scale radius, and a and c are empirically determined constants.

To justify the use of the above equation a plot of total length (millimeters) versus total scale radius (millimeters) was made for each species. A least squares analysis was also performed on the same data to determine the intercept and regression coefficient, constants a and c respectively. The R-square values derived from these analyses indicated that a linear relationship between total length and total scale radius did indeed exist.

Condition Factor

The relationship between length and weight of fish is often expressed by a coefficient of condition, the objective of which is to express the condition of the fish (degree of well-being, relative robustness, plumpness or fatness) in numerical terms (Lagler, 1956). A "fat" fish of a given species and length will show a higher condition factor than a thin fish of the same species and length. By the same token, the numerical values of fishes with laterally compressed but deep bodies, such as the white crappie, or the bluegill, are usually higher than the values obtained from fish with bodies of lesser depth such as the largemouth bass or carp (Bennett, 1962). As discussed by Lagler (1956), the condition factor may be expected to (1) change with age; (2) change with season; and (3) possibly change between sexes.

The formula which is used often for calculating relative condition requires the use of the weight of the fish in grams, and its standard length in centimeters (Hile, 1936; as described by Bennett, 1962). In this formula K, the "Coefficient of Condition," is equal to the weight of the fish in grams times 100, divided by the cube of the standard length in centimeters, thus:

$$K = \frac{100W}{L^3}$$

In this study, however, the length of the fishes was recorded as total length in millimeters. Therefore the following formula was derived to describe relative condition:

$$K_{TL} = \frac{100,000\ W}{L^3}$$

where, K_{TL}, the "Coefficient of Condition", is equal to the weight of the fish in grams times 100,000 divided by the cube of the total length in millimeters.

It should be emphasized again that the numerical values for K_{TL} mean nothing in themselves but serve to make comparisons between individuals or groups of fishes.

Fat Content Determination

Samples of fishes brought back to the laboratory for fat content analysis were scaled, eviscerated, decapitated just posterior to the pectoral girdle, and all fins were cut off at the base. Samples were then finely ground with a meat grinder and dried in an oven at 95° C for approximately 24 hours. The per cent moisture remaining in the samples at the end of the drying period ranged from 2.32 to 6.25 per cent.

Following the drying period, the samples were again finely ground and homogenized in a Virtus blender. A two gram subsample was then analyzed for per cent fat content. In the method employed, a Goldfisch apparatus was used as the extractor and isopropyl alcohol as the solvent (Method developed by Animal Nutrition Laboratory personnel, Kansas State University; aided by Association of Official Agricultural Chemists, 1960: 287).

For the purpose of making a valid comparison, all results were expressed on the basis of 100 per cent dry matter. This was calculated by dividing the per cent fat content by the per cent actual dry matter. For example, if it was determined that a specific sample contained 10 per cent fat and consisted of 95 per cent dry matter; on the basis of 100 per cent dry matter the sample contained 10.53 per cent fat.

Methods of Analyses

Analyses of variance were performed to determine which of the main effects (environment, sex and length group) or interactions contributed significantly to the variation of the variables under study (i.e. growth, per cent fat content, and relative condition). Significance of (α = .05; α = .01) of the F test for a given effect or interaction indicated that factor is contributing significantly to the variation of the variable being studied. An IBM 360/50 computer was used to perform all analyses and calculations.

<u>Age and Growth Investigation</u>. In order to estimate the length of each fish at each year of life it was necessary to determine the coefficients of regression of length on total scale radius. These constants, namely, the in-

tercept (a) and slope (c), were computed by means of the least squares analysis. Separate constants were determined for each species.

The length of fishes at each year of life was then estimated by using the empirically determined constants in the equation: $L = a + cS$ where L = total length, S = scale radius and a and c constants as previously defined. The grand mean length of fishes at each year from the two environments was computed and Fisher's Least Significant Difference procedure was used to determine if a significant difference existed between annual growth increments of reservoir and river fishes.

Fat Content Analysis. A two-way ANOVA with interaction was performed to determine if a significant difference in per cent fat content existed between river and reservoir fishes. The two parameters under study were sex and environment, and the variable was per cent fat content. Because of the small sample size and the fact that fishes were generally of the same length (and therefore approximately the same age), length and age were not taken into account as additional parameters which might affect fat content.

Relative Condition. Initially a four-way ANOVA with interaction was performed on the variable K, "Condition Coefficient." The established parameters were the two environments, sexes (male, female, and undetermined), ages, and three length groups (0–150 mm, 151–300 mm, and 301 mm and over). However, since age was confounded with length groups, age had to be disregarded in the analysis. Therefore a three-way ANOVA was performed (environment, sex, and length groups). In this analysis, the interaction effects were not estimable because of unequal numbers of observations.

RESULTS

Collection of both species of fishes began in the spring of 1967 and terminated in the fall of 1968. During this two-year period, data were obtained from a total of 501 carp and 407 carpsucker. Of the 501 carp, 353 were collected from the Smoky Hill River and 148 from Cedar Bluff Reservoir. The number of carpsucker collected from the river and reservoir were 225 and 182 respectively.

As previously mentioned, it was observed that the condition of carp in the reservoir was noticeably inferior (lacking robustness) to those in the river below the reservoir. The difference between the carpsucker in the two environments was observed to be not as pronounced as the difference exhibited by carp (Fig. 2, 3, 4, 5, 6, 7).

Condition Factor

<u>Carp</u>. The variable K_{TL} "Condition coefficient," was determined for each of 353 and 148 fish in the river and reservoir respectively. The factors tested were: 1.) environments; reservoir and river, 2.) sexes; male, female and undetermined, and 3.) length groups; 0-150 mm, 151-300 mm, and 301 mm and over. Tables 2 and 3 show the main effect factor means and Table 4 shows the results of the 3-way analysis of variance. Because of the number of cells with zero observation, it was not possible to test for interaction effects.

The difference in condition, as determined by the condition coefficient (K_{TL}), between carp in the reservoir and those in the river was highly significant (F value at 140.0). As indicated by the F value of 0.279, the condition coefficient of sexes in the two environments did not differ significantly. As would be expected, there was a highly significant difference

Fig. 2. Carp from the Cedar Bluff Reservoir

Fig. 3. Carp from the Smoky Hill River

Fig. 4. Carp from the Cedar Bluff Reservoir

Fig. 5. Carp from the Smoky Hill River

Fig. 6. River Carpsucker from the Cedar Bluff Reservoir

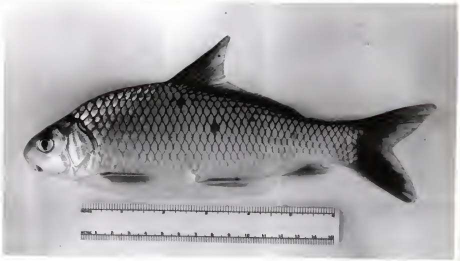


Fig. 7. River Carpsucker from the Smoky Hill River

Table 2. Carp data. Two-way means (environment, sex) of the condition coefficient (K_{TL}).

		Environment		
		Reservoir	River	Sex Means
	Undetermined	0.954 n=45	1.403 n=53	1.197 n=98
Sex	Male	0.927 n=48	1.314 n=168	1.228 n=216
	Female	0.938 n=55	1.336 n=132	1.219 n=187
Environment Means		0.939 n=148	1.336 n=353	

Table 3. Carp data. Two-way means (environment, length group) of the condition coefficient (K_{TL}).

		Environment		Length Group
		Reservoir	River	Means
	0–150 mm	1.505 n=1	1.705 n=11	1.688 n=12
Length Group	151–300 mm	1.268 n=2	1.450 n=117	1.447 n=119
	301 mm and over	0.931 n=145	1.258 n=225	1.130 n=370
Environment Means		0.939 n=148	1.336 n=353	

between the various length groups in the two environments. Using Fisher's LSD (Fryer, 1966) comparison procedure, it was determined that all length group means were significantly different from each other (Table 5). Fish in the length group 0-150 mm had the highest mean condition coefficient while fish in the length group 301 mm and over had the lowest. This was due to the fact that a small fish of a given species will usually have a higher condition coefficient than a large fish of that same species. In larger fish, weight does not increase as fast as the cube of the length (Bennett, 1962).

To determine if length group means differed significantly between the two environments, Fisher's LSD comparison procedure was performed on the respective environment/length group means from Table 3. The results are shown in Table 6. Only fish in the length group 301 mm and over differed significantly between the two environments. Length groups 0-150 mm and 151-300 mm in the reservoir have only 1 and 2 observations respectively. Therefore, it

Table 4. Carp data. Analysis of variance of the condition coefficient (K_{TL}). (* * indicates significance at the .01 level.)

Source	d. f.	M. S.	F-test
Environment	1	16.373	140.001 * *
Sex	2	0.033	0.279
Length Group	2	5.885	50.323 * *
Error	483	0.117	

could certainly be erroneous to conclude that these length groups in the two respective environments will always be similar.

Carpsucker. The condition factor was determined for each of 225 carpsucker collected from the river and 182 carpsucker collected from the reser-

Table 5. Comparison of carp length group (condition coefficient) means from Table 3 using Fisher's Least Significant Difference (LSD) procedure. Means lying above the same horizontal line are not significantly different; those over different lines are with $\alpha = 0.05$.

Length Group:	0–150 mm	151–300 mm	301 mm and over
Mean:	1.688	1.447	1.130

Table 6. Comparison of carp environment/length group (condition coefficient) means from Table 3 using Fisher's LSD procedure. (* indicates significance at the .95 level.)

Length Group	Mean Difference River - Reservoir	$LSD_{.95}$
0-150 mm	0.199	0.706
151-300 mm	0.182	0.470
301 mm and over	0.327	0.078*

voir. The estimated factor means are shown in Table 7 and 8 and the results of the 3-way analysis of variance of the condition coefficient (K_{TL}) in Table 9. As with the carp, it was necessary to perform the test without interaction because of the lack of observations.

The analysis of variance indicated that no significant difference existed between the condition coefficients of the carpsucker in the two environments. A significant difference did exist between sexes and length groups (6.56 and 11.97 F values respectively). The LSD comparison procedure was performed to determine which of the means differed significantly. Table 10 shows the comparison of sex means and Table 11 the length group means. No significant difference in condition existed between males and females, how-

Table 7. Carpsucker data. Two-way means (environment, sex) of the condition coefficient (K_{TL}).

		Environment		
		Reservoir	River	Sex Means
	Undetermined	1.485 n=105	1.509 n=84	1.496 n=189
Sex	Male	1.114 n=29	1.173 n=67	1.155 n=96
	Female	1.122 n=48	1.166 n=74	1.149 n=122
Environment Means		1.330 n=182	1.296 n=225	

Table 8. Carpsucker data. Two-way means (environment, length group) of the condition coefficient (K_{TL}).

		Environment		Length Group Means
		Reservoir	River	
	0–150 mm	1.497 n=102	2.254 n=26	1.650 n=128
Length Group	151–300 mm	1.192 n=5	1.190 n=149	1.190 n=154
	301 mm and over	1.113 n=75	1.113 n=50	1.113 n=125
Environment Means		1.330 n=182	1.296 n=225	

ever, both differed significantly from the condition of the undetermined sex. The majority of fish comprising the latter category were too small to sex accurately. Because it has been shown that a smaller fish of a given species has a higher K value than a larger fish of that same species (Bennett, 1962), the fish which could not be sexed because of their small size would be expected to have a higher condition coefficient than the larger fish which could be distinguished as male or female. That small fish have a higher condition coefficient was further exemplified by the comparison of length group means. No significant difference in condition existed between fish in the length groups 151-300 mm and 301 mm and over, however, both groups differed significantly from the condition of fish in the length group 0-150 mm.

Table 9. Carpsucker data. Analysis of variance of the condition coefficient (K_{TL}). (* and * * indicate significance at the .05 and .01 levels respectively.)

Source	d. f.	M. S.	F-test
Environment	1	0.119	0.130
Sex	2	5.994	6.557 *
Length Groups	2	10.944	11.970 * *
Error	389	0.914	

To determine if sex means differed significantly between the two environments, Fisher's LSD comparison procedure was performed on the respective environment/sex means from Table 7. Results shown in Table 12 indicated no significant difference in condition existed between respective sexes from the two environments. Results of the comparison of length group means (Table 8) from the two environments are shown in Table 13. Only fish in the length

Table 10. Comparison of carpsucker sex (condition coefficient) means from Table 7 using Fisher's LSD procedure. Means lying above the same horizontal line are not significantly different; those over different lines are with $\alpha = 0.05$.

Sex:	Undetermined	Male	Female
Mean:	1.496	1.155	1.149

Table 11. Comparison of carpsucker length group (condition coefficient) means from Table 8 using Fisher's LSD procedure. Means lying above the same horizontal line are not significantly different; those over different lines are with $\alpha = 0.05$.

Length Group:	0–150	151–300 mm	301 mm and over
Mean:	1.650	1.190	1.113

group 0–150 mm differed significantly in condition between the two environments.

Analysis of Fat Content

Carp. Ten carp from each environment were analyzed for percentage fat content on the basis of 100 per cent dry matter. The factors tested were environment and sex. Main effect means are shown in Table 14. Results of the 2-way analysis of variance with interaction are shown in Table 15. The F value of 93.66 indicates environment was contributing significantly to the difference in percentage fat content in carp. Sex did not assume a significant role; neither were environment and sex interacting to contribute significantly to the difference in percentage fat content in the carp.

Table 12. Comparison of carpsucker environment/sex (condition coefficient) means from Table 7 using Fisher's LSD procedure.

Sex	Mean Difference River - Reservoir	$LSD_{.95}$
Undetermined	0.023	0.274
Male	0.059	0.422
Female	0.044	0.372

Table 13. Comparison of carpsucker environment/length group (condition coefficient) means from Table 8 using Fisher's LSD procedure. (* indicates significance at the .95 level.)

Length Group	Mean Difference River - Reservoir	$LSD_{.95}$
0-150 mm	0.7576	0.412*
151-300 mm	-0.0023	0.843
301 mm and over	-0.0004	0.333

Table 14. Carp fat content data. Two-way (environment, sex) means of the percentage fat content.

		Environment		
		Reservoir	River	Sex Means
Sex	Male	4.089 n=7	15.540 n=7	9.814 n=14
	Female	3.850 n=3	19.203 n=3	11.527 n=6
Environment Means		4.107 n=10	16.639 n=10	

Table 15. Carp data. Two-way analysis of variance of percentage fat content. (* * indicates significance at the .01 level.)

Source	d. f.	M. S.	F-test
Environment	1	796.574	93.659 * *
Sex	1	12.315	1.448
Environment X Sex	1	15.986	1.880
Error	16	8.505	

Carpsucker. As with the carp, ten carpsucker from each environment were analyzed for percentage fat content. Environment and sex were the factors tested. Table 16 shows the main effect means and Table 17, the results of the 2-way analysis of variance with interaction.

The analysis of variance revealed no significant difference in percentage fat content existed between carpsuckers in the two environments. The main effect means (Table 16) indicate the carpsucker in the reservoir actually contained a slightly higher percentage of fats than the carpsucker in the river. In addition, neither sex or the interaction, environment times sex, showed a significant difference in percentage fat content between fish collected from the two environments. The environment/sex means (Table 16) indicated both males and females in the reservoir actually had a higher percentage of fat content.

Table 16. Carpsucker fat content data. Two-way (environment, sex) means of the percentage fat content.

		Environment		
		Reservoir	River	Sex Means
Sex	Male	11.175 n=2	8.500 n=2	9.838 n=4
	Female	14.878 n=8	13.749 n=8	14.313 n=16
Environment Means		14.137 n=10	12.699 n=10	

Table 17. Carpsucker data. Two-way analysis of variance of percentage fat content.

Source	d. f.	M. S.	F-test
Environment	1	10.339	0.632
Sex	1	64.100	3.919
Environment X Sex	1	1.913	0.117
Error	16	16.355	

Growth Rate

Carp. To determine the rate of growth of the carp, 122 fish were aged from the reservoir and 268 from the river. As previously mentioned, length-frequency plots were made to verify the ages of fish as determined by the scale method. Fig. 8 and Fig. 9 show the plots for reservoir and river fish respectively.

The peaks and trends of the distributions agreed in general with the ages of fish as determined by the scale method (i. e. fish at age I were approximately 80 mm in length, at age V, approximately 375 mm in length, etc.). The calculated (Tables 18 and 19) lengths of fish at the various ages were slightly higher than that indicated by the distributions. This was because of the high intercept value (constant a) which was used to derive calculated lengths of fish. This will be explained and discussed in greater detail later.

Fig. 10 is a plot of total length versus total scale radius of all the carp involved in this study. The plot shows this relationship was indeed linear, thereby justifying the use of the equation:

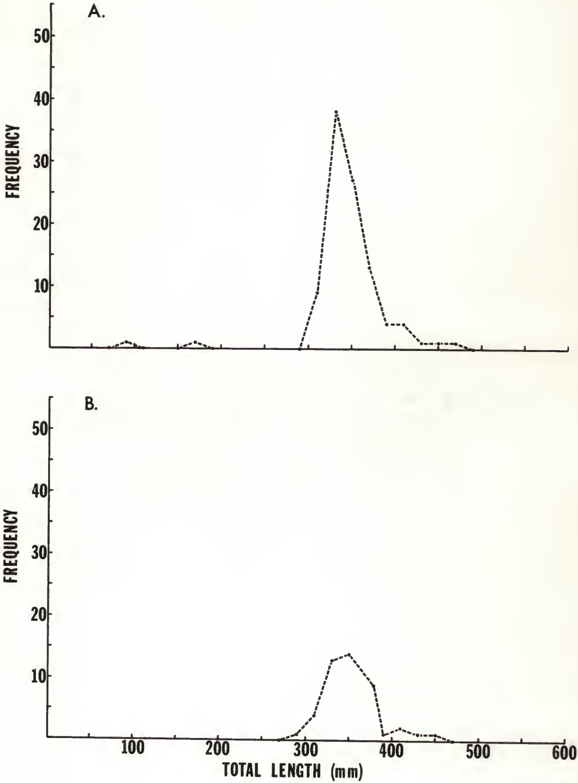
$$L = a + cS$$

EXPLANATION OF FIG. 8

Distribution, by length group, of carp from the Cedar Bluff Reservoir. Fish grouped by 20 mm lengths.

A. Collected from January 1 - June 30

B. Collected from July 1 - December 31

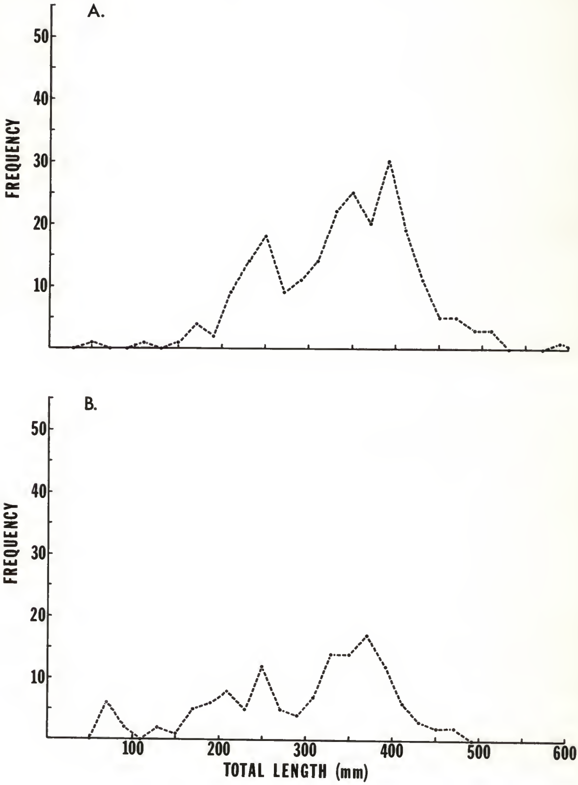

A.
B.
FREQUENCY
FREQUENCY
10
20
30
40
50
100
200
300
400
500
600
TOTAL LENGTH (mm)

EXPLANATION OF FIG. 9

Distribution, by length group, of carp from the Smoky Hill River. Fish grouped by 20 mm lengths.

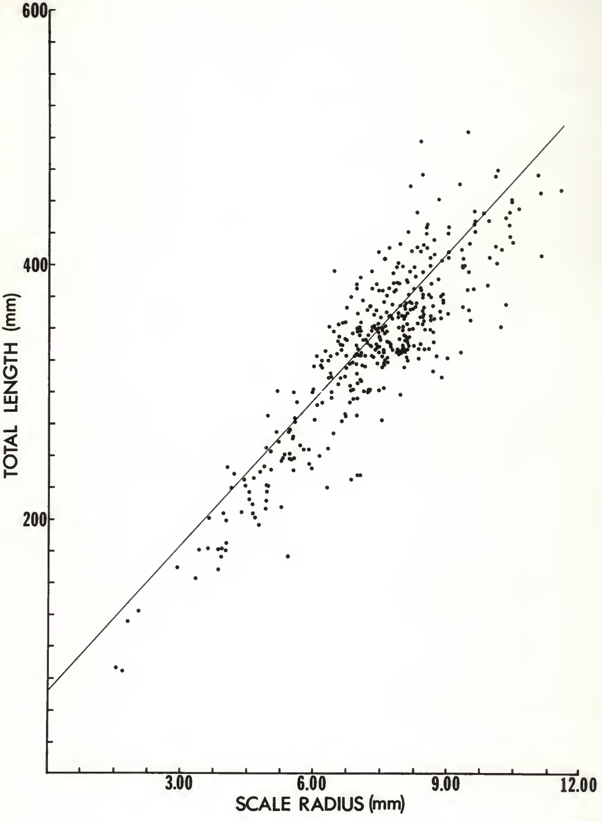
A. Collected from January 1 - June 30

B. Collected from July 1 - December 31


A.
B.
FREQUENCY
50
40
30
20
10
100
200
300
400
500
600
TOTAL LENGTH (mm)

EXPLANATION OF FIG. 10

Body length - scale radius relationship of carp collected from the Smoky Hill River and Cedar Bluff Reservoir.



600
400
200
TOTAL LENGTH (mm)
3.00
6.00
9.00
12.00
SCALE RADIUS (mm)

(terms previously defined in materials and methods) to predict the length of a fish at a previous age. The slope and intercept of the regression line drawn through the scatter diagram were determined by least square analysis. The intercept (constant a) was calculated to be 67.3 mm and the slope (constant c), 36.3 mm length/mm total scale radius. The R-square value for the same plot was .759 which indicated a high correlation (r=.87) existed between total length and total scale radius of the fish under study.

In order to make valid comparisons between mean lengths of fish in the reservoir and river, it was necessary to use the same constants (a and c) to predict length of fish collected from both environments. Separate correlations were made for fish in each distinct environment, however, the differences between the resulting coefficients were significant enough to make comparisons between mean lengths invalid. These differences resulted because of a lack of small carp collected from the reservoir. Table 19 shows only two fish under 200 mm in length were collected from the reservoir. The majority of fish ranged in length from 300 to 400 mm and were clustered together in a tight group on a scatter diagram. Because of this, it was extremely difficult to fit an accurate regression line to the plot and the calculated intercept was extremely high and from observation very unrealistic. Therefore, all carp from both environments were plotted together and only one set of constants (a and c) were calculated.

To justify the use of similar constants for the two distinct populations, it was necessary to assume the two populations have not been separated long enough to develop two distinct races, the difference of which could possibly be reflected in a different relationship between total length and scale radius. As mentioned above, the correlation of .87 indicated the relationship between length and scale radius for both populations was indeed similar.

Table 18. Calculated lengths (mm) of carp collected from the Smoky Hill River.

Year Class	No. of Observations Collected in 67	Collected in 68	Average Calculated Length at Age n 1	2	3	4	5	6	7	8
1967	4	9	127.8							
1966	1	6	142.5	213.3						
1965	27	13	134.5	202.9	260.6					
1964	16	25	135.1	202.7	260.9	312.2				
1963	46	19	130.5	192.2	249.9	296.7	335.0			
1962	50	16	130.3	193.2	249.4	298.2	338.8	381.9		
1961	26	6	132.3	195.1	246.7	298.1	339.3	370.9	421.5	
1960	11	0	128.1	185.6	236.0	286.9	330.0	363.6	396.3	
1959	2	0	130.5	195.4	254.5	317.5	367.7	407.1	433.7	456.0
Total No. of Observations			268	263	230	201	130	61	19	2
Grand Ave. Cal. Length (mm)			132.2	196.3	251.3	299.0	338.1	373.6	408.2	456.0
Standard Deviation of Cal. Length			9.60	19.54	22.81	25.39	26.25	31.15	39.19	73.76
Grand Ave. Increment (mm)			132.2	64.1	55.0	47.7	39.1	35.5	34.6	47.8

Table 19. Calculated lengths (mm) of carp collected from the Cedar Bluff Reservoir.

Year Class	No. of observations Collected in 67	Collected in 68	Average Calculated Length at Age n 1	2	3	4	5	6	7	8
1967	0	0	00.0							
1966	1	0	124.4							
1965	1	0	121.8	189.1						
1964	0	14	127.7	189.8	248.5	304.7				
1963	11	49	128.9	188.1	242.8	294.6	334.0			
1962	22	7	130.0	187.8	244.7	295.5	338.7	358.2		
1961	10	1	130.5	192.5	245.2	299.3	345.9	386.9	436.9	
1960	5	0	130.8	190.7	246.3	305.0	356.5	400.9	437.9	
1959	1	0	142.2	213.4	288.3	341.7	397.7	434.4	462.4	485.3
Total No. of Observations			122	121	120	120	95	24	7	1
Grand Ave. Cal. Length (mm)			129.3	189.0	244.7	297.3	338.7	383.4	441.2	485.3
Standard Deviation of Cal. Length			9.06	16.42	20.35	23.01	25.28	29.85	11.55	0.00
Grand Ave. Increment (mm)			129.3	59.7	55.7	52.6	41.4	44.7	57.8	44.1

Table 20. Comparison of mean calculated lengths (mm) of carp from Tables 18 and 19 using Fisher's LSD procedure. (* * indicates significance at the .01 level.)

Age	River carp Ave. Cal. Length	-	Reservoir carp Ave. Cal. Length	=		d.f.	LSD
1	132.2	-	129.3	=	2.9**	388	2.02
2	196.3	-	189.0	=	7.3**	382	3.52
3	251.3	-	244.7	=	6.6**	348	4.92
4	299.0	-	297.3	=	1.7	319	5.47
5	338.1	-	338.7	=	-0.6	223	5.55
6	373.6	-	383.4	=	-9.8	83	15.00

The calculated mean lengths of the carp collected from the Smoky Hill River are presented in Table 18. Those collected from the reservoir are shown in Table 19. Year class sizes are also presented in Tables 18 and 19. A strong year class of reservoir carp was apparently produced in 1963 (Table 19), as five-year fish were the dominant age group. The 1967, 1966 and 1965 year classes were represented by a total of only three fish.

Year classes of river carp (Table 18) were represented more consistently by a larger number of fish. The 1962 and 1963 year classes, however, did appear to be dominant.

The average calculated lengths of the carp in the two environments were analyzed by means of Fisher's LSD procedure (Fryer, 1966). Results are presented in Table 20. The growth rate of carp in the river significantly exceeded that of the reservoir carp only during the first three years of life.

The calculated mean lengths of carp in the one-year age group in both the river and reservoir was approximately 130 mm. From observation and length frequency plot (Fig. 8 and 9), it would probably be more realistic to say carp reach a length of around 95-100 mm at the end of one year. The higher calculated value can be attributed to the high calculated intercept. A larger number of fish ranging in length from 75 to 125 mm would have undoubtedly resulted in a lower, more realistic intercept.

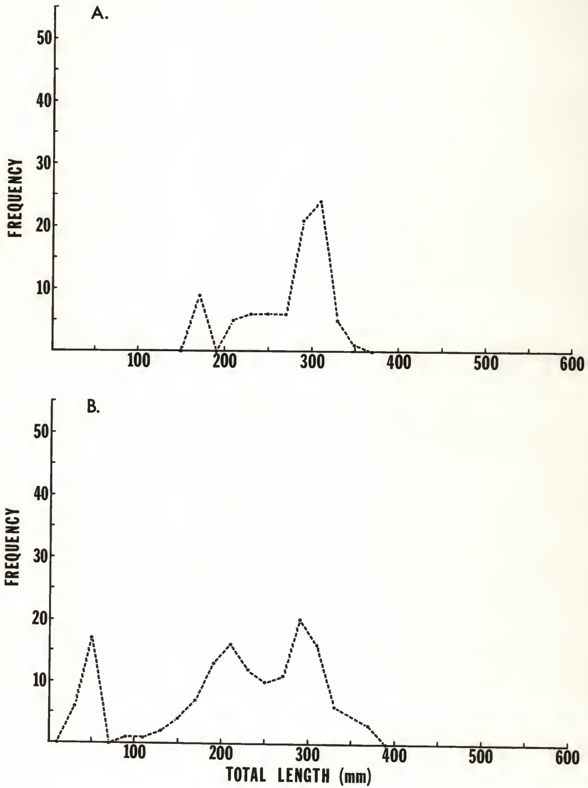
Carpsucker. Growth rate in carpsucker was determined from a sample of 152 fish collected from the river and 74 fish from the reservoir. Length-frequency plots were made to verify the ages of fish as determined by the scale method. Fig. 11 and Fig. 12 show these plots for river and reservoir fish respectively. Ages of fish as determined by the peaks and trends of the distributions were in good agreement with the lengths of fish at the various ages determined by the scale method.

EXPLANATION OF FIG. 11

Distribution, by length group, of carpsucker from the Smoky Hill River. Fish grouped by 20 mm lengths.

A. Collected from January 1 - June 30

B. Collected from July 1 - December 31

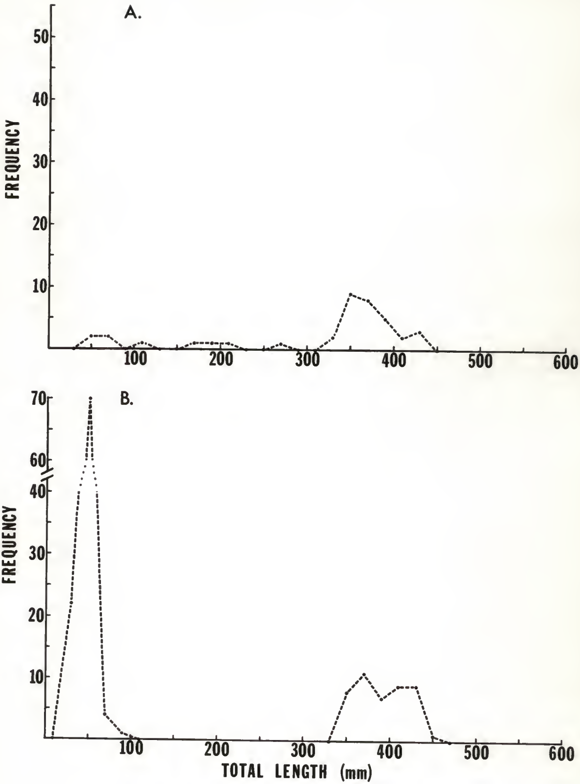

A.
B.
FREQUENCY
10
20
30
40
50
100
200
300
400
500
600
TOTAL LENGTH (mm)

EXPLANATION OF FIG. 12

Distribution, by length group, of carpsucker from the Cedar Bluff Reservoir. Fish grouped by 20 mm lengths.

A. Collected from January 1 - June 30

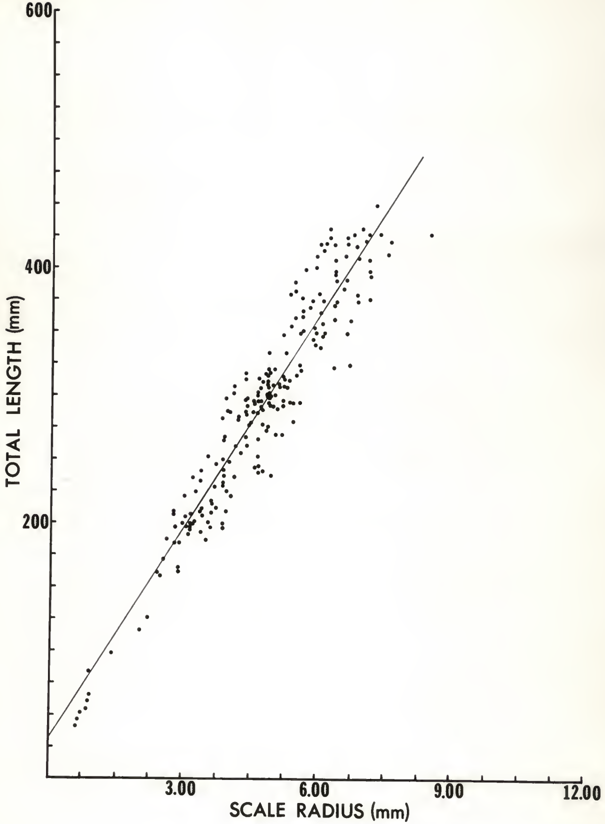
B. Collected from July 1 - December 31



A.
B.
FREQUENCY
FREQUENCY
10
20
30
40
50
60
70
100
200
300
400
500
600
TOTAL LENGTH (mm)

EXPLANATION OF FIG. 13

Body length - scale radius relationship of carpsucker collected from the Smoky Hill River and Cedar Bluff Reservoir.


600
400
200
TOTAL LENGTH (mm)
3.00
6.00
9.00
12.00
SCALE RADIUS (mm)

As with the carp, it was again necessary to determine one set of constants to predict the length of fish from both environments. The scatter diagram of total length and total scale radius of all the carpsucker from both environments is shown in Fig. 13. The slope and the intercept of the regression line drawn through the scatter diagram were determined by least square analysis. The intercept (constant a) was calculated to be 34.8 mm and the slope (constant c), 54.2 mm length/mm total scale radius. The resulting R-square of .884 indicated total length and total scale radius were very highly correlated (r = .94) and the same relationship between length and scale radius existed for both populations of fish. Therefore, use of the equation

$$L = a + cS$$

was justified as was the use of similar constants to predict the length of fish from both environments.

The calculated mean lengths of the carpsucker collected from the river are presented in Table 21. Mean lengths of the carpsucker collected from the reservoir are shown in Table 22. Data relating to year class strength are also presented in Tables 21 and 22. No dominating year class appeared to have existed in either the river or reservoir.

The mean calculated lengths (Tables 21 and 22) of the two carpsucker populations were compared using Fisher's LSD procedure (Fryer, 1966). Results are shown in Table 23. The rate of growth of carpsucker in the reservoir exceeded that of the carpsucker in the river in all five age groups; however, it was significant in only age groups II, III, and IV.

Table 21. Calculated lengths (mm) of carpsucker collected from the Smoky Hill River.

Year Class	No. of Observations Collected in 67	Collected in 68	Average Calculated Lengths at Age n: 1	2	3	4	5	6	7	8
1967	0	0	00.0							
1966	0	5	88.7	163.3						
1965	31	25	86.9	161.0	224.3					
1964	21	31	89.5	164.4	232.1	275.7				
1963	27	8	84.7	148.4	216.0	266.3	322.9			
1962	4	0	91.8	165.7	235.7	289.0	336.5			
Total No. of Observations			152	152	116	70	12			
Grand Ave. Cal. Length (mm)			87.5	159.4	225.7	271.8	327.4			
Standard Deviation of Cal. Length			9.48	18.01	25.50	28.13	41.91			
Grand Ave. Increment (mm)			87.5	71.9	66.3	46.1	55.6			

Table 22. Calculated lengths (mm) of carpsucker collected from the Cedar Bluff Reservoir.

Year Class	No. of Observations Collected in 67	Collected in 68	Average Calculated Length at Age n 1	2	3	4	5	6	7	8
1967	0	0	00.0							
1966	4	0	82.2							
1965	1	2	92.0	152.7	218.4					
1964	0	9	91.3	185.8	271.5	318.9				
1963	5	22	87.3	166.6	243.7	303.5	343.6			
1962	2	21	89.8	162.2	235.0	290.1	331.8	353.7		
1961	0	8	91.8	161.6	233.3	300.6	342.9	377.0	407.3	
Total No. of Observations			74	70	69	67	53	29	8	
Grand Ave. Cal. Length (mm)			89.0	166.5	242.5	300.6	338.4	360.1	407.3	
Standard Deviation of Cal. Length			11.32	25.39	32.27	30.90	30.87	54.65	35.83	
Grand Ave. Increment (mm)			89.0	77.5	76.0	58.1	37.8	21.7	47.2	

Table 23. Comparison of mean calculated lengths (mm) of carpsucker from Tables 21 and 22 using Fisher's LSD procedure. (* and ** indicate significance at the .05 and .01 levels respectively.)

Age	River carpsucker Ave. Cal. Length	-	Reservoir carpsucker Ave. Cal. Length			d.f.	LSD
1	87.5	-	89.0	=	-1.5	224	2.80
2	159.4	-	166.5	=	-7.1*	220	5.86
3	225.7	-	242.5	=	-16.8**	183	7.82
4	271.8	-	300.6	=	-28.8**	135	10.02
5	327.4	-	338.4	=	-11.0	63	21.20

DISCUSSION

The hypothesis tested in this study which stated impoundment had affected the two dominant species of rough fish, namely the carp and the river carpsucker, in Cedar Bluff Reservoir, was only partially acceptable. Carp have obviously been affected by impoundment while no significant differences existed between the carpsucker collected from the river and reservoir.

A food source was apparently limiting to growth of carp in the reservoir. The condition coefficient and the percentage fat content of the river carp were significantly higher than these same variables for the reservoir carp, while the growth rate of reservoir carp was only slightly lower than that of the river carp (age groups I, II, and III were significantly lower). This would lead to the conclusion that the food sources of the carp in the reservoir were substantial enough to sustain individual life and growth; however, not substantial enough to permit deposition of fats which would result in a robust condition. This conclusion immediately raises a question concerning what food sources were possibly limiting to the growth rate of the carp.

This study has indicated that impoundment has not affected the carpsucker population in the reservoir. Because carpsucker are primarily algae, microfauna and detritus feeders, there was apparently an abundance of phytoplankton and zooplankton in the reservoir. Koch's (1968) limnological study of Cedar Bluff Reservoir added evidence to this assumption. This leads to the question of why carp, which are omnivorous feeders, have not utilized the abundance of algae, microorganisms and settled out organic matter in the reservoir to a greater extent. Vass (1957, as described by Walburg and

Nelson, 1966), found that in over-stocked ponds, carp fed on algae, and with increased utilization of algae, growth rate decreased. In reference to fish feeding conditions in Russian plains reservoirs, Poddubnyy and Fortunatov (1961, as described by Walburg and Nelson, 1966), state that a decrease in benthos occurs after the first few years of impoundment. Fishes dependent on benthos exhibited a decrease in growth, transition to a microorganism diet unfamiliar to older fish, and increased detritus content in intestines. It was also stated that the nutritive value of detritus was low. Unfortunately, no data were available which indicated these phenomena have occurred in Kansas reservoirs.

Walburg and Nelson (1966) found that carp, Cyprinus carpio, river carpsucker, Carpiodes carpio, bigmouth buffalo, Ictiobus cyprinillus, and smallmouth buffalo, Ictiobus bubalus all experienced slow growth rates as a result of impoundment in Lewis and Clark Lake, South Dakota. It was suggested that the slow growth of these species was caused by low standing crops of plankton and bottom fauna. It was further emphasized that benthos was particularly limiting, forcing these fishes to utilize more plant material and detritus which are of apparent low nutritive value to these species. Low standing crops of plankton and bottom fauna were attributed to excessive turbidity and the rapid water exchange rate through the reservoir which inhibited the formation of a stable lacustrine community.

The following statement concerning bigmouth buffalo by Johnson (1963) may well apply to the carp in this study: "Buffaloes are more typically inhabitants of rivers than of lakes, and that while existence in lakes is possible, flourishing populations must be associated with a river or marsh with regular spring floods."

While carp are omnivorous, the principle foods are bottom organisms such as aquatic insect larvae, worms, crustaceans, small snails, and molluscs (Slastenenko, 1958; Moen, 1953; Cross, 1967; King and Hunt, 1967). It is therefore conjectured that bottom fauna was limiting in Cedar Bluff Reservoir forcing carp to utilize microorganisms which are of apparent low nutritive value to this species. Unfortunately, however, no data were obtained nor are any available from another source which would establish the fact that bottom fauna is in fact limiting in the reservoir. Concerning the environmental conditions existing in the river, it was observed during sampling that an abundance of bottom fauna prevailed. This would account for the sleek, robust condition of carp in the river.

Impoundment was apparently also responsible for the weakened year classes of carp in the reservoir. After an early post-impoundment study of fishes in Fall River Reservoir, Kansas, Schoonover and Thompson (1954) suggested that the reproductive rate of carp was lower than that prior to and immediately after impoundment. No reason was given for the decreased rate. Walburg and Nelson (1966) also reported that weak year classes of carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo have resulted since impoundment in Lewis and Clark Lake. Comparison of water levels with year-class strength suggested that rising water levels during the June-August period are necessary for successful spawning and survival of these species. Tarzwell (1941) pointed out the possibility of controlling carp reproduction in large reservoirs by fluctuating the water level at spawning time. Shields (1958), concluded that planned water level drawdown on Fort Randall Reservoir, South Dakota was primarily responsible for poor carp reproduction.

Because water was seldom released from the reservoir into the river (not once during the course of this study), it seems very unlikely that fluctuating water level was responsible for lowering the reproductive rate and/or survival of young fish. From observation, it appeared this phenomenon could more realistically be attributed to two factors: 1.) Cedar Bluff Reservoir is not characterized by shallow, weedy bays or flooded plains which would create suitable spawning habits for carp, and 2.) the continental climate of this area varies considerably and extended periods of drought, even during the spring of the year, are not uncommon. Such a spring-time drought would effectively eliminate the possibility of a rising water level which apparently enhances carp spawning activities.

None of the three variables studied indicated a significant difference existed between the carpsucker in the river and those in the reservoir. However, the river carpsucker was one of the species Walburg and Nelson (1966) found to be negatively affected by impoundment in Lewis and Clark Lake, South Dakota. As previously mentioned, the slow growth rate was attributed to low standing crops of plankton and bottom fauna, which in turn was a result of excessive turbidity and the rapid water exchange rate through the reservoir. Walburg and Nelson further reported that the carpsucker in age groups II, IV, and VI attained an average approximate length of 140 mm, 240 mm and 315 mm respectively. The calculated mean length of the carpsucker in Cedar Bluff Reservoir for the same age groups were 166.5 mm, 300.6 mm, and 360.1 mm (Table 22).

Reservoirs where the growth rate of carpsucker was comparable to that attained by this species in Cedar Bluff Reservoir includes two main stem Missouri River reservoirs—Oahe (Fogle, 1963) and Fort Randall (Sprague, 1961) both in South Dakota, and Lake Texoma (Bass and Riggs, 1959) in Oklahoma. All three of the above reservoirs are relatively deep and clear as is Cedar

Bluff Reservoir. It was therefore speculated that Cedar Bluff Reservoir was a suitable habitat for carpsucker because they were able to efficiently utilize the abundance of algae and microfauna in the reservoir. To verify this, however, a follow-up study on the food habits of the carpsucker in this system would be necessary.

SUMMARY

1. The purpose of this study was to determine the effects of impoundment on the carp, *Cyprinus carpio*, and the river carpsucker, *Carpiodes carpio*, in the Cedar Bluff Reservoir, western Kansas.

2. Fishes were collected from the reservoir and the Smoky Hill River immediately below the reservoir by various means including electrofishing, trapping, and rotenone treatment. Collection of fishes began in the spring of 1967 and terminated in the fall of 1968.

3. The variables employed to determine if differences existed between reservoir and river fishes were: growth rates, per cent fat content, and a condition factor (numerical terms describing the general condition, robustness or fatness of fishes.)

4. Analyses of length and weight data indicated the condition of the carp in Cedar Bluff Reservoir was significantly inferior to that of the carp in the Smoky Hill River. The condition coefficient did not significantly differ between male and female carp in the reservoir. The most significant difference between carp in the two environments existed between fish in the length group 301 mm and over. The mean condition coefficient of reservoir carp in this length group was .93, while that for river carp in the same length group was 1.26.

5. Environment significantly affected the percentage fat content in carp. On the basis of 100% dry matter, carp in the river averaged 16.6 per cent fat while reservoir carp averaged only 4.0 per cent fat. Sex was not a significant factor in determining the percentage of fats in carp.

6. Growth rate of river carp exceeded that of reservoir carp only during the first three years of life.

7. Year classes of carp in the reservoir fluctuated in size, while those of carp in the river were relatively stable.

8. The mean condition coefficient of the carpsucker in the reservoir was not significantly different from that of the carpsucker in the river. The condition coefficient did not differ significantly between the sexes in the two environments.

9. The per cent fat content of the carpsucker analyzed from the two environments did not differ significantly; neither did the per cent fat content between sexes in the two environments differ significantly.

10. Growth of the carpsucker in the reservoir was significantly higher than that of the carpsucker in the river.

11. The carpsucker year class sizes did not noticeably fluctuate in either the river or the reservoir.

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LITERATURE CITED

Atton, F. M. 1959. The invasion of Manitoba and Saskatchewan by carp. Transactions of the American Fisheries Society 88 (3):203-205.

Bass, J. Carl, and Carl D. Riggs. 1959. Age and growth of the river carpsucker, Carpiodes carpio Rafinesque, of Lake Texoma. Proceedings of the Oklahoma Academy of Science 39:50-69.

Bennett, George W. 1962. Management of Artificial Lakes and Ponds. New York: Reinhold Publishing Corporation. 266 pp.

Brezner, Jerome. 1958. Food habits of the northern river carpsucker in Missouri. Progressive Fish Culturist 20(4):170-174.

Buchholz, Marvin. 1957. Age and growth of river carpsucker in Des Moines River, Iowa. Proceedings of the Iowa Academy of Science 64:589-600.

Bulletin of the United States Bureau of Fisheries. 1927. Volume 43, pp. 120-123.

Cahn, Alvin R. 1937. The fisheries program in the Tennessee Valley. Transactions of the American Fisheries Society 66:398-402.

Call, L. E. 1961. Agricultural research at Kansas State Agricultural College before enactment of the Hatch Act (1887). Agric. Exp. Sta., Kansas State Univ., Bull. 441:1-43. October.

Cross, Frank B. 1967. Handbook of fishes of Kansas. Univ. of Kansas Publ., Mus. Nat. Hist., pp. 72-75.

Eddy, Samuel. 1957. How to Know the Freshwater Fishes. Wm. C. Brown Company. 253 pp.

Ellis, M. M. 1937. Some fishery problems in impounded waters. Transactions of the American Fisheries Society 66:63-75.

English, Thomas S. 1952. Growth studies of the carp in Clear Lake, Iowa. Iowa St. Col. Journ. Sci. 24(4):537-540.

Eschmeyer, R. W., and Tarzwell, C. M. 1941. An analysis of fishing in the TVA impoundments during 1939. Jour. Wildl. Mgt. 5(1):15-41.

Fogle, Ned E. 1963. Report of fisheries investigations during the fourth year of impoundment of Oahe Reservoir, South Dakota, 1961. Dingell-Johnson Project F-1-R-11. 36 pp.

Fryer, H. C. 1966. Concepts and Methods of Experimental Statistics. Boston: Allyn and Bacon Inc. 593 pp.

Gunther, L. G. 1880. Introduction to Study of Fishes. pp. 589-593.

Hile, Ralph. 1937. Age and growth of the cisco, Leucichthys artedi (LeSueur) in the lakes of the northeastern highlands, Wisconsin. Bull. U. S. Bur. Fish. 48 (1935):209-317, 11 figs.

Harlan, James R. and Everett B. Speaker. 1951. Iowa Fish and Fishing. Iowa State Conservation Commission. 2nd edition. 184 pp.

Huntsman, Gene R. 1967. Nupital Tubercles in Carpsuckers (Carpiodes). Copeia 2:457-458.

Information Bulletin Number 279. 1962. Cedar Bluff Reservoir. Kansas Forestry, Fish and Game Commission.

Jenkins, R. M. 1961. Reservoir Fish Management-Progress and Challenge. Sport Fishing Inst., Washington, D. C. pp. 1-22.

Jenkins, R. M. 1965. Bibliography on Reservoir Fishery Biology in North America. U. S. Dept. of the Interior, Research Report 68. 57 pp.

Johnson, R. P. 1963. Studies on the life history and ecology of the bigmouth buffalo, Ictiobus cyprinellus (Valenciennes). Fisheries Research Board of Canada 20(6):1397-1429.

Jordan, David Starr. 1905. Fishes. New York: Holt & Co. Volume 2, pp. 170-171.

King, Dennis R., and Hunt, George S. 1967. Effect of carp on vegetation in a Lake Erie Marsh. Jour. of Wild. Mgt. 31(1):181-188.

Koch, David L. 1968. Some limnological characteristics of Cedar Bluff Reservoir, Trego County, Kansas. Master's thesis. KSC, Ft. Hays.

Lagler, Karl F. 1956. Freshwater Fishery Biology. Dubuque, Iowa, Wm. C. Brown Company. 2nd edition. 404 pp.

Lanbou. 1963. Making plastic impressions of fish scales with a roller press. Progressive Fish Culturist 25 (3). July.

Lundberg, John G. 1967. Pleistocene Fishes of the good creek formation, Texas. Copeia No. 2. pp. 453-455.

Moen, Tom. 1953. Food habits of the carp in northwest Iowa lakes. Iowa Acad. Sci. Proc. 60:665-686.

Moore, E. 1931. A follow-up program on the impounded waters of the Sacandaga Reservoir. American Fisheries Society Transactions 61:139-142.

Morris, Larry A. 1965. Age and growth of the river carpsucker Carpiodes carpio in the Missouri River. American Midland Naturalist 73(2): 423-429.

Official Methods of Analysis of the Association of Official Agricultural Chemists. 1960. William Harwitz (Editor). 9th edition. Published by the Association of Official Agricultural Chemists; Washington, D. C.

Peterson, C. G. J. 1891. Eine Methods zur Bestimmung des Alters and Wushses der Fische. Milth. Deutsch. Seefischerei Ver., 11:226-235.

Poddubnyy, A. G., and M. A. Fortunatov. 1961. Problems of reservoir use by fisheries in various geographical zones. (Translated from the Russian in the Office of Technical Services, U. S. Department of Commerce, Washington, D. C., OTS: 63-31702). Voprosy Ikhtiologii (Problems of Ichthyology), Moscow, 1(4):599-611.

Schoonover, R. and Thompson, W. H. 1954. A post-impoundment study of the fisheries resources of Fall River Reservoir, Kansas. Trans. Kansas Acad. Sci. 57:172-179. Aug. 2.

Sharp, Robert W. 1942. Some studies of the distribution and ecology of the German carp in Minnesota, with suggested control measures. Minn. Div. Game & Fish. Fish. Resr. Invest. Rept. 45. ms.

Shields, James T. 1958. Experimental control of carp reproduction through water drawdowns in Fort Randall Reservoir, South Dakota. Transactions of the American Fisheries Society 87(1957):23-33.

Sigler, William F. 1958. The ecology and use of carp in Utah. Utah St. University, Ag. Ex. Station, Bulletin 405.

Slastenenko, E. P. 1958. The freshwater fishes of Canada. Toronto: Kiev Printers, pp. 182-183.

Smith, Stanford H. 1954. Method of producing plastic impressions of fish scales without using heat. Prog. Fish. Cult. 16(2):75-78.

Sprague, James W. 1961. Report on fisheries investigations during the seventh year of impoundment of Fort Randall Reservoir, South Dakota, 1959. Dingell-Johnson Project F-1-R-9. 49 pp.

Stroud, Richard H. 1967. Summary, Reservoir Fishery Resources Symposium: In Reservoir Fishery Resources Symposium at Athens, Georgia, Am. Fish. Soc. pp. 556-569.

Struthers, P. H. 1929. Carp control studies in Erie Canal. New York Cons. Dept. Ann. Rept. Supp. 18:208-219.

Swee, U. Boon, and McCrimmon, Hugh R. 1966. Reproductive Biology of the carp. Trans. Amer. Fish. Soc. 95(4):372-380.

Tarzwell, Clarence M. 1942. Fish populations in the backwaters of Wheeler Reservoir and suggestions for their management. Transactions of the American Fisheries Society 71(1941):201-214.

U. S. Dept. of Interior. 1963. Reservoir management plan, Cedar Bluff Reservoir, Kansas. Bureau of Reclamation, McCook, Neb. 175 pp.

Van Oosten, John. 1929. Life History of the lake herring (Leucichthys artedi LeSucur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bull. U. S. Bur. Fish., 44(1928): 265-428, 43 Figs.

Vass, K. F. 1957. Studies on food and feeding habits of the common carp in Indonesian ponds. (1) Changes in the diet during growth. Indo-Pacific Fisheries Council 7th Session, Bandung, Indonesia. (IPFC/C57/Tech. 13-1). 25 pp. Mimeographed.

Walburg, Charles and William R. Nelson. 1966. Carp, River Carpsucker, Smallmouth Buffalo and Bigmouth Buffalo in Lewis and Clark Lake, Missouri River. U. S. Fish and Wildlife Service Research Report Number 69. pp. 1-30.

Wickliff, E. L. 1932. Are newly impounded waters in Ohio suitable for fish life. American Fisheries Society Transactions 62:275-277.

THE EFFECTS OF IMPOUNDMENT ON THE CARP, *CYPRINUS CARPIO*, AND THE RIVER CARPSUCKER, *CARPIODES CARPIO*, IN THE CEDAR BLUFF RESERVOIR, WESTERN KANSAS

by

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ABSTRACT

This study was concerned with the effects of impoundment on two species of rough fish, the carp, *Cyprinus carpio*, and the river carpsucker, *Carpiodes carpio*, in the Cedar Bluff Reservoir, Kansas.

Observations revealed that a noticeable difference in condition existed between these species in the reservoir and those in the river below the reservoir.

The hypothesis tested was that impoundment has affected both species under study. The variables selected to test this hypothesis were: 1.) growth rate, 2.) per cent fat content, and 3.) condition factor of fishes.

Data were obtained from 353 carp and 225 carpsucker collected from the river and from 148 carp and 182 carpsucker collected from the reservoir. Fishes were aged using the scale method. Calculated lengths of fishes at previous ages were determined using the equations $L = 67.3 + 36.3S$ and $L = 34.8 + 54.2S$ for carp and carpsucker respectively. Analysis of mean calculated lengths using Fisher's LSD comparison procedure ($\alpha = .05$) revealed that the growth rate of river carp significantly exceeded that of the reservoir carp in age groups I, II, and III. The growth rate of carpsucker in the reservoir exceeded that of carpsucker in the river; significantly so, at age groups II, III, and IV.

Percentage fat content in fishes was determined on the basis of 100 per cent dry matter using a Goldfisch apparatus with isopropyl alcohol as the solvent. Two-way analyses of variance were performed on the results with the factors tested being environment (river and reservoir) and sex.

The percentage fat content of the carp in the river was significantly greater than that of the carp in the reservoir. Carpsucker in the reservoir contained a slightly higher, yet non-significant, percentage of fats than this species in the river. Sex did not contribute significantly to the percentage fat content in either species.

A numerical term describing the relative condition (robustness, fatness) of each fish was determined using the equation $K_{TL} = \frac{100,000W}{L^3}$ where K_{TL} = condition coefficient, W = weight in grams, and L = total length in millimeters. A three-way analysis of variance was performed on the parameters; environment, sex, and length group (0–150 mm, 151–300 mm, and 301 mm and over). The condition coefficients of the carp in the river were very significantly higher than those of carp in the reservoir. No significant difference existed between the carpsucker in the two environments. As expected, length groups contributed significantly to the condition coefficients of both species with the factors being higher in the smaller fishes. Sex, however, had no effect in either species.

It was concluded that the initial hypothesis be accepted concerning carp, but rejected concerning carpsucker. Impoundment in Cedar Bluff Reservoir has affected the carp. The slow growth rate, low percentage of fats, inferior condition and weak year classes of carp in the reservoir were attributed to the apparently low standing crop of bottom fauna and the lack of suitable spawning habitats in the reservoir.

Carpsucker, however, have apparently adapted to the new environment by utilizing the abundance of algae, microfauna, and settled out organic matter in the reservoir and thus have found it quite a suitable habitat.