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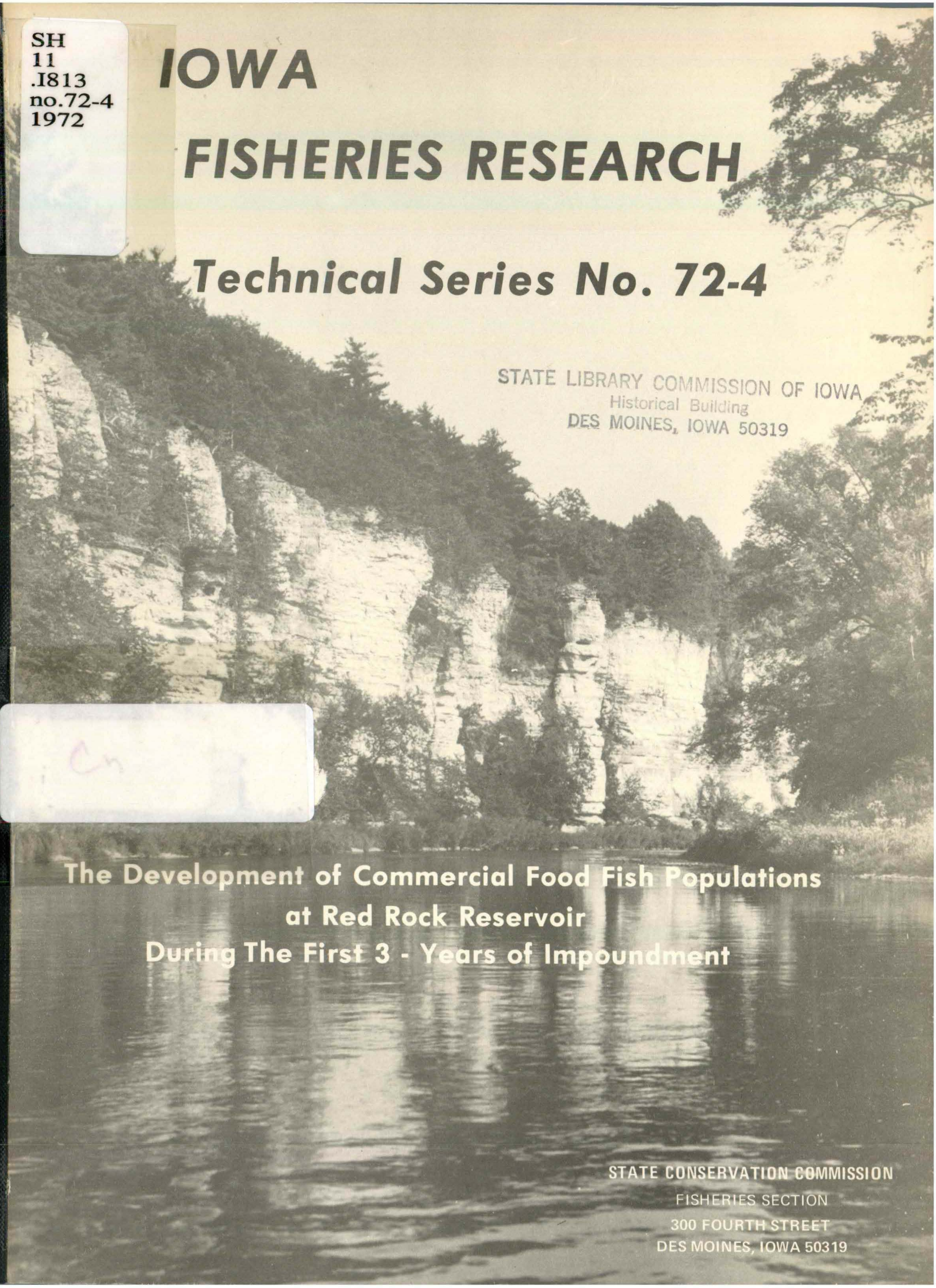

The Development of Commercial Food Fish Populations at Red Rock Reservoir During The First 3 - Years of Impoundment

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THE DEVELOPMENT OF COMMERCIAL FOOD FISH POPULATIONS AT RED ROCK RESERVOIR DURING THE FIRST 3-YEARS OF IMPOUNDMENT[1]

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ABSTRACT

Commercial food fish populations were studied at Lake Red Rock, a flood control reservoir, during the first three years of impoundment. The fish species of main interest were carp, river carpsucker, buffalo and channel catfish. Primary objectives of the study were to define changes in the food fish populations as the reservoir filled and as populations were exploited by an experimental net fishery. Total catch was 321,937 food fish weighing 151,533 lbs. Carp dominated the catch in the first two years, but were replaced as the most prevalent species by river carpsucker during the third year. Relative abundance indices based on catch statistics showed both river carpsucker and buffalo were becoming increasingly more important in the fishery and carp were decreasing. Commercial food fish comprised about 80% of the fishery by number and 88% by weight. Sport fish species, with the exception of bullhead and crappie, were found in low numbers. Four different types of fishing gear, including frame nets, gill nets, baited hoop nets and slat traps were used in the fishery. Catch success was highest in the second year of impoundment for all gear except gill nets. Nearly 103,000 commercial food fish weighing over 59,000 lbs were exploited in the experimental fishery during the second and third years. Total market value of the two year fishery was estimated at $10,300. Numerical population estimates during the first year of study revealed the standing crop of commercial food fish at about 150 lbs per surface acre at conservation pool elevation. Of this value, 112 ± 8 lbs was carp, 22 ± 6 lbs was river carpsucker, 8 ± 2 lbs was buffalo and 7 lbs was channel catfish. Early life history investigations of gizzard shad and carp populations were conducted during the second year of the study. Weekly samples of 0-age populations of these fish showed gizzard shad were nearly equally distributed throughout the reservoir, but young carp populations were higher in the upper portion of the reservoir and in the shallow embayments. Annual mortality rate of the shad population was estimated at .381, but this value did not include samples past late summer. Maximum population density of 0-age gizzard shad in Lake Red Rock was estimated at 6.62×10^8 with a standing crop of 20 lbs per surface acre. Initial impoundment to an elevation of nearly 39 ft above conservation pool resulted in rapid growth of fish in the first year. When the reservoir was reduced to the authorized level, growth slowed to nearly nothing in the second year, but returned to more normal rates in the third year. The experimental fishery showed no measurable affects on growth or body condition. A discussion of the biological characteristics of commercial food fish populations at Lake Red Rock during the first three years of impoundment was presented along with recommendations for utilization of surplus commercial food fish stocks.

INTRODUCTION

Impoundment of Red Rock Reservoir in 1969 had profound influence upon studies of commercially valuable food fish conducted near this locality of the Des Moines River since 1966 (Mayhew, 1972). As the region transformed from river habitat to lake environment distinctive changes took place in the fish population structure. Large year classes of fish with commercial and industrial food fish value predominated within a short period of time, and it was quickly evident characteristics of fish populations in the reservoir were going to be somewhat different from those at Coralville Reservoir where similar investigations pertaining to commercial fisheries were initiated during 1966. Since most future reservoirs constructed in Iowa will be similar to Red Rock Reservoir the project was designed primarily to monitor development of commercial food fish populations and determine their potential for orderly harvest. In a long term prospective the primary objectives were to determine the abundance and distribution of food fish populations, the biological effects and potential of a net fishery, factors influencing the abundance and development of year classes of food fish, and developmental testing of useful types of fishing gear and procedures for exploitation of commercial fishes.

During the first year, with initial flooding of the reservoir, most data were collected on the biological characteristics and early development of fish populations. The most important parameters were population size, age structure, species composition, growth in body length and weight, success of reproduction and catch success with entrapment types of gear, particularly pound nets.

The following year commercial food fish populations, including carp, carpsucker, buffalofish and channel catfish were exploited by a simulated commercial fishery. No attempt was made to market catches of fish, but all captured fish were removed from the lake at a rate not to exceed 20% of the estimated numerical population density for each species. A large population of gizzard shad developed during this project segment and this species was added to the list of commercial food fish because of their industrial value. Concomitant data were collected to ascertain overall affects of the fishery and formed the baseline for further evaluation of commercial fisheries. The efficiency of fishing gear, such as gill nets and slat traps, were also evaluated for use as exploitation gear.

Associated studies of the distribution, abundance, mortality and growth of 0-age fish were completed during this segment. Eleven species of larval and post-larval fishes were captured in a weekly sampling regime by small mesh tow nets. Only gizzard shad and carp were found at a density required for statistical analysis. Results of commercial food fish investigations at Coralville Reservoir by Mayhew and Mitzner (1967, 1968 and 1969) indicated both species composition and catch success was directly related to year class abundance. Bigmouth buffalo comprised < 6% of the numerical catch at Coralville Reservoir in pound nets prior to recruitment of a large 1966 year class, and 18-34% after

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[1]Study was partially financed by Project 4-11-R; Commercial Fisheries Research and Development Act (PL 88:309) administered by National Marine Fisheries Service, NOAA.

the year class entered the fishery. Catch success of bigmouth buffalo was 2 fish per net day (FND) before recruitment and increased to 11-17 FND after the year class became vulnerable to commercial gear, reaching a maximum of 30 FND at peak vulnerability. Many other studies of reservoir fish populations indicated year class strength was formed during early life stages (Walberg, 1971; Elrod and Hassler, 1971; Beckman and Elrod, 1971; Hauser and Netsch, 1971). Originally, this phase of the study was scheduled for at least two segments, but the effectiveness of sampling was so hampered by floating debris, shallow mud flats and uncleared woodland the program was terminated after the first year. The immediate goal of defining characteristics of 0-age fish populations was accomplished, only comparisons of abundance, distribution and growth between years remained unresolved.

The final year of the investigation dealt mainly with the overall affects of further exploitation, particularly changes in the population structure, evaluation of different types of fishing gear and attractor baits for catfish and carp.

RESERVOIR DESCRIPTION AND OPERATION

Red Rock Reservoir was authorized by the US Congress in 1938 as a part of the Upper Mississippi River basin flood control project. Construction of the impervious filled, earthen dam began in September 1960 and was completed in March 1969. The damsite is located in the middle portion of the Des Moines River basin in Marion County at mile 143 above its confluence with the Mississippi River about 50 miles downstream from Des Moines.

Maximum fluctuation of the reservoir water level is from elevation 725 ft MSL at conservation pool to 780 ft MSL at flood capacity. At the lower level the lake is about 11 miles in length and contains 8,950 surface acres and 90,000 acre ft of water (Plate 1). The flood pool has a length of nearly 36 miles and covers 65,500 surface acres with a storage capacity of 1,740,000 acre ft. With the average recorded discharge of 4,757 CFS from the outlet structure the mean storage time for water at conservation pool elevation is slightly more than nine days. Maximum depth of the lake at the lower level is 35 ft and increases to 90 ft at flood capacity. Flood frequency to elevation 780 ft MSL is about once in every 100 yrs. Minimum discharge through the outlet structure is 300 CFS, but may range up to 130,000 CFS during maximum release. The Des Moines River reached the maximum value only twice since 1851.

The watershed of Lake Red Rock contains 13,323 square miles of the total drainage basin area of 14,540 square miles. No major tributaries enter the Des Moines River downstream from the damsite. Besides the Des Moines River; Whitebreast Creek, South River, North River and Middle River discharge directly into the reservoir below flood pool elevation. Robert's Creek Lake is a small, 250 surface acre sub-impoundment located near mid-reservoir along the north shoreline. Much of the watershed is intensively farmed for small grain crops, although the flood plain is covered in many localities with dense stands of mature woodland.

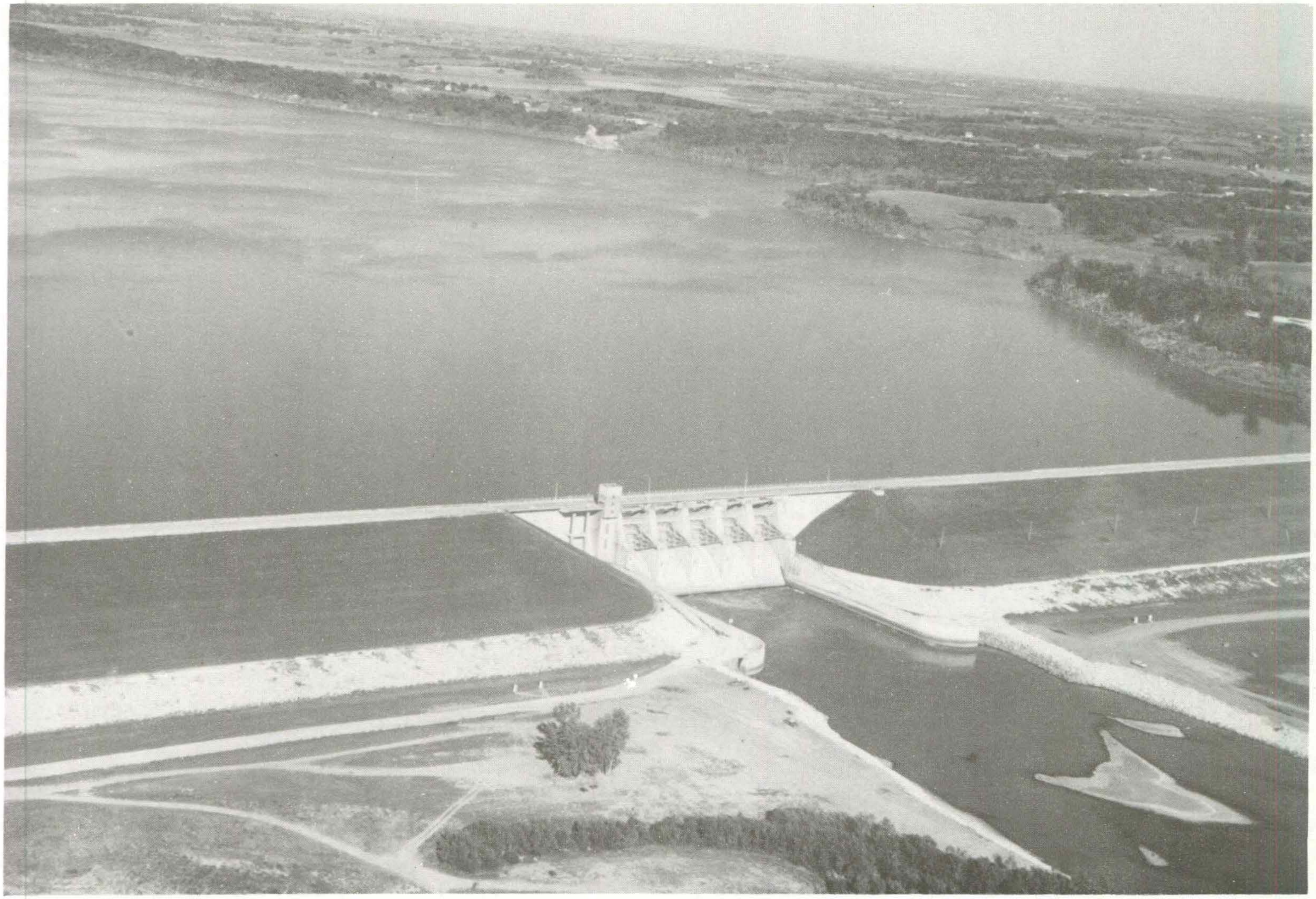

Plate 1. Aerial view of Lake Red Rock at conservation pool elevation 725 ft MSL.

Impoundment commenced on 18 April and conservation pool elevation was reached by 21 April. Accumulation of snow cover to an average depth of nearly 10 inches throughout the drainage basin during the winter of 1968-69 reduced the time required to fill the reservoir to conservation pool level from the predicted two months to three days. Moisture from spring runoff and accompanying abnormally high summer precipitation held the reservoir above conservation pool until 15 September. Surface area of the lake ranged from 8,950 acres at conservation pool to approximately 44,000 acres on 2 August. During the first year of impoundment the mean surface area of the reservoir was about 26,000 acres.

Water level fluctuation of Lake Red Rock in 1970 was unimportant. Maximum pool level during the year was 735.2 ft MSL or 10.2 ft above minimum elevation. The raise lasted 14 days from late May through early June. Other minor fluctuations ranging from 2-ft to 3.7-ft occurred during the season. Duration of increased water level > 1-ft was never more than seven days.

During 1971 water level was also stable. Maximum pool elevation of 736.5 ft MSL, or 11.5 ft above conservation pool occurred during a 13 day period in late February. From 5-28 March the lake level was increased by 5.3 ft to elevation 731.3 ft MSL. Several minor fluctuations were recorded but they were generally < 2 ft.

Overall water quality, especially from sedimentary turbidity, is quite low in Lake Red Rock. At conservation pool elevation mean depth of the impoundment is slightly more than 8-ft, and numerous embayments and shoals are < 4-ft in depth. Prevailing wind action into the shallow regions and high unprotected clay bluffs results in high turbidity much of the open water season. During windy periods from either northwesterly or southeasterly directions turbidity becomes severe in shallow water areas and along the entire windward shoreline.

Water samples were collected biweekly at eight locations from January 1970 through November 1971 to measure changes in water quality resulting from storage. Stations 1 and 5 were located in the tailwaters and headwaters (Figure 1). Three stations were located in the reservoir, one each in the upper (4), middle (3) and lower segments (2). Each reservoir station was sampled at the surface and 20 ft deep. Mean values for the 15 parameters and sample ranges at the mid-reservoir surface station are listed in Table 1.

The data revealed rather wide variations in turbidity, coliform bacteria and enrichment components, such as PO_4, NH_3, NO_2 and NO_3. Turbidity was influenced both by inflow rate and wind action on shoals. Fluctuation of other parameters was influenced primarily by the efficiency of domestic and industrial waste treatment at the Des Moines Waste Water Treatment Plant. Although this installation underwent extensive remodeling and enlargement shortly before impoundment of the lake there were still periods when treatment was inadequate for acceptable water quality.

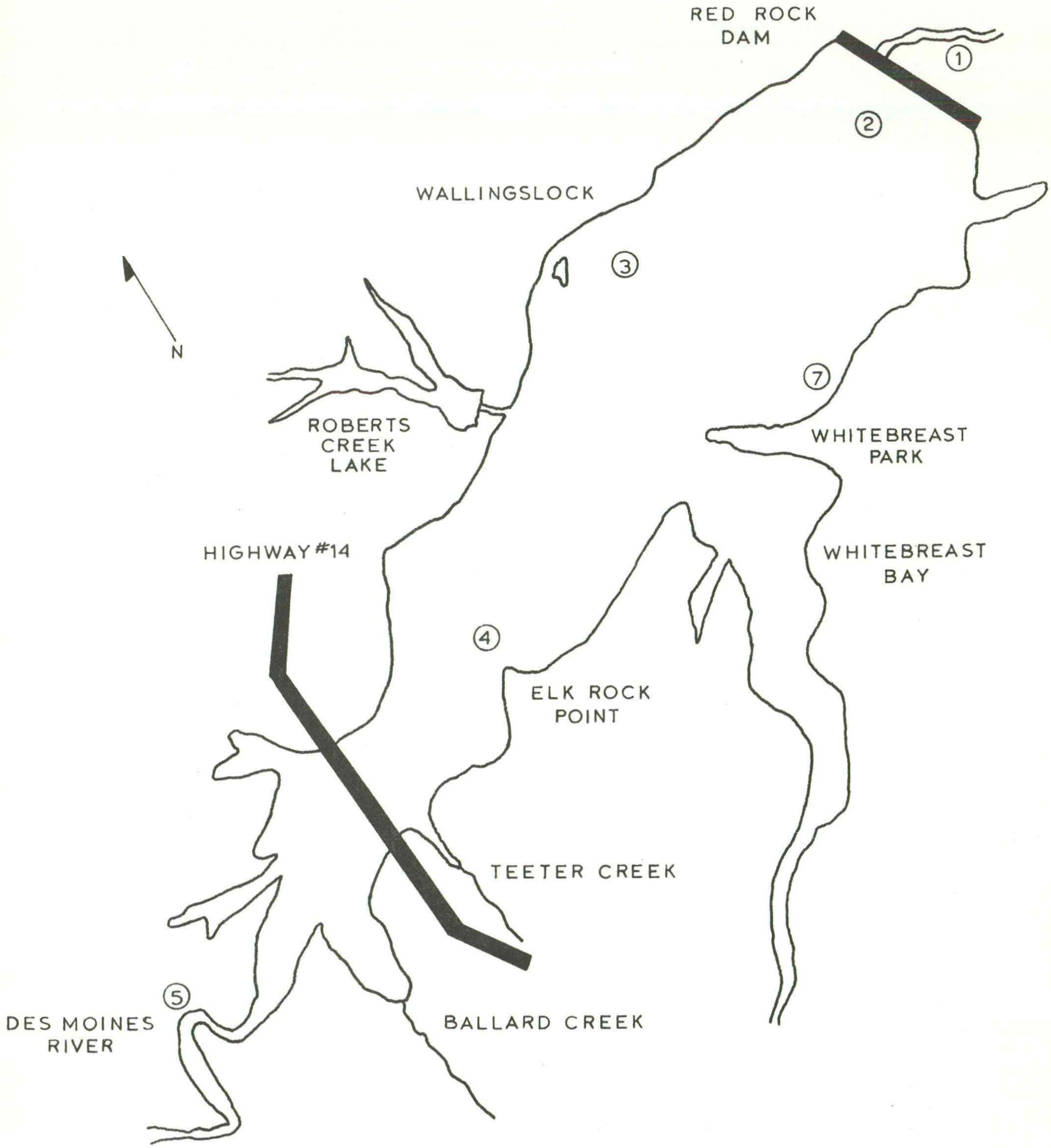

Figure 1. Location of sampling stations for water quality and meter net tows at Lake Red Rock.

Table 1. Mean, standard deviation and range of 15 water quality parameters at the mid-reservoir surface station from January 1970 through November 1971

Parameter	Mean	Standard deviation	Range
DO	11.1 ppm	± 4.2	3.3 - 20.7
BOD (5 days)	4.5 ppm	± 2.7	1 - 12
COD	22.3 ppm	± 5.9	12.3 - 33.2
PO_4	.15 ppm	± .11	.1 - .52
Total PO_4	.20 ppm	± .10	.1 - .62
Organic N	.98 ppm	± .26	.6 - 1.7
NH_3	.19 ppm	± .24	< .01 - 1.1
NO_2	2.63 ppm	± 1.69	.4 - 6.8
NO_3	.095 ppm	± .097	.011 - .32
pH	7.8	± .3	7.3 - 8.2
Turbidity	116 JTU	± 124	11 - 520
Total alkalinity	196 ppm	± 63	72 - 360
Total solids	414 ppm	± 93	156 - 638
Hardness	16 gpg	± 4.8	6.1 - 27.4
Coliform bacteria	209 N/100 ml	± 482	< 10 - 1,900

METHODS AND PROCEDURES

Experimental netting commenced on 12 May, 1969 soon after the reservoir reached conservation pool elevation. To eliminate repetitious use of individual sampling dates in subsequent project segments the open water season was equally divided into biweekly intervals. Periods were consecutively numbered from 16 March through 30 November with the same number retained from year to year after minor shifting of dates so netting always started on Monday (Table 2). Unpredictable delay was anticipated occassionally from ice cover or flooding. Cold weather usually terminated netting in early November.

Pound nets were used exclusively for the initial fishery. These gear were constructed of 2-inch stretch measure web on 2 1/2-ft hoops and 2 1/2 x 5-ft frames. A single 60 ft lead of 2-inch mesh was attached to the frame. A typical set was made perpendicular to the shoreline at sufficient depth to cover the frame and lead. Nets were raised at 24-hr intervals on weekdays and all captured fish counted, weighed in aggregate, fin clipped and released. Because of a large embayment in the Whitebreast Creek basin, fish were marked differently from the main lake to test discreteness of these populations and measure intra-reservoir movement during high water levels. Scale samples were also collected from randomly selected fish in each area for age and growth studies.

Table 2. Biweekly netting intervals at Red Rock Reservoir

Biweekly interval	Dates of interval
1	16-29 March
2	30 March-12 April
3	13-26 April
4	27 April-10 May
5	11-24 May
6	25 May-7 June
7	8-21 June
8	22 June-5 July
9	6-26 July
10	27 July-9 August
11	10-23 August
12	24 August-6 September
13	7-20 September
14	21 September-4 October
15	5-18 October
16	19 October-1 November
17	2-15 November
18	16-30 November

Sampling was concentrated into the headwaters from Period 15-17 for channel catfish. Hoop nets with 2-ft circular frames and 1 1/2-inch stretch mesh were baited with cheese clippings or soybean cake and set in flowing water. Netting procedure was identical with the pound net fishery with sampling confined to week days and the tail-ropes opened on weekends. Captured fish were counted, weighed and a pectoral spine removed from a sub-sample of all sized channel catfish.

Netting effort for the first segment was 847 net days (ND). The pound net fishery comprised 727 ND, which was about equally divided between the main pool and Whitebreast bay. Baited hoop nets contributed the remaining 120 ND.

The fishery in the second study segment experimentally exploited commercial food fish populations during 17 biweekly periods and employed three different types of fishing gear. Netting began at Period 2 on 30 March and extended into Period 18 on 23 November. At least one type of gear was used in each period making a continuous fishery between these dates.

Standardized pound nets were used in all periods except 5 and 14. Baited hoop nets were fished in Periods 5, 7, 9, 12 and 14. Gill nets, with a length of 200 yds, 6-ft in depth and 5-inch stretch measure, were fished exclusively during Period 5. Total effort of the fishery was 761 ND, of which five were with gill nets, 182 with baited hoop nets and 574 with pound nets.

Fish populations were exploited with pound nets, gill nets and slat traps from the main pool during Periods 3-12 of the third project segment. Pound nets were used during Periods 3-12 for 206 ND, gill nets were fished in Periods 6-12 for 39 ND, and slat traps were fished in Periods 7-12 for 137 ND.

SPECIES COMPOSITION AND CATCH STATISTICS

The initial fishery lasted 11 biweekly periods and produced a catch of 102,556 fish weighing 36,177 lbs (Table 3). Carp dominated the numerical catch with 69.9%. Bullhead ranked second in importance comprising 13.3%, and river carpsucker was third with 7.6%. Channel catfish and bigmouth buffalo, which have the highest commercial food fish value, made up slightly more than 6% of the catch. Fish primarily with sporting value or small commercial value comprised about 17% of the catch.

Table 3. Catch statistics of the experimental net fishery at Red Rock Reservoir

	1969			1970			1971		
Species	N	Lbs	$\overline{X}$ wgt	N	Lbs	$\overline{X}$ wgt	N	Lbs	$\overline{X}$ wgt
Carp	71,994	24,909	.35	85,627	31,933	.37	16,761	12,699	.76
R carpsucker	4,781	4,617	.59	33,046	21,836	.66	17,825	18,041	1.01
Buffalofish	4,280	1,624	.38	17,622	9,140	.51	4,014	5,334	1.33
C catfish	1,471	533	.36	6,106	2,000	.32	1,407	1,410	1.00
Others[a]	17,530	4,493	.24	25,382	7,819	.44	11,552	5,143	.45

[a]Species listed in the table as others included bluegill (*Leopmis machrochirus*), green sunfish (*L. cyanellus*), pumpkinseed sunfish (*L. gibbosus*), largemouth bass (*Micropterus salmoides*), gizzard shad (*Dorosoma cepedianum*), northern pike (*Esox lucius*), white sucker (*Catostomus commersoni*), northern redhorse (*Moxostoma aureolum*), golden redhorse (*M. erythrurum*), golden shiner (*Notemigonus crysoleucas*), white bass (*Roccus chrysops*), yellow bass (*R. interrupta*), black bullhead (*Ictalurus melas*), flathead catfish (*I. olivaris*), freshwater drum (*Aplodinotus grunniens*), eel (*Anguilla rostrata*), yellow perch (*Perca flavescens*), goldfish (*Carassius auratus*), shortnosed gar (*Lepisosteus platostomus*).

Carp also dominated the catch by weight making up 68.9% of the fishery. River carpsucker ranked second with 12.2%, followed in importance by bullhead, 10%; buffalo, 4.5%; and channel catfish, 1.5%. By weight, commercial fish species made up nearly 88% of the catch.

Total catch during 1970 was 167,823 fish with a combined weight of 72,729 lbs (Table 3). Carp predominated as the most prevalent species of commercial food fish comprising 51% of the numerical catch. Species composition of the remainder of river carpsucker, 19.7%; buffalo, 10.5%; and channel catfish, 3.6%. By weight, species compsoition was carp, 44%; river carpsucker, 30.1%; buffalo, 12.6% and 2.7% channel catfish. Overall, fish with commercial and industrial value comprised nearly 85% of the numerical catch and 89% of the weight.

River carpsucker became the most abundant species of commercial food fish in the fishery during 1971. They comprised 34.6% of the numerical catch and 42.3% of the catch by weight. Carp ranked second in importance making up 32.5% of the number and 29.8% of the weight. Buffalo were third in abundance making up 7.8% of the numerical catch and 12.5% of the weight. The channel catfish fishery was confined to the main pool with baited slat traps and comprised 2.7% of the number and 3.3% of the weight in the fishery. Sport fishes made up 22.4% of the catch by number and 12.1% by weight. Total catch for the season was 51,559 fish weighing 42,627 lbs. Fish with commercial food fish value dominated the fishery with 78% of the numerical catch and 88% of the weight.

Catch success of fish varied considerably depending upon season and type of gear. As shown in Table 4, mean catch success for combined species in all gear was 42 fish per net day (FND) in 1969, 54 FND in 1970 and 21 FND in 1971. Analysis of variance of catch success in a one-way classification showed no significant difference between yearly mean values ($P < .10$).

Catch success by individual species varied greatly between project segments and netting intervals. Carp ranged from 8 FND for Period 6 in 1969 to 618 FND for Period 2 in 1970. Mean catch effort for carp was 128 FND during the first two project segments and declined to 34 FND in the last segment. River carpsucker catch success became progressively greater each year. During the initial fishery catch effort of this species ranged from 5-59 FND with a mean of 19 FND, and in the second year mean catch effort was 36 FND and ranged from < 1-70 FND. Catch success varied from 11-97 FND and averaged 37 FND in 1971. Yearly mean catch effort of buffalo was 8 FND in 1969, 29 FND in 1970 and 10 FND in 1971. Mean catch rate of channel catfish was 3 FND for the first and third project segments and 13 FND for the second year. The latter value reflected extensive use of baited hoop nets in the headwaters.

Pound nets and baited hoop nets were the most effective gear for taking carp (Table 5). Nearly 51% of the fish taken by pound nets in 1970 and 33% in 1971 were carp. Hoop nets catches consisted of 54.7% carp in 1970 and 32.6% the following season. Gill nets were most effective for carp, river carpsucker and buffalo. The 1970 gill net fishery was made up of 29.6% carp and 16% buffalo. The following year 40.6% was river carpsucker and 35.9% buffalo. Seasonal fluctuation in gill net catches were quite wide, due mostly to increased movement to shallow depths for spawning. Channel catfish catches were greatest in baited hoop nets comprising 37.9% of the fishery during 1970 and 48.8% in 1971. Catfish occurrence in gill nets and pound nets was 1.4% or less. Baited hoop nets took few river carpsucker and buffalo.

Table 4. Catch-effort of commercial fish at biweekly netting intervals (all values expressed in FND)

Netting interval	Carp 1969	Carp 1970	Carp 1971	R carpsucker 1969	R carpsucker 1970	R carpsucker 1971	Buffalofish 1969	Buffalofish 1970	Buffalofish 1971	C catfish 1969	C catfish 1970	C catfish 1971
2		618			9	29		52	27		<1	<1
3		124	65		18	11		55	5		10	<1
4		160	27		3	45		2	9		21	<1
5	18	70	47	32	<1	32	3		16	<1	<1	<1
6	8	191	31	7	52	19	<1	55	11	<1	7	1
7	11	111	44	13	41	22	<1	15	5	<1	3	3
8	17	165	36	59	61	29	1	70	10	2	20	5
9	112	78	32	12	56	46	<1	20	6	<1	2	3
10	427	51	20	14	109	97	8	33	4	<1	<1	8
11	434	143	23	9	44	37	18	28	5	1	19	6
12		173	17		30			11			1	
13		54			70			51			83	
14	348	62		16			24			11	<1	
15	65	120			40			17		2		
16	12	93			16			12		5		
17	70	39		5	18		15	8		<1		
18		91			9			5			8	
$\overline{X}$	138	138	34	19	36	37	8	29	10	3	13	3
$S_{\overline{x}}$	±53	±32	±5	±6	±7	±7	±3	±6	±7	±1	±6	±1

Table 5. Species composition of the catch of commercial fish in three different types of gear during 1970 and 1971

Species	Gill nets % N	Gill nets % Wgt	Hoop nets % N	Hoop nets % Wgt	Pound nets % N	Pound nets % Wgt
Carp						
1970	29.6	16.7	54.7	84.1	50.9	40.7
1971	18.3	28.3	32.6	73.7	33.0	28.8

Table 5. (Continued)

Species	Gill nets % N	Gill nets % Wgt	Hoop nets % N	Hoop nets % Wgt	Pound nets % N	Pound nets % Wgt
R carpsucker						
1970	2.6	3.4	.1	.2	21.6	32.9
1971	40.6	29.5	[a]	[a]	35.4	44.7
Buffalo						
1970	16.0	12.9	< .1	< .1	11.3	13.6
1971	35.9	34.7	[a]	[a]	7.0	10.7
C catfish						
1970	.1	.3	37.9[b]	14.1[b]	.5	1.7
1971	< .1	1.5	48.8[b]	21.6[b]	1.4	3.0
Others						
1970	6.6	23.6	7.7	1.5	15.3	10.7
1971	4.2	6.0	18.6	4.7	23.2	12.8

[a]Absent from catch during the entire season.

[b]Gear included baited slat nets in the main pool.

ESTIMATED SIZE OF FISH POPULATIONS

Estimates of population size were completed for carp, river carpsucker, buffalo and channel catfish during the first year of impoundment. Portions of each population was marked by excision of one or more fins in a coded regime to determine intra-reservoir distribution and movement as well as the marked to unmarked ratios for extrapolation of numerical estimates. All marked fish were released near the location of original capture.

The Schnabel method of computation for multiple sample censuses from the equation

$$\hat{N} = \frac{\Sigma(C_t M_t)}{\Sigma R_t}$$

where

$\hat{N}$ = estimated number of fish in the population

M_t = total number of marked fish at large at interval t

C_t = total number of fish in the sample at interval t

R_t = number of marked fish in C_t

was used for estimating population density. Confidence interval at the 95% level were set around $\hat{N}$ in the usual fashion for a Poisonnian distribution.

Following marking of the initial group of fish and whole or partial homogenious distribution of marked and unmarked segments of the population this method yielded both independent and cumulative estimates of the population for each biweekly sampling interval. Marking was continuous for 11 periods terminating on 1 November, although netting continued until 15 November.

ESTIMATED SIZE OF THE CARP POPULATION

During 12 biweekly periods, 52,508 carp were marked and released from a catch of 72,159. The total number of carp recaptured was 703 or 1.3% of the number marked. Recaptured fish showed almost equal distribution in all localities of the lake. Independent population estimates among individual sampling periods ranged from 35,830 at Period 6 to 168,347,926 at Period 17 (Table 6). Variations in the independent estimates were directly related to the number of marked fish recaptured within the netting interval. Cumulative estimates ranged from 35,889 at Period 6 to 2,854,436 at Period 18. The final estimate was considered the most precise because it was based on the largest number of recaptured fish. At the 95% level this estimate varied no more than ±228,004.

Table 6. Population estimates for carp at Lake Red Rock during 1969

Period	Cumulation N marked	N captured	N recaptured	Independent $\hat{N}$	Cumulative $\hat{N}$
5	1,256				
6	1,597	1,655	58	35,839	35,839
7	2,115	523	5	167,046	46,252
8	2,624	512	3	360,960	60,557
9	8,819	6,261	66	248,922	154,739
10	21,564	12,795	50	2,256,782	732,223
11	40,866	19,507	205	2,051,946	1,431,301
14	47,400	13,910	118	4,817,339	2,222,494
15	52,248	4,977	129	1,838,758	2,142,381
16	52,385	1,582	61	1,355,021	2,073,274
17	52,508	9,641	3	168,347,928	2,787,922
18	52,508	1,156	5	12,139,849	2,854,436
Total	52,508	72,159	703		

Rapid acceleration in the cumulative estimates between Periods 8-14 was attributable to recruitment of 0-age carp into the segment of the population which was wholly vulnerable to pound nets. Most carp $\leq$ 11 inches TL could escape by passing through the 2-inch stretch measure mesh. Length frequency distribution during individual biweekly periods showed the occurrence of carp $\leq$ 11 inches TL increased greatly in catches after Period 6 and became progressively more important until they comprised about 95% of the catch after Period 10 (Figure 2). From Period 11 size structure of biweekly samples remained nearly constant. Population estimates showed nearly the identical trend except inflections were delayed by about two periods. These data would support the premise systematically increased population estimates were from recruitment of young carp into the fishery.

Estimated standing crop of carp in Lake Red Rock was directly associated with water level elevations because increased water levels also increased surface area. From a constant estimated population size, as water level and surface area increased, poundage per unit became less. The carp population density was estimated at 2,854,436 ± 228,004 and had a combined weight of 999,053 ± 79,814 lbs ($\overline{X}$ = .35 lbs from mean weight of carp from all samples). At the mean surface area of 26,000 acres in 1969, poundage per acre would be 39 ± 2 lbs. When standing crop was computed for the conservation pool of 8,950 acres this value increased to 112 ± 8 lbs per acre.

ESTIMATED SIZE OF THE BUFFALO POPULATION

Bigmouth buffalo were marked during nine biweekly netting periods. Total catch of buffalo was 4,278 and 2,086 were marked and released. Eleven buffalo or < 1% of the number marked were recovered. Four periods contained no recaptured fish and cumulative estimates were not computed because $\hat{N}$ could only become greater due to the increased ratio between components in the equation.

Independent yields for individual biweekly intervals ranged from 32,538 in the first sampling period to 2,053,442 in Period 17 (Table 7). Cumulative estimates ranged from 9,685 in Period 6 to 186,676 in the last period. Although the total number of recaptured fish was quite small and estimates varied widely among periods, the final cumulative estimate was considered the most reliable. Confidence intervals were computed for a Poisson distribution and showed the final estimate would vary no more than ±69,336 fish at the 95% level of sampling probability. The rapid increase in later sampling periods was mostly attributable to recruitment of 0-age buffalo into the fishery, as with carp.

Standing crop of buffalo was estimated at 2.7 ± 1 lbs per acre at the average elevation for the season. At conservation pool elevation standing crop was estimated at 7.9 ± 2.9 lbs per acre.

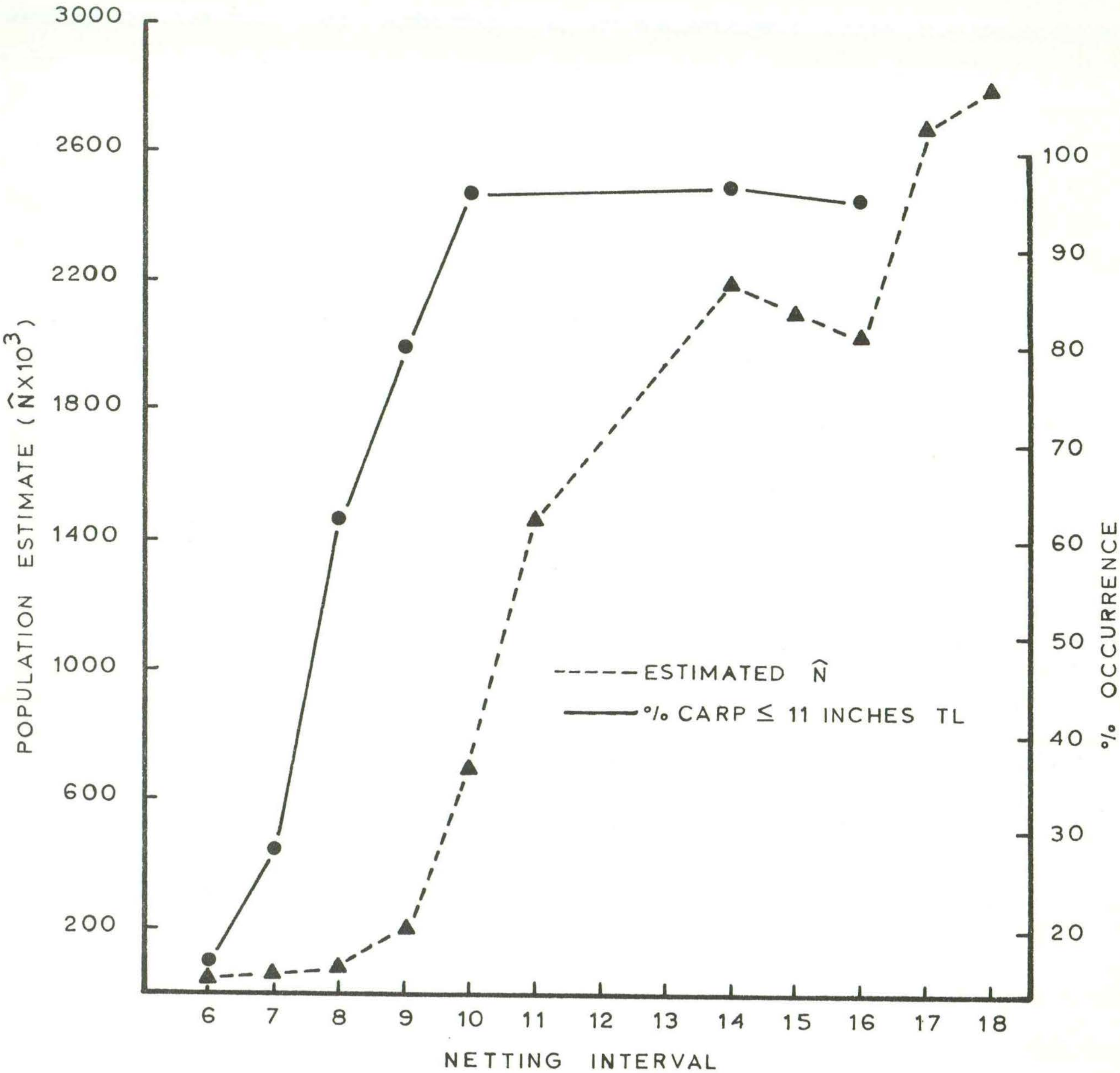

Figure 2. Estimated population size and per cent occurrence of carp ≤ 11 inches TL in the catch at biweekly intervals.

Table 7. Population estimates for bigmouth buffalo at Lake Red Rock during 1969

Period	Cumulative N marked	N captured	N recaptured	Independent $\hat{N}$	Cumulative $\hat{N}$
5	174				
6	185	187	2	35,538	16,269
7	188	3			
8	219	33	2	38,742	9,685
9	234	19			
10	481	248	1	96,774	19,354
11	1,276	795			
14	2,010	940			
17	2,086	2,057	6	2,053,442	186,676
Total	2,086		11		

ESTIMATED SIZE OF THE RIVER CARPSUCKER POPULATION

From a catch of 7,516 river carpsucker 6,780 were marked and released during the eight biweekly periods. Numerical catch within sampling periods ranged from 381 in Period 11 to 2,571 in Period 6. As shown in Table 8, 86 carpsucker were recaptured but 63 were taken in Period 6. High return of marked fish shortly after initial marking indicated mixing within the population was incomplete, and sampling was actually taking place within sub-populations. By Period 8 several fish marked in the Whitebreast Creek embayment were recaptured in the main pool suggesting nearly uniform distribution of carpsucker throughout the reservoir. The number of recaptured carpsucker declined after the sixth period to 10 or fewer for each interval.

Independent population estimates ranged from 89,780 in Period 6 to 3,272,532 in Period 9. Cumulative estimates increased systematically due to recruitment of carpsucker into the fishery from 89,780 in Period 6 to 319,075 in the last period. At the 95% level this value would vary no more than ±88,651.

Standing crop of river carpsucker in Lake Red Rock also varied directly with water level. Based on a mean weight of .59 lbs, poundage per acre was estimated at 7.2 ± 2 lbs at 763 ft MSL and 22.4 ± 6 lbs at conservation pool elevation.

Table 8. Population estimates for river carpsucker at Lake Red Rock during 1969

Period	Cumulative N marked	N captured	N recaptured	Independent $\hat{N}$	Cumulative $\hat{N}$
5	2,200				
6	2,508	2,571	63	89,780	89,780
7	3,075	572	5	286,915	104,276
8	4,899	1,834	10	563,955	163,209
9	5,566	668	1	3,272,532	202,567
10	5,993	429	2	1,193,907	227,045
11	6,380	388	1	2,325,284	252,633
14	6,780	1,054	4	1,681,130	319,075
Total	6,780	7,516	86		

ESTIMATED SIZE OF THE CHANNEL CATFISH POPULATION

Channel catfish population estimates were, for the most part, considered invalid because the number of fish marked and recaptured was insufficient for this large body of water. Results of the estimates are reported only for information and interest.

During eight biweekly intervals 1,422 catfish were marked. One hundred and ninety-nine were captured in the pool and 1,223 in the lower reaches of the headwaters. One fish was recaptured in the pool and four in the headwaters. Recoveries were too few to test discreteness of these populations. Assuming distribution was uniform in both regions, the cumulative numerical population density was estimated at 183,015 fish. Confidence intervals computed from a total recapture of five fish were wholly unrealistic. At conservation pool level the standing crop of channel catfish was estimated at about 7 lbs per surface acre.

CHANGES IN RELATIVE ABUNDANCE

Species composition of the pound net fishery and catch success of commercial food fish over the three seasons indicated some changes occurred in relative abundance of fishes. The numerical occurrence of carp in pound net catches systematically decreased from 69.9% in 1969 to 51% in 1970 and 32.5% in 1971. At the same time the importance of river carpsucker increased from 7.6% in the first year to 19.7% the next year and 32.5% the last year. Occurrence of buffalo showed no distinct trend comprising 3% of the catch in 1969, followed by 10.5% in 1970 and 7.5% in 1971. Low catches of other species precluded comparison of catch statistics between project years.

Catch success of commercial food fish showed nearly the same distribution. Carp catch rate in pound nets was highest in 1969 and 1970 with 138 FND followed by a sharp decline to 34 FND in 1971. Catch success of river carpsucker was 19 FND in 1969, increased to 36 FND in 1970 and 37 FND in 1971. Buffalo catch rate was highest in the second year with 29 FND compared to 8 FND the first season and 10 FND the final year.

In lieu of estimates of actual population size for the second and third project years an index of relative abundance was computed from mean catches of fish in pound nets during Periods 3-12. Pound nets were fished in these periods in all years. Mean catch rate values within each netting period were transformed to common logarithms and compared with a seasonal curve of average availability. The resulting index was a geometric mean showing the rate of change in one year to each successive year. Use of the geometric mean has two advantages. First, the difference in efficiency between pound nets was fully discounted and second, low catch success have equal influence in determining the geometric mean as higher catch success. For computation of the relative abundance index it was assumed there was linear relationship between catch effort values and population size. Negative index values were eliminated by adding 100 to each annual estimate.

Using the following notations (from Rounsefell and Everhart, 1953)

$a_1, a_2, \ldots a_n$ = mean numerical catch for one netting period in various years

$b_1, b_2, \ldots b_n$ = mean numerical catch for successive netting periods in the same year

V = mean availability of fish in one period

n = number of years

N = number of netting periods in one year

I_E = geometric mean value of ratios for the mean catch effort during one period in one year to the seasonal availability curve

then

$$V = \frac{a_1 + a_2 + \cdots + a_n}{n}$$

and

$$I_E = [(\log b_1 - \log V_1) + (\log b_2 - \log V_2) + \cdots + (\log b_n - \log V_n)]/N.$$

For all three species relative index values were highest during 1971, ranging from 108 for carpsucker, 113 for carp and 114 for buffalo (Table 9). Indices for 1969 showed all values were below the base value, but carp remained the most abundant species with 83 followed by 69 for carpsucker and 56 for buffalo. All values in 1971 were also below the index base but confirmed carpsucker and buffalo were becoming most important with 95 and 82 compared with 72 for carp.

Table 9. Relative abundance index for three species of commercial food fish at Lake Red Rock

Project year	Carp	R carpsucker	Buffalo
1969	83	69	56
1970	113	108	114
1971	72	95	72

EXPERIMENTAL EXPLOITATION

One of the primary objectives of this study was to experimentally harvest food fish populations at controlled rates by a simulated commercial fishery and test the affects of increased exploitation on several biological parameters. The maximum rate for initial exploitation was 20% of the estimated numerical population. If no perceptable changes occurred in biological characteristics of populations due to sustained harvest, exploitation rates would be increased to a higher level. Within a short time it became apparent the 20% level was unachievable with small fishery crews, particularly when they also collected biological statistics. The fishery would have required enlargement by more than five fold to attain the desired rate and this was impractical. Exploitation continued in 1970 and 1971 at the highest rate achievable with two netting crews, with most emphasis placed on catch success and species selectivity of different types of commercial fishing gear.

The fishery operated continuously in 1970 from Period 6 through Period 18 with exploitation occurring in all intervals except Period 14. Total harvest of food fish was 115,457 having a combined weight of 53,703 lbs. On a per unit basis, this value represented a harvest of about 14 fish weighing slightly more than 6 lbs per surface acres, far below the expected potential.

Carp was the most important food fish species in the fishery with a total catch of 62,186 fish weighing 22,108 lbs for an exploitation rate of 2.2%. Harvest of river carpsucker was 32,454 fish with an aggregate weight of 21,411 lbs, or slightly more than 10% of the population estimate. Buffalo harvest was 15,605 fish weighing 8,337 lbs, nearly 9% of the population. Total channel catfish exploitation was 5,212 fish with a combined weight of 1,846 lbs or $<$ 3% of the estimated population density.

Total market value of the fishery using average Mississippi River landing prices for fish in the round was slightly more than $6,800. Many of the carp and buffalo were unmarketable because of their small size and young age.

Harvest of commercial food fish the following year was 40,007 fish weighing 37,484 lbs. River carpsucker was the most important species with a harvest of

17,825 fish and an aggregate weight of 18,041 lbs. Carp ranked second in importance with exploitation of 16,761 fish weighing 12,699 lbs. Total harvest of buffalo was 4,014 fish with a combined weight of 5,334 lbs. Channel catfish harvest was 1,407 fish and 1,410 lbs. Exploitation rates based on the 1969 population estimates were river carpsucker, 6%; carp, 1%; buffalo, 2%; and channel catfish, 1%. Market value of the fishery was slightly less than $3,500. Total market value of the two year fishery was about $10,300.

EARLY LIFE HISTORY OF GIZZARD SHAD AND CARP

Sampling to determine the distribution, abundance, mortality rates and growth of 0-age fishes began in 1970. Year class strength in fish populations is usually formed in the first year of life and is dependent upon production and mortality. When there is a paucity of young fish there is little chance the year class will become important to the population structure in subsequent years. Mortality rate is greatest in early life stages and usually diminishes at an exponential rate with increased age. There is no production or increase in the number of fish in a year class after the first year. Early evaluation of year class abundance and determination of mortality rate for 0-age fishes is desirable for proper management, particularly with food fish populations where early failure to recognize low population density could manifest over harvest or at least cause economic marketing chaos among commercial fishermen.

Numerical estimation of 0-age fish populations by conventional methods are impossible and before precise estimates are mathematically extrapolated from catch means, some measure of the vertical and horizontal distribution of fishes must be completed.

The main objective of this project segment was to determine the distribution and abundance of larval and postlarval food fishes at Lake Red Rock and develop sampling procedures for early estimation of population density. Associated objectives were to determine the rate of natural mortality within populations of 0-age fish and define major causes for success and failure of year classes. The sampling procedure was designed with flexibility so comparisons of abundance could be evaluated yearly, although this phase of the study at Lake Red Rock was terminated after the first year because of constant sampling problems from floating debris, flooded woodland and submergent vegetation in the shallows.

At least 11 species of 0-age fish were captured, but only gizzard shad and carp were captured in sufficient numbers for statistical treatment of the data. Crappie, green sunfish, freshwater drum, river carpsucker, walleye, bigmouth buffalo, channel catfish, bullhead and several species of cyprinids and catastomids were also collected. Failure to capture these species was not from sampling error, but from low population density due to poor reproductive success.

METHODS AND PROCEDURES OF 0-AGE FISH COLLECTION AND ANALYSIS

Sampling for 0-age fish was accomplished with standardized meter net tows. The conical shaped net was constructed with a 5/8-inch steel head ring and 1/32-inch nylon mesh. Inside diameter of the head ring was exactly 1-meter and the entire net was about 10 ft in length. A 16 x 28 inch stabilizing depressor was attached to the center of a three point towing bridle hung below the head ring so turbulence from the depressor would not interfere with small fish entering the net.

Weekly samples were collected for 16 consecutive weeks from 10 May through 4 September (Periods 5-13 from Table 1). Four main sampling stations were established in the main pool of the reservoir (Figure 1). Station 2 was located in mid-water approximately 1/4 mile westward from the dam. Maximum depth in this locality was about 27 ft. Tows were made at the surface and at 6 m deep which were designated Stations 2A and 2B, respectively. Station 3 was located at mid-reservoir near the small island along the Wallingslock shoreline. Maximum depth was 33 ft. Tows were made at both depth levels and designated Station 3A and 3B. Station 4 was located in the upper pool segment near Elk Rock point. Maximum depth was 23 ft. Samples were collected at both depth levels and designated Stations 4A and 4B. Station 7 was located near the south shoreline along the Whitebreast Park recreation area. Tows at this station were made at the surface, close to the shoreline to determine if young fishes concentrated in large numbers in shallows.

Sampling commenced shortly after darkness between 10 PM-2 AM to diminish the affects of sight schooling by several species of fish. Each tow was five minutes in duration at a constant speed of 4 MPH (1350 RPM standard engine setting). The sampling sequence was completely randomized. No compensation was made for wind speed or direction because wind velocity after darkness in summer is usually of quite low magnitude. Depth of towing was controlled by the angle and length of the towing warp. The net was retrieved while the boat was in forward motion at idle speed with a powered winch system. Most hauls were made on selected compass headings after starting from a fixed location at each station. Bottom depth was monitored constantly with an echosounder while the net was towed.

Fish from each haul were preserved immediately with 2.5% buffered formalin. Sorting, counting and measurements of total body length was done in the laboratory (Plate 2). Larval fish keys written by Mansuetti and Hardy (1967), May and Gasaway (1967) and Meyer (1970) were used for identification. When vertebral and meristic counts were required the muscular tissue was cleared with a 1:250 solution of trypsin (commercial hog pancreas) and the bony structure stained with Alizarin Red S.

Numerical counts of larval fish catches were combined into biweekly periods and averaged. In this array the original 16 weeks were replaced by eight replicates numbered in sequence from 5-12. Since the experiment was designed to test differences between mean catches of 0-age fish, computation could follow an analysis of variance procedure in both two-way and factorial classifications. Counts of larval and postlarval fish were transformed into logarithms according to Snedecor and Cochran (1967) by

Plate 2. Larval fish sample taken at Station 3A in Period 8. Most of the fish are gizzard shad.

$$Y_{ijk} = \log_{10}(X_{ijk} + 1)$$

where Y_{ijk} was the transformed value of $X_{ijk} + 1$, and X_{ijk} was the numerical catch value for the k^{th} biweekly interval at the i^{th} sampling station and j^{th} depth.

Transformation eliminated zero catches from tows early in the season and normalized the distribution of residual sums of squares. Probability plotting of the emperical cumulative distribution of residuals showed this transformation was satisfactory. The logarithmic transformed values were also used in estimating mortality rate directly from catch values.

Differences between the abundance of 0-age fish for surface sampling Stations 2A, 3A, 4A and 7 were tested in a two-way classification. Residuals mean squares were the unbiased estimated error for the transformed catch values after deviations due to stations and period were removed from total variability. The random effects model used for analysis of variance was

$$X_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij},\ i = 4 \text{ and } j = 8$$

where μ represented the overall mean catch, α_i was station effect and β_j was period effect.

Analysis of variance in mean catches of 0-age fish for surface and subsurface sampling Stations 2A, 2B, 3A, 3B, 4A and 4B was measured by factorial contrast. Error mean squares estimated the same parameter as before except deviations mean squares due to depth level was included in the model. The model with k replications was

$$X_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk};\ i = 3,\ j = 2 \text{ and } k = 8$$

where μ and α_i are the same as before with a two-way classification and β_j represented the unique effects of depth level. Comparison of all paired means were made for factors having significant values by using a studentized Newman-Kuel multiple range test with the value of t set at the .05 level.

DISTRIBUTION AND ABUNDANCE OF GIZZARD SHAD

Total catch of 0-age gizzard shad for the 56 samples was 11,567 with a mean of 207 per tow (Table 10). The number of shad per haul ranged from 0 at Stations 4B and 7 in the fifth period to 1,566 at Station 3B in the seventh period. There was no evidence larval shad concentrated into one region of the reservoir more than another. Mean catches for combined stations was 184, 334, 214 and 181 for Stations 2-7, respectively. Analysis of variance (Table 11) in the two-way table showed no significant difference between mean catches in surface hauls. The factorial classification showed equal vertical and horizontal distribution of shad. Both analyses indicated nearly homogeneous distribution of 0-age shad regardless of sampling location or depth level.

Table 10. Mean number of 0-age gizzard shad in meter net tows

		Sampling interval							
Station	Depth	5	6	7	8	9	10	11	12
2	Surface	9	56	35	97	81	144	14	19
	6 m	7	35	272	274	79	105	113	7
3	Surface	8	131	910	726	214	39	34	6
	6 m	26	492	1566	1023	87	64	34	4
4	Surface	4	88	83	37	167	341	628	393
	6 m	0	82	222	28	161	414	256	499
7	Surface	9	611	574	116	87	12	46	3
Sampling interval $\overline{X}$		8	214	523	329	125	160	161	133

Table 11. Analysis of variance in catches of 0-age gizzard shad in meter net tows

Source of variation	df	MS	Parameter estimated
TWO-WAY CLASSIFICATION			
Periods	7	1.422*	$\sigma^2 + p\sigma_S^2$
Station	3	.370	$\sigma^2 + s\sigma_P^2$
Residual	21	.356	σ^2
FACTORIAL CLASSIFICATION			
Periods	7	1.500**	$\sigma^2 + \sigma_{PSD}^2 + p\sigma_{PS}^2 + s\sigma_{PD}^2 + sp\sigma_P^2$
Station	2	.459	$\sigma^2 + \sigma_{PSD}^2 + p\sigma_{PS}^2 + p\sigma_{SD}^2 + p\sigma_S^2$
Depth	1	.074	$\sigma^2 + \sigma_{PSD}^2 + \sigma_{PD}^2 + p\sigma_{SD}^2 + ps\sigma_D^2$
S x D	2	.075	$\sigma^2 + p\sigma_{SD}^2$
Residual	35	.334	σ^2

*Significant at the .05 level.

**Significant at the .01 level.

Biweekly distribution of combined mean catches showed a progressive increase of larval shad from Period 5 through Period 7 followed by a systematic decline until sampling ceased (Figure 3). Mean catch increased from 8 in Period 5 to 523 in Period 7 and decreased to 133 in Period 12.

There was significant difference ($P < .05$) in periods when surface hauls were compared in the two-way table and highly significant difference ($P < .01$) in periods by factorial contrasts. The Newman-Kuel test of all paired observations for surface samples showed Periods 5 and 6; 10 and 11; and 8 and 12 had common mean values at the .05 level. In the factorial classification Periods 5 and 12; 8 through 12; and 7 through 11 had common means.

Mean numerical shad catches indicated the population size increased steadily from initial spawning until the third sampling interval. Mortality of young shad was constantly reducing population size, but production was much greater than loss by death. When spawning activity diminished and finally ceased, mortality continued at the usual exponential rate resulting in a steadily declining population density, which was reflected in numerical catches of shad.

From the catch data it was evident initial spawning commenced in early May prior to the first sampling interval. Size distribution of samples in the fifth period had a range in total body length of 7012 mm (Figure 4). By the next period larval shad size ranged from 7-16 mm with a mode appearing at the 11-12 mm class interval. Meter net hauls on 15 June had two distinct size groups indicating second spawning. The first group, which was attributed to initial spawning ranged from 25-30 mm in length, while the second group was 7-18 mm in length with the 9-10 mm class interval most numerous. On 29 June the first group of shad had a size range of 47-51 mm and the second group 7-14 mm. An intermediate size interval ranging from 37-40 mm was also present, but they comprised < 4% of the sample.

Samples collected on 13 July indicated spawning activity increased for the third time. Size distribution of shad captured on this data was 26%, 68+ mm; 62%, 35-56 mm; and 12%, 15-20 mm. At the next sampling date both the first and second hatches of shad were 73+ mm and the later group ranged from 55-70 mm. By the tenth interval on 10 August, it was impossible to separate 0-age shad by length distribution because all were 75+ mm. The maximum length of young shad captured was 154 mm.

Spawning activity and production of 0-age gizzard shad evidently started near 10 May and continued through 15 July. Within this time interval there were three distinct periods of intensified spawning activity. Estimated dates peak activity were 20 May, 5 June and 2 July.

GROWTH OF 0-AGE GIZZARD SHAD

Plots of mean body length of fish by biweekly intervals (Figure 5) showed typical exponential growth characteristics except in the later periods. Length measurements in Period 5 ranged from 7-12 mm with a mean of 10 mm. Mean TL of shad captured in Period 6 increased to 12 mm and ranged from 7-17 mm. By the

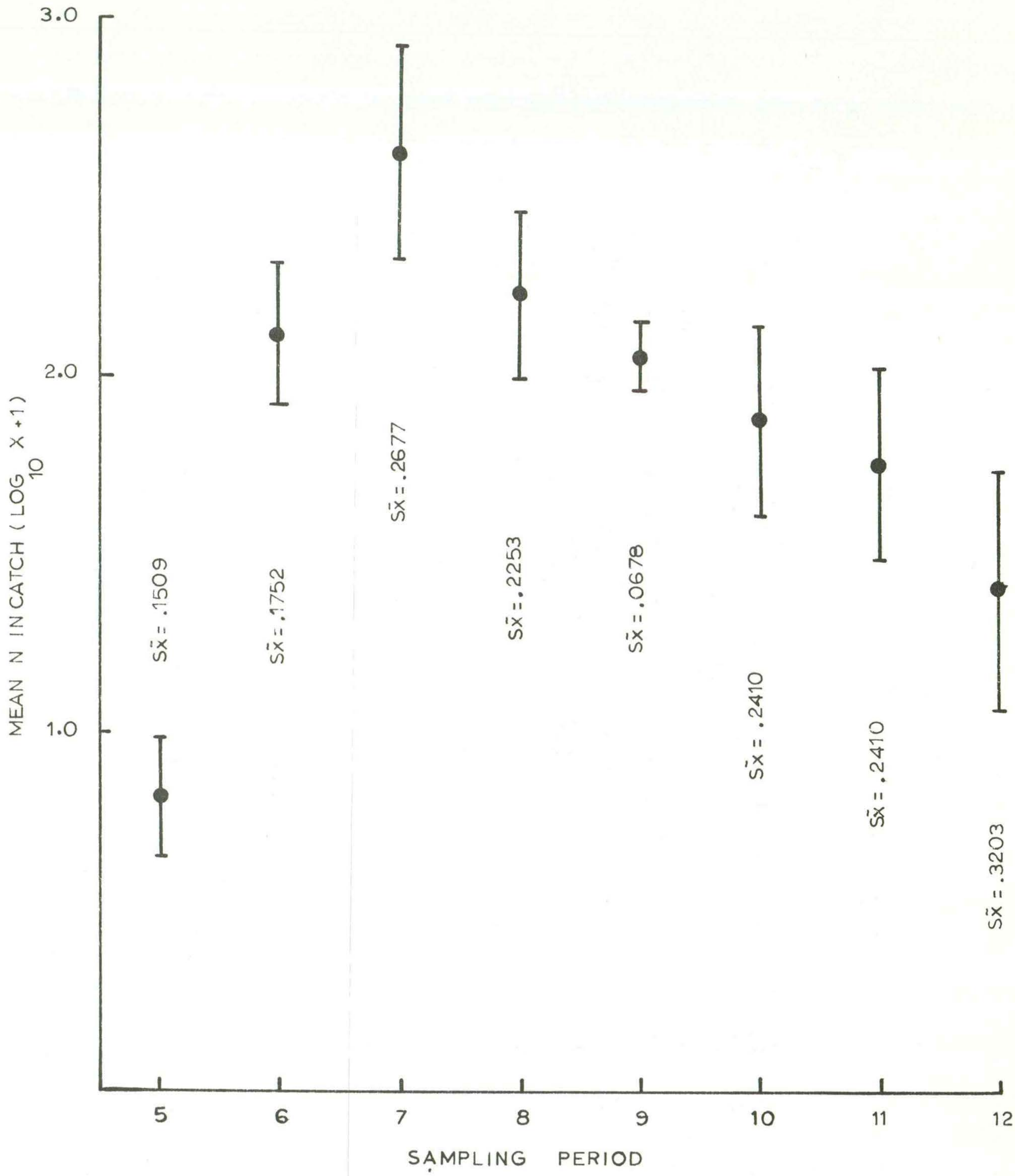

Figure 3. Catch curve of 0-age gizzard shad in meter net tows. Brackets denote sample standard error.

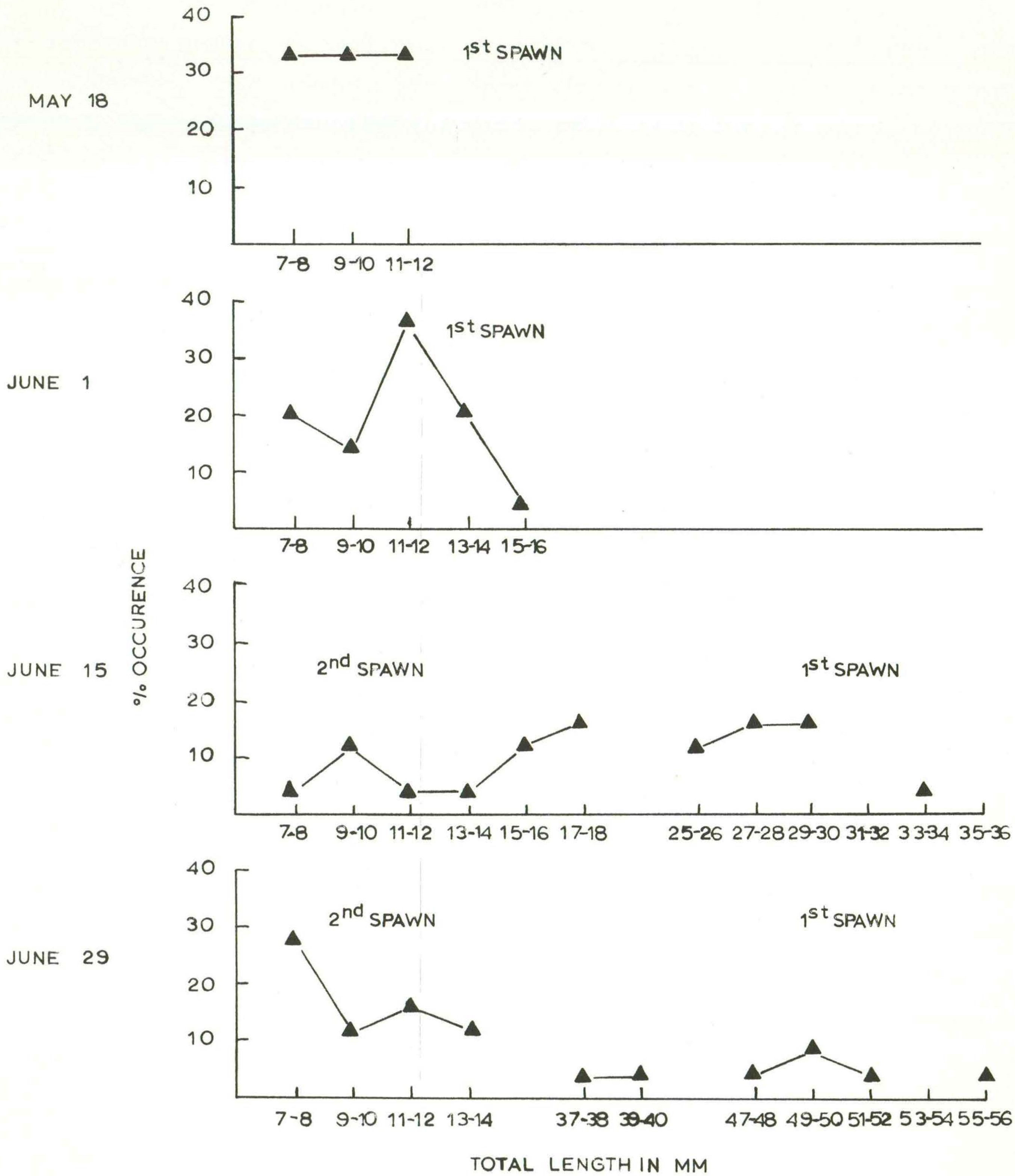

Figure 4. Length frequency distribution of 0-age gizzard shad in meter net tows.

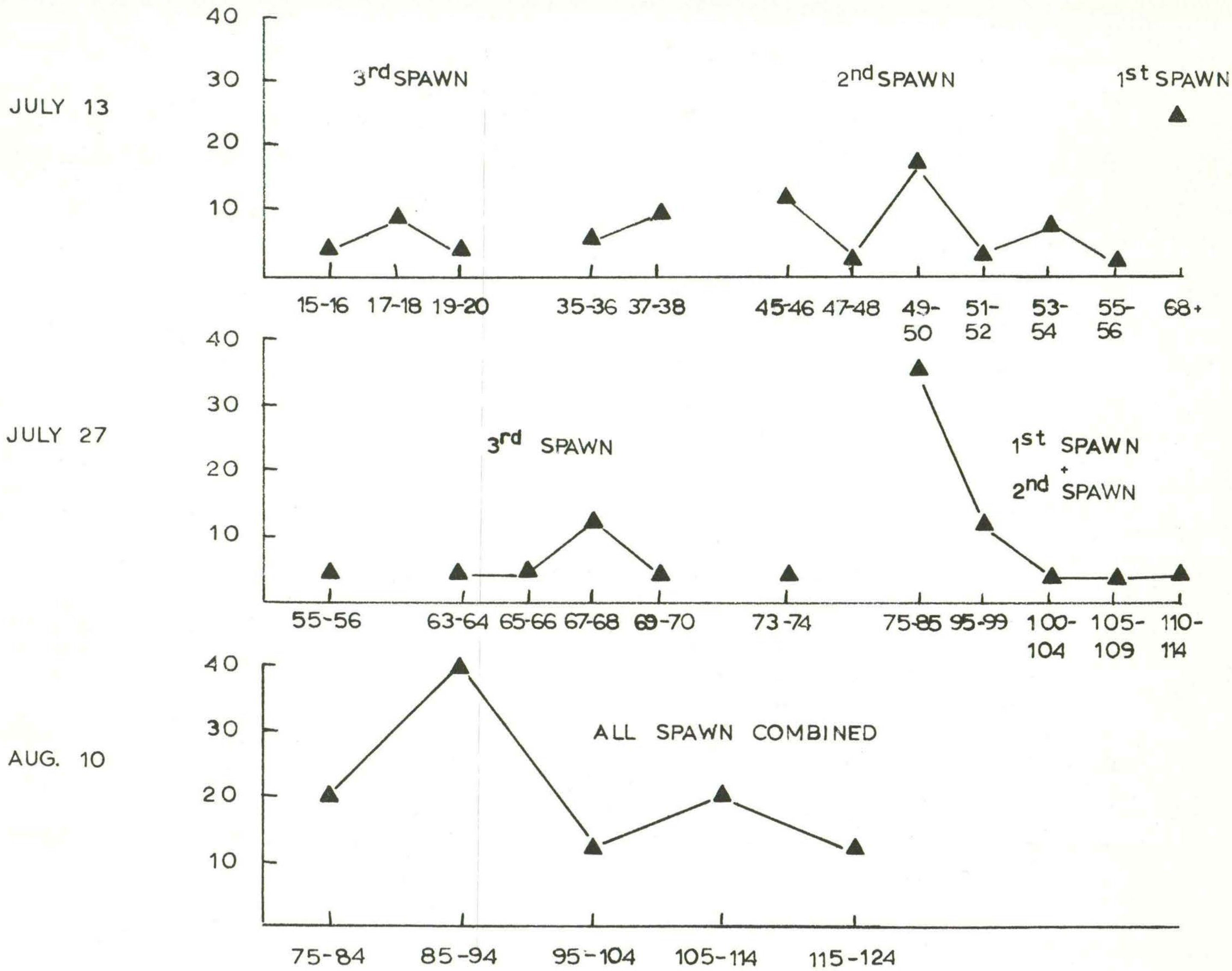

Figure 4. (continued)

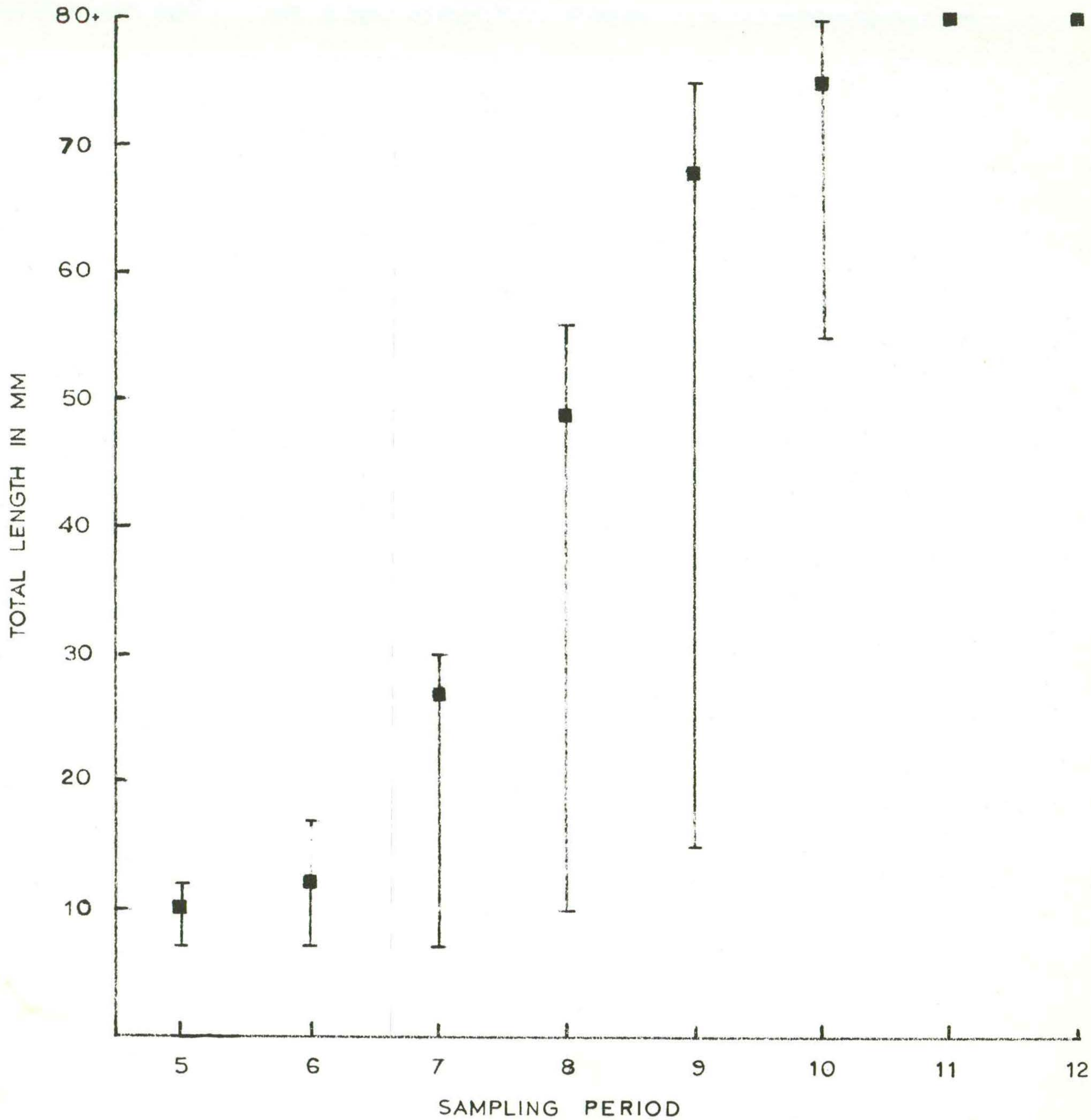

Figure 5. Growth of 0-age gizzard shad in meter net tows. Brackets are size range of sample in mm.

seventh period mean TL of the sample was 27 mm and ranged from 7-30 mm. In Period 8 the body length of shad varied from 10-56 mm with a mean of 49 mm. The smaller group resulted from second spawning. Mean length of young shad captured in the last three periods was 68 mm, 75 mm and 80+ mm, respectively.

Growth data for 0-age gizzard shad showed body length seldom exceeded 80 mm, although information from mid-water trawling and small mesh seine hauls revealed large numbers of shad ranging from 100-135 mm were present in the population after Period 11. Apparently the true growth characteristics of the shad population were being masked by gear avoidance for fish 80+ mm in length. Since initial inflection in the growth curve occurred at about 63-64 mm, it was postulated this interval was the critical size where escapement commenced in significant numbers. As body size increased, the physical ability of shad to avoid capture by meter nets also became greater. Growth rate appeared constant at this point, when in reality shad exceeding this length merely avoided capture.

MORTALITY OF 0-AGE GIZZARD SHAD

Mortality in a fish population usuably occurs at the maximum rate during the first year of life, and is highest closest to the time of embryonic development. Estimated rate of mortality cannot be computed until the abundance of fish diminishes with each subsequent sample. For the 0-age gizzard shad population in Lake Red Rock the number in biweekly sample began to decrease after Period 7. Although production of young shad continued after this interval, it was at this point natural mortality surpassed the number recruiting into the minimum size vulnerable to the meter net.

Estimated instantaneous mortality of 0-age gizzard shad was computed from a modification of the method suggested by Rounsefell and Everhart (1953:86). Instead of using age frequency distribution a straight line was fitted to the right limb of the transformed catch distribution curve by the least squares procedure where slope of the line estimated mortality rate. Since catch values were already transformed into common logarithm values these values were converted into Naperian logarithm by

$$1/\log_{10} e = 2.303$$

after one was subtracted from the original value for the elimination of zero counts in the transformation.

The instantaneous mortality rate (i) of 0-age shad was determined from the sample regression equation

$$\log_e \hat{Y}_{ij} = \log_e \overline{Y} + bs$$

where $\hat{Y}_{ij}$ was the transformed value of the number of 0-age gizzard shad for the j^{th} sample at the i^{th} sampling interval and s was written as $S - \overline{S}$. The b value was the estimated instantaneous mortality rate. For shad in 1970 b was .48 ± .09 and had a correlation coefficient (r) of .989. Annual rate of mortality (a) was computed from a table of exponential function as $a = 1 - e^{-i}$. The annual mortality rate was .381 for 0-age shad.

ESTIMATED POPULATION SIZE OF 0-AGE GIZZARD SHAD

Conventional methods of estimating the numerical population size of 0-age shad cannot be used because their abundance and small size preclude any type of reliable marking experiments. The analysis of variance in both two-way and factorial classifications showed no significant difference in the vertical and horizontal distribution of young shad so it was assumed they were equally distributed throughout the reservoir and could be estimated by mathematical extrapolation from the mean catch among samples. Confidence intervals were set around these estimates in the usual fashion using the standard error of estimate for each sampling interval.

Mean catch values ranged from 331 in Period 3 to 27 in the last period. At conservation pool elevation the 0-age population estimates for each period ranged from $6.62 \times 10^8 \pm 7.39 \times 10^7$ at Period 7 to $5.39 \times 10^7 \pm 8.19 \times 10^7$ in Period 12 (Table 12). Confidence intervals for the last estimate were not reliable because of the small sample size and large variation among samples.

Table 12. Numerical population estimates of 0-age gizzard shad based on extrapolation from catch means

Period	$\overline{X}$ per tow	Estimated $\hat{N}$	95% Confidence intervals
3	331	6.62×10^8	7.39×10^7
4	159	3.18×10^8	6.60×10^7
5	117	2.34×10^8	4.80×10^7
6	69	1.38×10^8	6.60×10^7
7	55	1.09×10^8	6.60×10^7
8	27	5.39×10^7	8.19×10^7*

*Confidence intervals were large because of small sample size and large variation among samples.

Several sub-samples of young shad were counted and weighed in each period and had an overall mean of about 800 shad per kg. Using this value for the mean weight in each period and converting to the English system the maximum population biomass of 0-age shad was estimated at about 20 lbs per surface acre. At the 95% level of probability this value would vary no more than ±2.7 lbs.

DISTRIBUTION AND ABUNDANCE OF 0-AGE CARP

Total catch of 0-age carp in the first six sampling periods was 715 with a mean of about 13 per tow. No young carp were captured after Period 10. The number of carp for individual tows ranged from 0 at most stations early in the season to 130 at Station 7 in Period 8 (Table 13).

Table 13. Mean number of 0-age carp in meter net tows

		Sampling interval					
Station	Depth	5	6	7	8	9	10
2	Surface	0	5	1	7	0	0
	6 m	0	3	3	6	0	1
3	Surface	0	0	42	33	0	1
	6 m	4	3	41	77	4	2
4	Surface	0	0	32	86	8	0
	6 m	0	0	98	79	6	0
7	Surface	0	5	17	130	19	1
Sampling interval $\overline{X}$		<1	2	33	60	5	<1

Both surface and sub-surface tows showed a systematic increase in the numerical catch of 0-age carp as sample location moved from near the dam toward the headwaters and shallow depths. Analysis of variance (Table 14) in the two-way classification showed significant difference at the four surface stations at the .05 level of sampling probability. Mean catch values were Station 2A, 2; Station 3A, 13; Station 4A, 23 and Station 7, 29. The Newman-Kuel test of all paired means showed Station 3A, 4A and 7 had common mean catch values and Station 2A was significantly lower than all others. By factorial classification there was highly significant ($P < .01$) difference between mid-water stations. Mean catches for each tow was 2 at Station 2, 17 at Station 3 and 26 at Station 4.

The multiple range test of paired means revealed Station 3 and 4 had common values, but Station 2 was significantly lower than all other stations. There was no significant difference in the vertical distribution of 0-age carp at the .05 level.

Table 14. Analysis of variance in catches of 0-age carp in meter net tows

Source of variation	df	MS	Parameter estimated
		TWO-WAY CLASSIFICATION	
Periods	5	1.577**	$\sigma^2 + p\sigma_S^2$
Stations	3	.420*	$\sigma^2 + s\sigma_P^2$
Residual	15	.84	σ^2
		FACTORIAL CLASSIFICATION	
Periods	5	2.106**	$\sigma^2 + \sigma_{PSD}^2 + p\sigma_{PS}^2 + s\sigma_{PD}^2 + sp\sigma_P^2$
Stations	2	.730*	$\sigma^2 + \sigma_{PSD}^2 + p\sigma_{PS}^2 + p\sigma_{SD}^2 + p\sigma_S^2$
Depths	1	.346	$\sigma^2 + \sigma_{PSD}^2 + \sigma_{PD}^2 + p\sigma_{SD}^2 + ps\sigma_D^2$
S X D	2	.116	$\sigma^2 + p\sigma_{SD}^2$
Residual	25	.149	σ^2

*Significant at the .05 level.

**Significant at the .01 level.

Biweekly distribution of combined mean catches of young carp (Figure 6) indicated population size was increasing from Period 5 through Period 8 and was followed by precipitous decline in the last two intervals. Mean catch of 0-age carp ranged from < 1 in Period 5, increasing to 60 at Period 8 and declining to < 1 in Period 10. Differences in the catch of 0-age carp between sampling intervals was highly significant (P < .01) in both classifications. The multiple range test for the two-way classification showed common mean catch values for Periods 5-8; Periods 5, 8 and 9; and 5, 8, 9 and 12. Periods 5, 6, 11 and 12; and Periods 7-9 had common means at the 95% level.

Carp spawning began prior to the first interval in early May. Fish captured in Period 1 ranged from 7-10 mm in TL (Figure 7). At Period 2 a mode occurred at the 9-10 mm class interval and comprised 42% of the sample size. Body length ranged from 7-16 mm. By Period 3 the preponderance of postlarval carp remained in the 7-8 mm class interval representing about 52% of the catch, but the 9-10 mm class interval increased to 40% occurrence. The latter class remained most numerous until the ninth period. Length frequency distribution of the last period showed the 19-20 mm and 23-24 mm class intervals were most numerous.

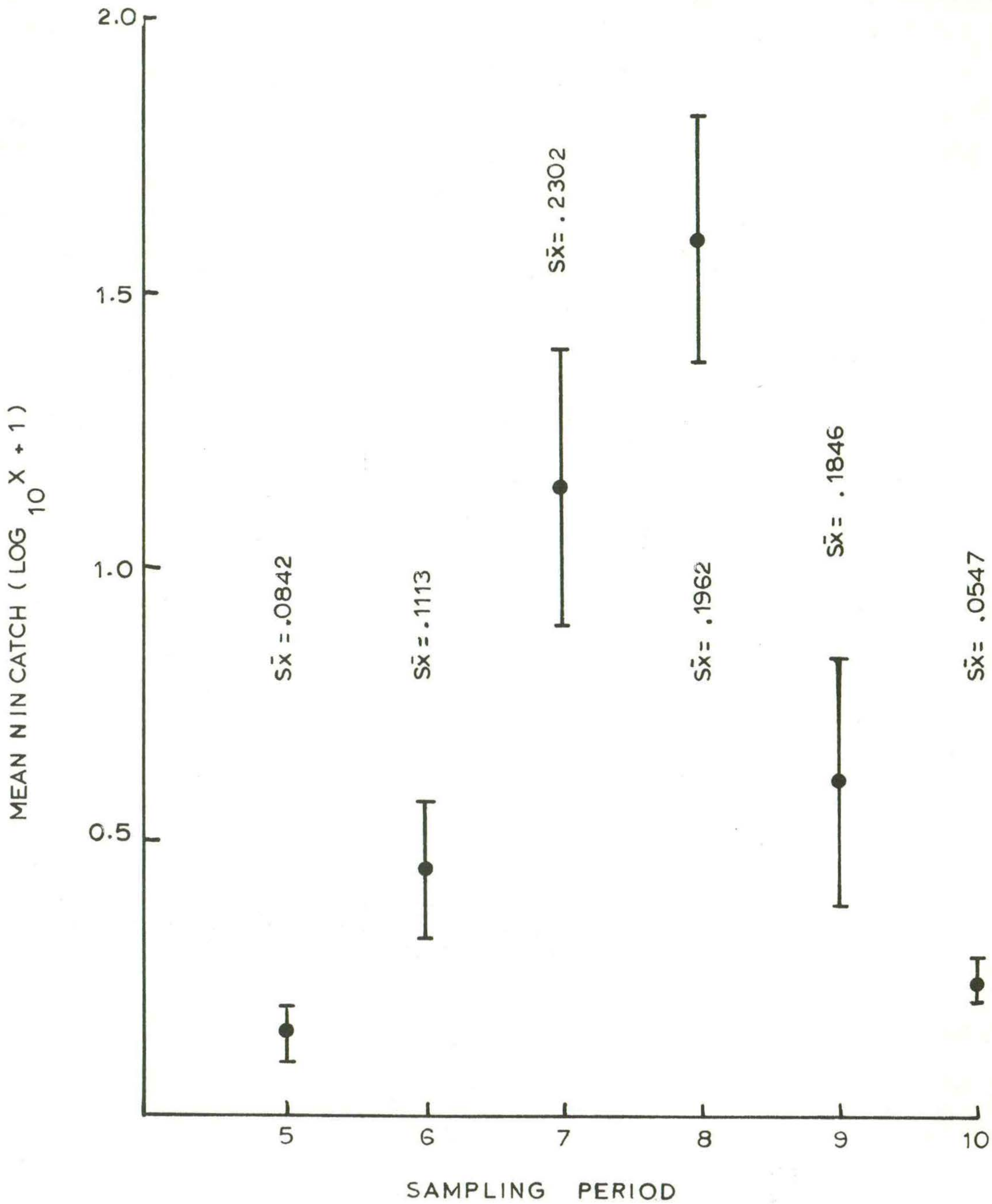

Figure 6. Catch curve of 0-age carp in meter net tows.

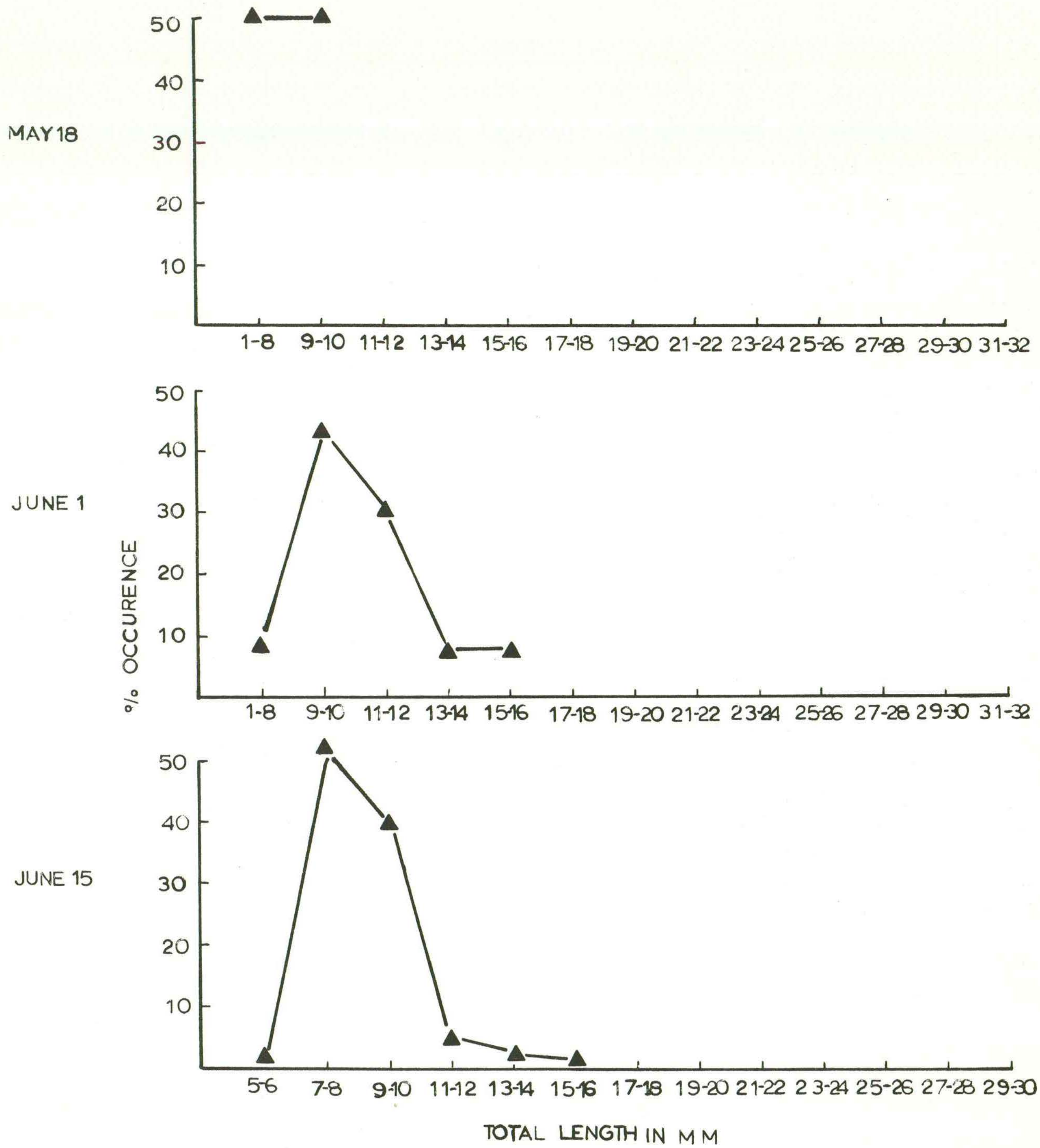

Figure 7. Length-frequency distribution of 0-age carp in meter net tows.

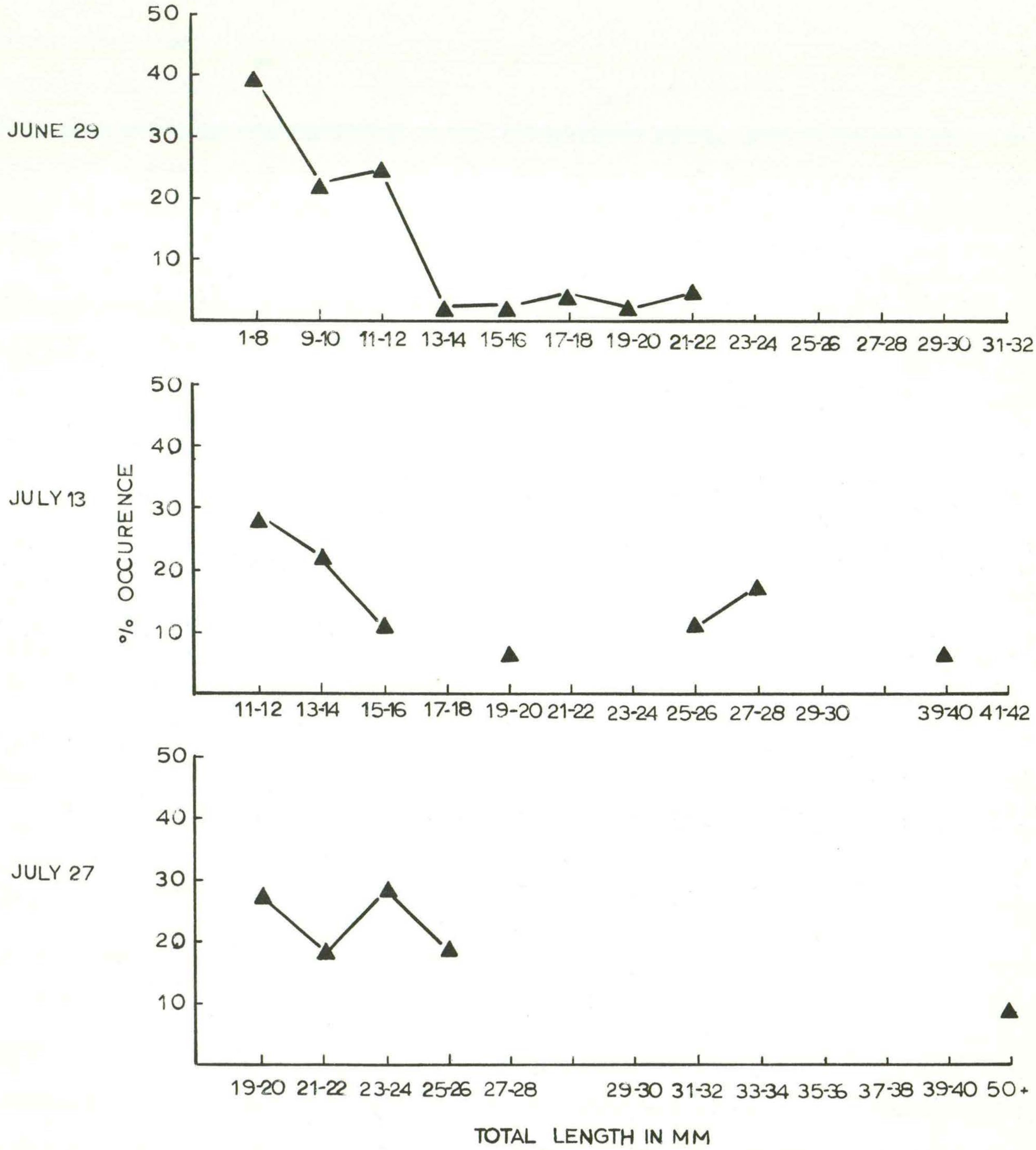

Figure 7. (continued)

Spawning commenced in early May and continued until late July. The intensity of activity appeared almost constant because recruitment of young carp into the samples at 7-8 mm TL was nearly constant and of rather low frequency. From the size distribution of young carp in meter net hauls it was estimated peak spawning activity occurred around the 5-10 June period.

0-age carp were not captured by meter nets after 27 July and probably resulted from gear avoidance as body size increased. Gear avoidance would also account for a large portion of the steep downward slope in catch success after Period 8 and preclude reliable estimates of mortality rates and population size.

GROWTH OF 0-AGE CARP

Growth rate of 0-age carp was computed by plotting mean body length by biweekly period (Figure 8). This plot showed rather slow increasing TL for Periods 5-8 followed by large increases in Periods 9 and 10. Mean TL of carp captured in Period 5 was 9 mm and ranged from 7-10 mm. At the next sampling interval mean body length increased to nearly 10 mm with a sample range of 5-18 mm. By Period 8, TL averaged 12 mm and ranged from 9-26 mm. Mean body length was 18 mm in Period 9 and 26 mm in Period 10.

Maximum body length of 0-age carp captured in meter net tows was 42 mm. This value undoubtedly represented the size where all young carp were capable of avoiding capture. Gear avoidance began at a slightly smaller size interval and increased systematically until all fish avoided capture.

AGE AND GROWTH OF COMMERCIAL FOOD FISH

The main objective of the age and growth studies was to discern changes occurring within commercial food fish populations with the changes from stream environment due to impoundment and with the advent of experimental exploitation. Parameters investigated included length-frequency distribution, length-weight relationship, condition factor and growth.

METHODS AND PROCEDURES

Measurements of TL and weight along with a scale or pectoral spine sample were collected from randomly selected subsamples of fish throughout the season. Computation of age and growth statistics was done by computer using conventional programming methods (Mayhew, 1972).

Length-weight relationships were computed by the logrithmic transformed linear equation

$$\log_{10} W = \log_{10} a + b \log_{10} L$$

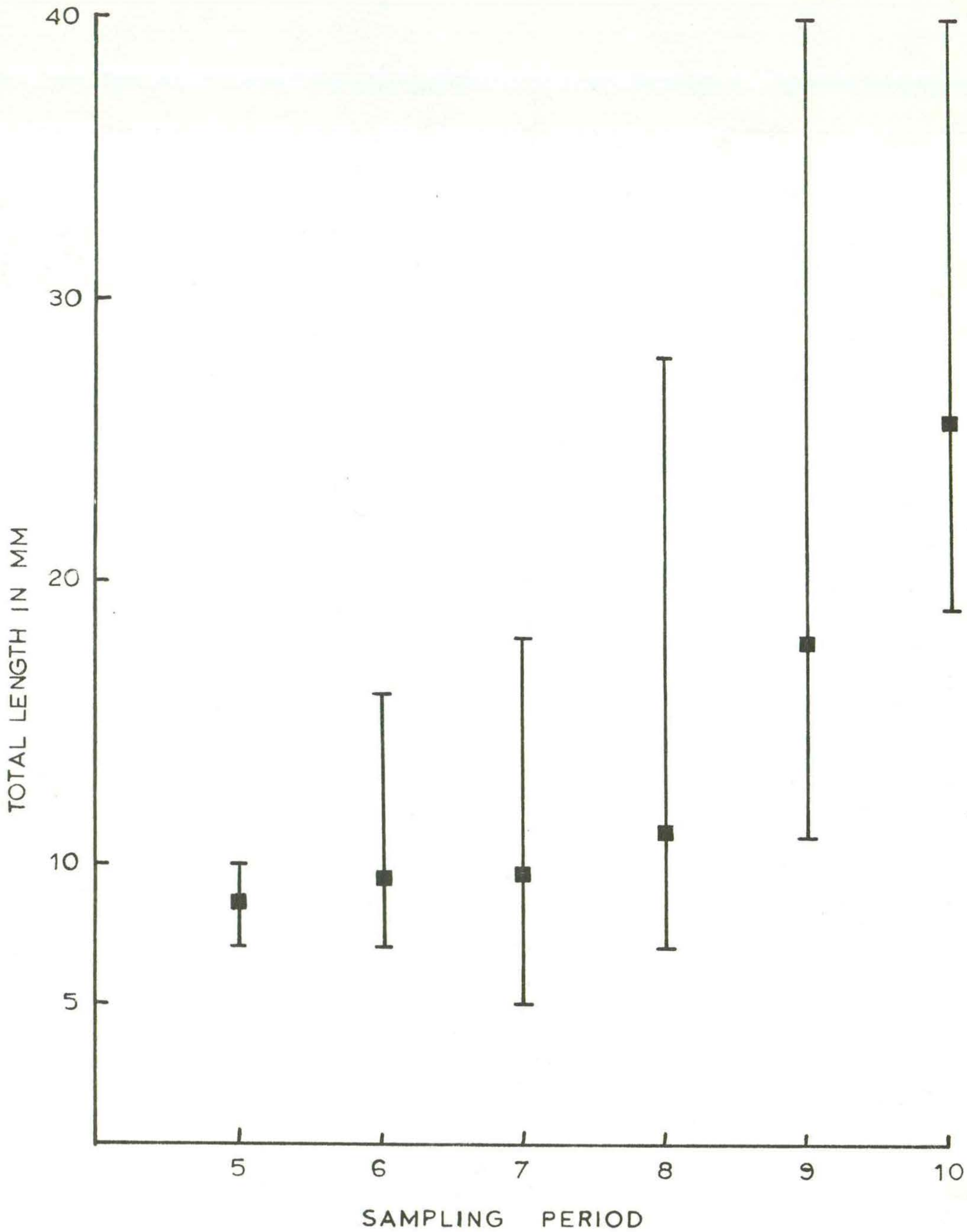

Figure 8. Growth of 0-age carp in meter net tows. Brackets are size range of sample in mm.

where W is weight in .01 lbs and L is total body length in .1 inches. Standard deviations of the regression coefficients were tested statistically at the 95% confidence level using the Student's t test in a two-tailed distribution. Coefficients of the length-weight equations were combined for each species to form pooled equations. Observed mean weights for age II, IV and VI fish for each calendar year were plotted against predicted values from the pooled equation to graphically illustrate deviations in mean weight for selected age groups.

Condition factors were calculated by use of reciprocals in the equation

$$C = (1/W)^3(L) \times 10^4$$

where W and L were the same as before.

Body-scale regressions were computed by the linear function

$$L = a + bS,$$

the linear function centered through the origin

$$L = bS$$

and the quadratic form

$$L = a + bS + cS^2$$

where L is TL and S is the scale/spine radius measurement. An analysis of variance from regression was used to find the equation with the best fit for each species.

TL at the end of each year of life (NAGE) was estimated by mathematical extrapolation through the body-scale equations and combined for each species in this report. TL was reported using both grand mean estimates of TL at NAGE and successive summation of grand mean increments. A growth index for each project year was compiled by using the per cent deviation of mean increments from the grand average increment for combined age groups adjusted to the base 100. Values below 100 indicated subnormal growth and those above 100 indicated above average growth.

AGE AND GROWTH OF CARP

Body measurements were collected from 569 carp including 271 in 1969, 168 in 1970 and 130 in 1971. Range in TL was 5.4 to 27.1 inches in 1969, 6.0 to 24.3 inches in 1970 and 6.5 to 21.0 inches in 1971. Body weight ranges were .10 to 11.7 lbs, .10 to 8.2 lbs and .21 to 3.9 lbs, respectively. The length-weight relationships for individual years were described by the equations

$$1969: \log_{10}W = -3.096 + 2.835 \log_{10}L$$

$$1970: \log_{10}W = -3.193 + 2.861 \log_{10}L$$

$$1971: \log_{10}W = -3.007 + 2.715 \log_{10}L$$

Standard deviations of the slope values were ±.029, ±.029 and ±.036, respectively. Common b values were notes at the 95% confidence level for 1969-1970 and 1969-1971. The 1970 and 1971 b values differed significantly at this level. Ranges in C-factors were 36-76 in 1969, 40-57 in 1970 and 41-62 in 1971. Means were 52, 45 and 51, respectively (Table 15).

Table 15. Range and mean for C-factors of four species of commercial food fish

Year		Carp	R carpsucker	Buffalo	C catfish
1969	range	36-76	42-56	42-68	27-48
	mean	52	47	55	34
1970	range	40-57	40-54	28-60	25-41
	mean	45	45	50	33
1971	range	41-62	42-61	37-128	28-41
	mean	51	52	57	34

The body-scale relationships were described by the equations

$$1969:\quad L = .4 + 2.7S$$

$$1970:\quad L = 3.2 + 1.34S + .12S^2$$

$$1971:\quad L = .5 + 1.54S$$

The quadratic equation was used in 1970 because analysis of variance from regression showed this function was significantly more accurate at the .05 level than the linear form.

Estimations of total body length at NAGE were combined for the collection years and averaged 4.0, 7.4, 10.2, 12.8, 14.7, 16.4, 17.9, 20.2, 20.7, 22.2 and 21.5 inches at each annulus for the first 11 years of life. The decline in TL at age 11 was based on only 3 fish from collection year 1969. Successive summation of grand average increments were 4.0, 7.4, 10.2, 12.8, 14.7, 16.5, 18.1, 20.3, 20.5, 21.8 and 23.0 inches for ages 1 through 11 (Table 16).

A growth index was compiled from the combined TL data and ranged from 23 in 1970 to 174 in 1968. The index revealed a trend toward above average growth for the 1966 through 1969 year classes. The index for year class 1968 was abnormally high for carp as it was for the other species and was due to changes in environmental conditions brought about by impoundment.

Table 16. Calculated length and mean growth increments for carp at Lake Red Rock

Year class	N in years sampled 1971	1970	1969	Total N sampled	Estimated TL at NAGE 1	2	3	4	5	6	7	8	9	10	11	Growth index
1970	5	**	***	5	3.5											23
1969	41	47	***	88	6.3	7.6										119
1968	16	70	39	125	4.8	10.7	10.3									174
1967	21	21	21	63	3.9	7.4	12.7	13.4								141
1966	10	12	14	36	3.6	7.0	10.0	14.6	15.3							136
1965	12	8	9	29	3.8	7.0	10.2	12.9	14.6	16.4						81
1964	9	5	11	25	3.8	7.4	10.2	12.9	15.3	17.8	17.6					104
1963	13	7	9	29	4.2	7.8	11.0	13.1	15.1	16.8	18.6	18.6				91
1962	3	10	7	20	4.0	6.8	9.5	12.1	14.0	15.9	17.8	19.8	19.1[a]			85
1961	*	1	6	7	2.9	6.4	9.0	12.1	13.6	15.0	16.9	23.7	21.5[b]			88
1960	*	1	4	5	3.8	7.4	9.5	11.8	14.6	15.9	18.2	19.6	21.1	23.1[b]		86
1959	*	**	4	4	3.9	7.0	10.4	13.5	16.2	18.3	19.7	21.2	22.4	23.2[b]		83
1958	*	**	3	3	3.9	6.8	9.6	11.9	13.3	14.9	16.7	18.1	19.2	20.3	21.5[b]	89
Gr. $\overline{X}$ est. TL					4.0	7.4	10.2	12.8	14.7	16.4	17.9	20.2	20.7	22.2	21.5	
Gr. $\overline{X}$ increments					4.0	3.4	2.8	2.6	1.9	1.8	1.6	2.2	.2	1.3	1.2	
Sum of increments					4.0	7.4	10.2	12.8	14.7	16.5	18.1	20.3	20.5	21.8	23.0	

[a]Based on 3 observations in 1971.

[b]Age group absent from sample.

*Year class absent from 1971 samples.

**Year class absent from 1970 samples.

***Year class absent from 1969 samples.

AGE AND GROWTH OF RIVER CARPSUCKER

Body measurements and scale samples were taken from 265 fish, of which 106 were from 1969, 101 from 1970 and 58 from 1971. Range in total body length was 5.8 to 16.8 inches in 1969, 6.1 to 17.7 inches in 1970 and 5.4 to 17.8 inches in 1971 (Table 17). Median lengths for river carpsucker by collection year were 9.9, 11.2 and 11.8 inches, respectively. Modes occurred in the length frequency distribution at 8.8 and 9.8 inches in 1969, 7.3 inches in 1970 and 16.8 inches in 1971.

Table 17. Length frequency distribution of river carpsucker

Class range	1969		1970		1971	
	N	% frequency	N	% frequency	N	% frequency
5.0- 5.5	0	0			2	3
5.5- 6.0	3	1			0	0
6.0- 6.5	8	3	1	<1	3	5
6.5- 7.0	14	5	1	<1	2	3
7.0- 7.5	13	5	7	7	2	3
7.5- 8.0	15	6	5	5	1	2
8.0- 8.5	17	6	5	5	2	3
8.5- 9.0	23	9	5	5	3	5
9.0- 9.5	20	8	5	5	1	2
9.5-10.0	25	9	5	5	3	5
10.0-10.5	15	6	5	5	3	5
10.5-11.0	11	4	5	5	3	5
11.0-11.5	14	5	5	5	2	3
11.5-12.0	9	3	5	5	3	5
12.0-12.5	12	5	5	5	2	3
12.5-13.0	9	3	5	5	3	5
13.0-13.5	13	5	5	5	2	3
13.5-14.0	9	3	5	5	3	5
14.0-14.5	11	4	4	4	2	3
14.5-15.0	8	3	5	5	2	3
15.0-15.5	5	2	4	4	3	5
15.5-16.0	6	2	5	5	3	5
16.0-16.5	0	0	3	3	1	2
16.5-17.0	4	2	5	5	4	7
17.0-17.5			0		2	3
17.5-18.0			1	<1	1	2
18.0-18.5						
18.5-19.0						
Sum	264		101		58	

The length-weight regressions were best described by the following equations

$$1969: \log_{10}W = -3.392 + 3.046 \log_{10}L$$

$$1970: \log_{10}W = -3.314 + 2.970 \log_{10}L$$

$$1971: \log_{10}W = -3.193 + 2.911 \log_{10}L$$

Standard deviations of the slope values were ±.047 for 1969, ±.058 for 1970 and ±.054 for 1971. Testing of the b values by the Student's t distribution showed no significant difference at the .05 level for the three years. The regression coefficients were pooled to form the equation

$$\log_{10}W = -3.299 + 2.976 \log_{10}L$$

Plotting of observed weight values at mean TL for ages II, IV and VI against predicted values in the pooled equation did not show great change in length-weight relationships between collection years (Figure 9). Observed weight of age II river carpsucker was .31 lbs in 1969, .40 lbs in 1970 and .25 lbs in 1971. Age IV weights were .95, .88 and .90 lbs and age VI were 1.52, 1.65 and 1.65 for 1969, 1970 and 1971, respectively.

Condition factors for river carpsucker ranged from 42 to 56 in 1969, 40 to 43 in 1970 and 42 to 61 in 1971. Mean C-factors were 47, 45 and 52, respectively. Essentially no change was evident between means of 1969 and 1970, with a slight increase in the mean for 1971 (Table 15).

TL at the end of each year of life was estimated from body-scale equations

$$1969: L = -.3 + 4.05S$$

$$1970: L = .1 + 3.70S$$

$$1971: L = -.2 + 2.20S$$

where L represented total body length and S represented scale radius.

Estimations of TL at NAGE were combined for this report because little variation was evident in growth between collection years and the general trend was for decreasing increments in TL after the first year of life. Grand average estimated total body length at each annulus was 2.9, 5.4, 7.8, 9.8, 11.6, 13.2, 14.4, 14.7, and 16.5 inches, respectively. Successive summation of mean increments yielded estimated TL values of 2.9, 5.5, 8.0, 10.2, 12.2, 13.9, 15.6, 17.4 and 18.7 inches for the first 9 years of life (Table 18).

The growth index computed from the total body length data combined for the three collection years ranged from 80 in 1970 to 117 in 1969, but the overall trend showed little variation (Table 18).

AGE AND GROWTH OF BIGMOUTH BUFFALO

Body measurements and scale samples were taken from 255 fish, including 47 in 1969, 133 in 1970 and 75 in 1971. TL range was 5.8 to 25.0 inches in

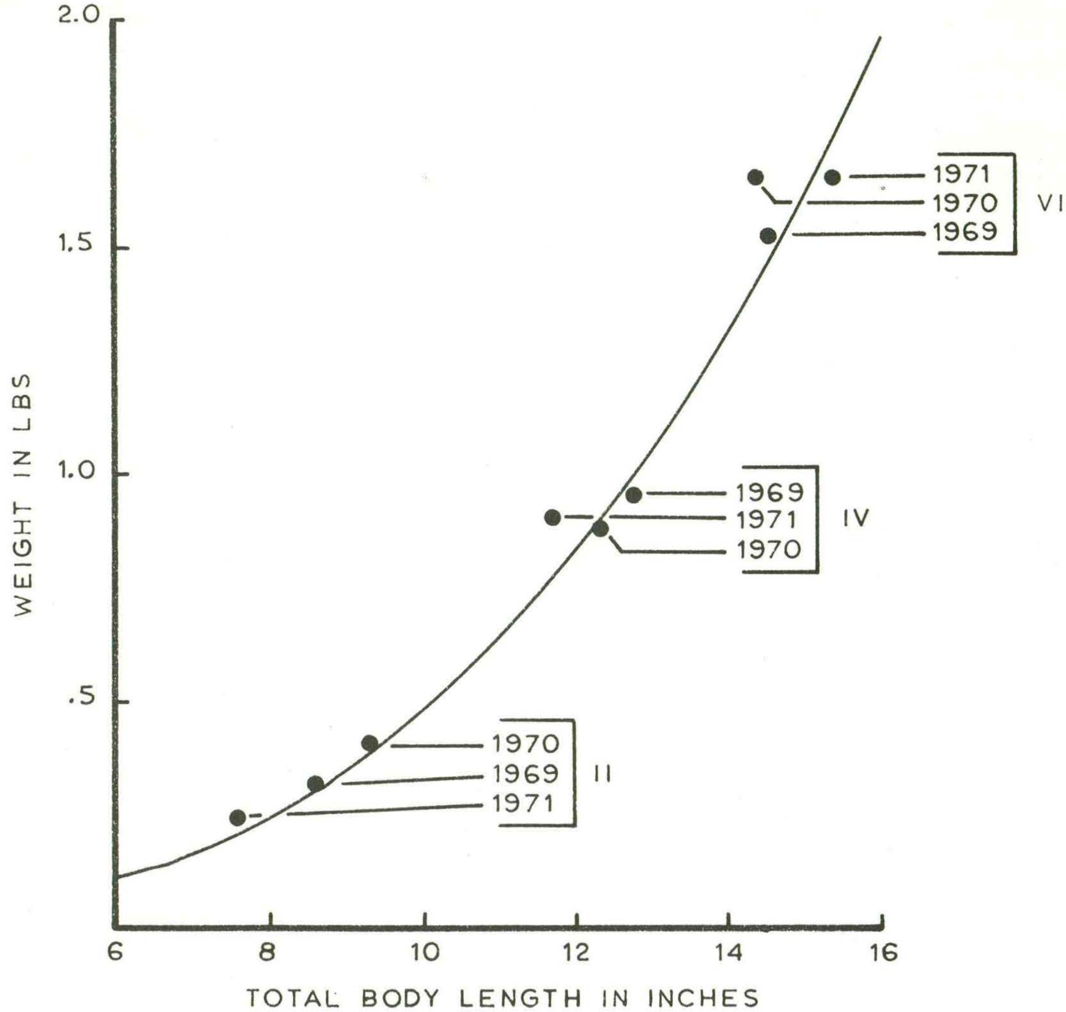

Figure 9. Pooled length-weight regression of river carpsucker for 1969, 1970 and 1971 with mean length-weight values of age groups II, IV and VI.

Table 18. Calculated length and mean growth increments for river carpsucker at Lake Red Rock

Year class	N in years sampled			Total N sampled	Estimated TL at NAGE									Growth index
	1971	1970	1969		1	2	3	4	5	6	7	8	9	
1970	4	*	**	4	2.6									80
1969	9	9	**	18	3.9	5.2								117
1968	13	28	21	62	3.1	6.5	8.9							113
1967	10	17	25	52	2.6	5.6	8.3	10.0						99
1966	3	10	15	28	2.8	5.3	8.0	10.6	12.5					100
1965	4	15	12	31	2.9	5.3	7.8	10.2	12.3	14.3				94
1964	9	16	14	39	2.9	5.1	7.5	9.6	11.6	13.5	14.0			98
1963	4	6	15	25	3.1	5.1	7.2	9.1	10.9	12.7	14.2	14.2		105
1962	2	0	5	7	2.4	4.7	7.1	8.8	10.6	12.0	13.7	15.2	16.5	90
Gr. $\overline{X}$ est. TL					2.9	5.4	7.8	9.8	11.6	13.2	14.4	14.7	16.5	
Gr. $\overline{X}$ increment					2.9	2.6	2.5	2.2	2.0	1.7	1.7	1.8	1.3	
Sum of increments					2.9	5.5	8.0	10.2	12.2	13.9	15.6	17.4	18.7	

*Year class absent from 1970 sample.

**Year class absent from 1969 sample.

1969, 6.8 to 25.7 inches in 1970 and 7.3 to 26.1 inches in 1971 with median lengths at 17.2, 17.1 and 16.8 inches, respectively. The length frequency data yielded a mode at 17.0-17.9 inches (18%) in 1969, and two secondary modes of 11% each at 16.0-16.9 and 21.0-21.9 inches. Frequency distribution for 1970 and 1971 were more evenly distributed over the class ranges and no apparent modes were established. Eight per cent frequency was most common and represented the 1965 and 1968 year classes. These strong year classes were the result of increased spawning success after the winter kill in the Des Moines River in 1965 and the impoundment of Lake Red Rock in the spring of 1969 (Table 19).

Table 19. Length frequency distribution of buffalo

Class range	1969 N	1969 % frequency	1970 N	1970 % frequency	1971 N	1971 % frequency
5.0- 5.9	1	2				
6.0- 6.9	3	5	2	2		
7.0- 7.9	4	7	9	7	1	1
8.0- 8.9	2	4	10	8	1	1
9.0- 9.9	2	4	10	8	6	8
10.0-10.9	0	0	11	8	4	5
11.0-11.9	1	2	9	7	6	8
12.0-12.9	1	2	3	2	5	7
13.0-13.9	0	0	0	0	4	5
14.0-14.9	3	5	2	2	6	8
15.0-15.9	4	4	5	4	3	4
16.0-16.9	6	11	5	4	2	3
17.0-17.9	10	18	5	4	5	7
19.0-19.9	2	4	10	8	5	7
20.0-20.9	1	2	10	8	4	5
21.0-21.9	6	11	10	8	6	8
22.0-22.9	1	2	11	8	4	5
23.0-23.9	2	4	6	5	3	4
24.0-24.9	1	2	3	2	3	4
25.0-25.9	2	4	3	2	2	3
26.0-26.9			0	0	1	1
27.0-27.9			1	<1		
Sum	57		133		75	

The length-weight regressions were best described by the equations

1969: $\log_{10}W = -3.524 + 3.222 \log_{10}L$

1970: $\log_{10}W = -3.378 + 3.070 \log_{10}L$

1971: $\log_{10}W = -3.088 + 2.853 \log_{10}L$

Standard deviations of the b values were ±.066, ±.031 and ±.058 for 1969, 1970 and 1971, respectively. Testing at the 95% confidence level gave common b values for 1969 and 1970. The values for 1969-1971 and 1970-1971 were significantly different.

Comparison of 1969 and 1971 regression lines gave a point of intersection at 15.2 inches. Above this length the 1969 fish were heavier than 1971 fish and below this point the reverse occurred. The intersection point for the 1970 and 1971 regressions was 21.7 inches and fish above this point weighed more in 1970 than in 1971. Fish below this point weighed less. The coefficients of the length-weight regressions were combined to form the pooled equation

$$\log_{10} W = -3.330 + 3.049 \log_{10} L.$$

Condition factors for buffalo ranged from 42 to 68 in 1969, 28 to 60 in 1970 and 37 to 128 in 1971 with means of 55, 50 and 57, respectively. Disregarding condition factors in 1971 of 37 and 128, for which there was only one observation each, the mean was adjusted to 54, which was similar to the 25¢ 1969 value. Condition factors were lower for fish of 1970 (Table 15).

Plotting of observed weight values at mean total length for ages II, IV and VI showed little difference in length-weight relationships between collection years for ages II and IV fish. Significant changes were revealed for age VI fish between collection years and may be due primarily to the small number of fish in the samples. Observed weights of age II buffalo at mean TL were 1.6 lbs in 1969, .8 lbs in 1970 and 1.1 lbs in 1971. Age IV observed weights were 3.3 lbs in 1969, 3.2 lbs in 1970 and 3.8 lbs in 1971. Age VI observed weights were 4.4 lbs in 1969, 5.5 lbs in 1970 and 7.8 lbs in 1971 (Figure 10).

Total body length at NAGE was estimated by the following equations

$$1969: \quad L = -.7 + 2.71S$$

$$1970: \quad L = .5 + 3.21S$$

$$1971: \quad L = -1.34 + 2.79S - .06S^2$$

Analysis of variance from regression of linear and quadratic equations for body-scale relationship showed a significant difference for 1971 at the 95% confidence level and the latter form was used for estimating TL at NAGE.

Combined estimated total body length at NAGE gave grand averages at each annulus of 5.1, 9.8, 13.7, 16.4, 18.5, 20.5, 22.1, 22.2, 23.1 and 23.9 inches for the first 10 years of life. Successive summation of mean increments for buffalo were 5.1, 10.1, 14.0, 16.6, 18.9, 21.0, 23.1, 24.4, 25.6 and 27.9 inches, respectively (Table 20).

Growth index computations from the combined total body length data ranged from 82 in 1962 and 1963 to 121 in 1969. The general trend was an increase in growth rate from 1963 to 1970 year classes, with minor fluctuations in various year classes between the two (Table 20).

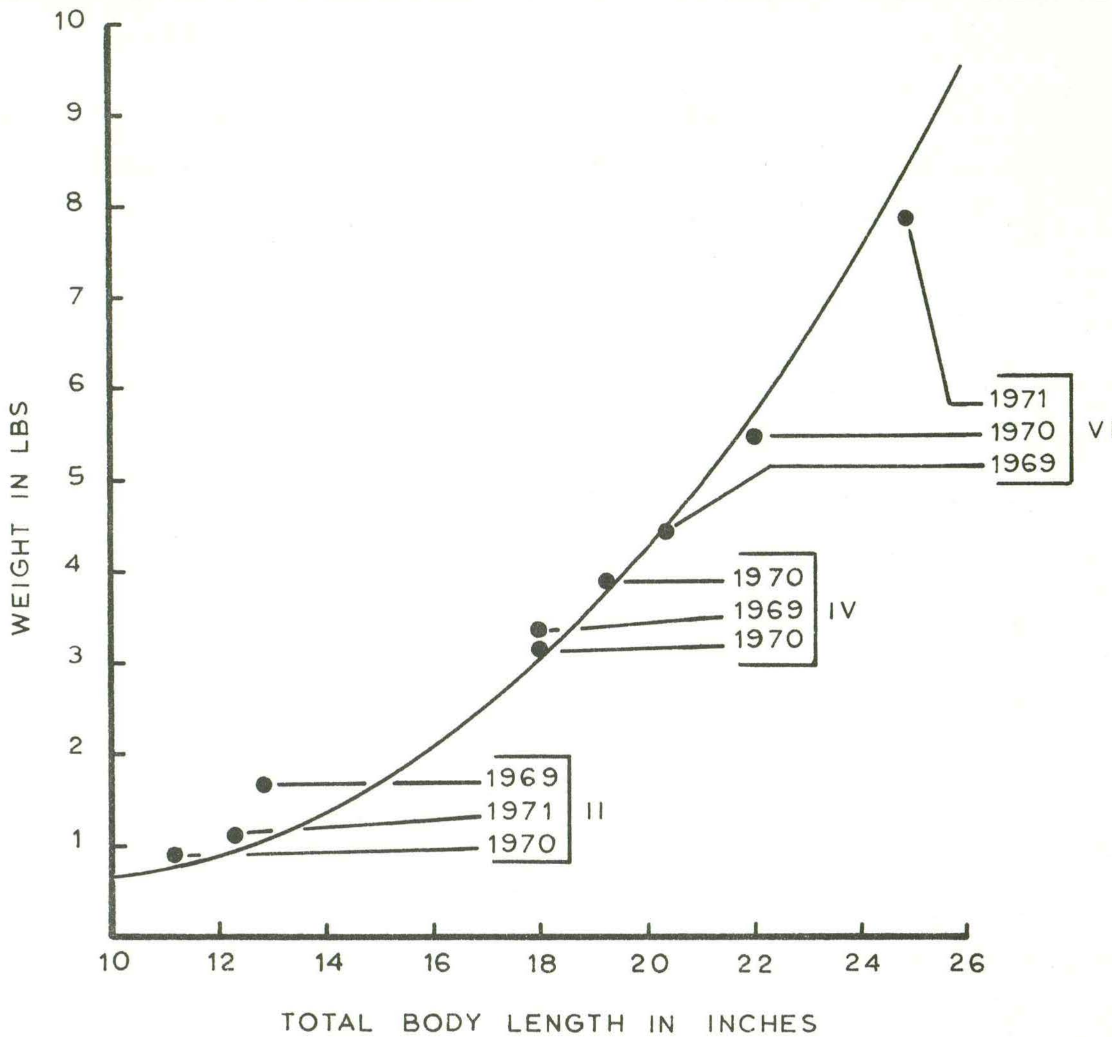

Figure 10. Pooled length-weight regression of bigmouth buffalo 1969-1971 with mean length-weight values of age groups II, IV and VI.

Table 20. Calculated length and mean growth increments for bigmouth buffalo at Lake Red Rock

Year class	N in years sampled 1971	1970	1969	Total N sampled	Estimated TL at NAGE 1	2	3	4	5	6	7	8	9	10	Growth index
1970	1	**	***	1	7.4										120
1969	29	38	***	67	6.4	10.3									121
1968	12	18	1	31	4.5	9.2	14.1								102
1967	5	7	4	16	4.9	10.2	15.1	17.8							96
1966	23	18	12	53	4.7	9.4	13.7	17.6	20.5						95
1965	4	22	12	38	4.9	9.8	13.6	17.0	20.1	22.9					99
1964	1	15	8	24	4.1	9.9	13.6	16.5	19.0	22.1	24.6				87
1963	*	3	5	8	4.2	9.6	12.6	15.4	17.6	19.8	23.3[a]				82
1962	*	7	5	12	4.2	9.6	13.7	16.3	18.4	20.0	21.6	22.6[a]			82
1961	*	4	***	4	5.1	9.5	12.8	15.2	17.3	19.4	20.8	22.2	23.6[a]		107
1960	*	1	***	1	5.6	11.1	14.0	15.3	16.5	18.5	20.1	21.7	22.6	23.9[a]	111
Gr. $\overline{X}$ est. TL					5.1	9.8	13.7	16.4	18.5	20.5	22.1	22.2	23.1	23.9	
Gr. $\overline{X}$ increments					5.1	5.0	3.9	2.6	2.3	2.1	2.1	1.3	1.2	1.3	
Sum of increments					5.1	10.1	14.0	16.6	18.9	21.0	23.1	24.4	25.6	27.9	

[a]Age group absent from sample.

*Year class absent from 1971 sample.

**Year class absent from 1970 sample.

***Year class absent from 1969 sample.

AGE AND GROWTH OF CHANNEL CATFISH

Subsamples from 327 fish, including 96 in 1969, 139 in 1970 and 92 in 1971 were used for computation of age and growth for channel catfish. Ranges in TL over individual collection years were 4.9 to 26.7 inches in 1969, 5.2 to 25.1 inches in 1970 and 6.8 to 26.1 inches in 1971. Medians were 11.2, 13.7 and 15.7 inches, respectively (Table 21). The increase for each successive collection year was the result of increased netting effort in the reservoir where catfish are larger in comparison with fish in the headwaters. A mode in the length frequency distribution was present at 9.0-9.9 inches in 1969 and comprised 15% of the sample. In 1970 and 1971 TL frequency was evenly distributed over most class intervals with no apparent modes.

Table 21. Length frequency distribution of channel catfish

Class range	1969		1970		1971	
	N	% frequency	N	% frequency	N	% frequency
4.0- 4.9	2	<1				
5.0- 5.9	4	1	2	1		
6.0- 6.9	21	7	5	4	2	2
7.0- 7.9	31	11	8	6	6	7
8.0- 8.9	28	10	10	7	5	5
9.0- 9.9	42	15	10	7	5	5
10.0-10.9	28	10	10	7	5	5
11.0-11.9	19	7	9	6	4	4
12.0-12.9	15	5	10	7	6	7
13.0-13.9	22	8	10	7	5	5
14.0-14.9	30	11	9	6	4	4
15.0-15.9	7	2	11	8	6	7
16.0-16.9	10	4	9	6	4	4
17.0-17.9	9	3	9	6	6	7
18.0-18.9	5	2	9	6	5	5
19.0-19.9	4	1	7	5	5	5
20.0-20.9	1	<1	7	5	4	4
21.0-21.9	0		1	<1	6	7
22.0-22.9	1	<1	3	2	5	5
23.0-23.9	0		1	<1	4	4
24.0-24.9	1	<1	0		4	4
25.0-25.9	0		1	<1	0	
26.0-26.9	1	<1			1	1
Sum	281		141		92	

Length-weight relationships for the three project years were described by the following equations

$$1969: \quad \log_{10} W = -3.616 + 3.137 \log_{10} L$$

$$1970: \quad \log_{10} W = -3.640 + 3.123 \log_{10} L$$

$$1971: \quad \log_{10} W = -3.781 + 3.256 \log_{10} L$$

Standard deviations of the b values were ±.045 for 1969, ±.069 for 1970, and ±.039 for 1971. The b values did not differ significantly between the individual project years when tested at the 95% level. Pooling of the coefficients yielded the equation

$$\log_{10} W = -3.6791 + 3.1722 \log_{10} L$$

Observed weights of age II fish were .17 lbs in 1969, .36 lbs in 1970, and .19 lbs in 1971. Age IV catfish were 1.21 lbs in 1969, 1.37 lbs in 1970 and 1.37 lbs in 1971. Age VI fish were variable between collection years yielding observed weights of 2.0 lbs in 1969, 3.0 lbs in 1970 and 3.74 lbs in 1971 (Figure 11).

Channel catfish condition factors ranged from 27-48 in 1969 with the mean at 34. C-factors for 1970 ranged from 25-41 with the mean at 33 and the 1971 factors ranged from 28-41 with a mean of 34. There was essentially no change in condition over the three collection years (Table 15). A systemic trend toward increasing C-factors was apparent in larger sizes in all project years. Observed weight values at mean total length for ages II, IV and VI showed little variation in length-weight relationships between collection years for age II and IV fish when plotted against the pooled equation.

The following equations were used to estimate total length at NAGE

$$1969: \quad L = 3.55S$$

$$1970: \quad L = 2.90S$$

$$1971: \quad L = 3.10S$$

Estimations of total body length at NAGE were combined for the project years to give grand averages of 1.8, 4.9, 7.6, 10.6, 13.2, 15.6, 17.1, 17.9, 17.6 and 20.8 inches at each annulus for the first 10 years of life. Successive summation of mean increments gave 1.8, 5.0, 8.2, 11.8, 15.2, 18.6, 21.1, 22.9, 24.5 and 26.7 inches for the first through the tenth years of life (Table 22).

The growth index from the combined data gave a range in growth from 70 for the 1963 year class to 187 for year class 1969. A general upward fluctuating trend was apparent in the growth rate in year classes after 1963 (Table 22).

CONCLUSIONS AND RECOMMENDATIONS

Intensive netting with several different types of gear for three seasons from March 1969 through October 1971 at Lake Red Rock showed fish with commercial and industrial food fish value dominated the population structure. Total catch was 321,937 fish weighing 151,533 lbs. Commercial food fish comprised up to 85% of the numerical catch and 88% of the weight. Carp was the most important species in the first two years, but was replaced by river carpsucker

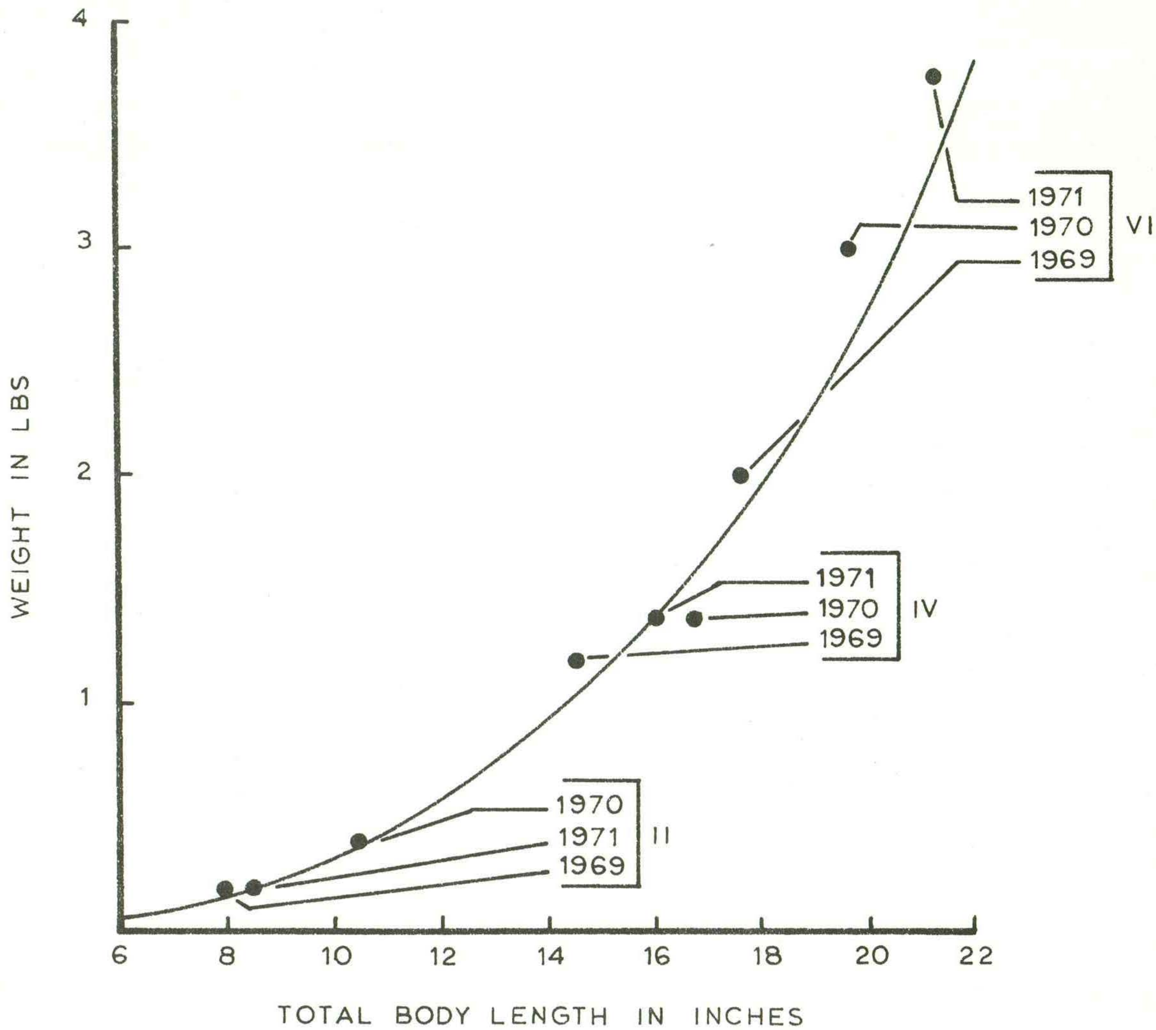

Figure 11. Pooled length-weight regression of channel catfish 1969-1971 with mean length-weight values of age groups II, IV and VI.

Table 22. Calculated length and mean growth increments for channel catfish at Lake Red Rock

Year class	N in years sampled			Total N sampled	Estimated TL at NAGE										Growth index
	1971	1970	1969		1	2	3	4	5	6	7	8	9	10	
1970	1	*	**	1	2.8										123
1969	17	9	**	26	3.4	8.7									187
1968	21	59	38	118	1.9	9.4	12.5								92
1967	17	9	12	38	1.5	4.8	12.1	15.3							97
1966	10	22	14	46	1.4	4.0	7.4	14.4	18.2						72
1965	9	36	24	69	1.2	3.5	7.1	10.0	16.4	19.5					77
1964	8	4	4	16	1.1	3.1	4.9	8.0	11.1	18.1	20.2				77
1963	5	*	4	9	1.2	3.6	6.0	9.6	12.4	14.3	18.2	21.4			70
1962	2	*	**	2	1.9	2.9	4.2	6.2	7.7	11.5	13.8	15.5	16.7		94
1961	2	*	**	2	1.9	4.0	6.8	10.4	13.3	14.4	16.1	16.7	18.6	20.8	114
Gr. $\overline{X}$ est. TL					1.8	4.9	7.6	10.6	13.2	15.6	17.1	17.9	17.6	20.8	
Gr. $\overline{X}$ increments					1.8	3.2	3.2	3.6	3.4	3.4	2.5	1.8	1.6	2.2	
Sum of increments					1.8	5.0	8.2	11.8	15.2	18.6	21.1	22.9	24.5	26.7	

*Year class absent from 1970 sample.

**Year class absent from 1969 sample.

in the last year. The relative abundance index indicated both carpsucker and buffalo were becoming increasingly abundant while carp importance was decreasing.

Catch success of food fish in the experimental fishery varied widely according to type of gear and species. There was also wide seasonal fluctuations in catch success, particularly with pound nets and baited hoop nets. Pound nets were most effective for carp, carpsucker and buffalo near shallow shoals and small embayments. Most channel catfish were taken in baited hoop nets near the headwaters in slight current. Quite large catches of carp were taken using soybean cake for bait in hoop nets, but few buffalo and carpsucker were captured with this gear. Gill nets were quite effective in the main pool for all species, except catches of large northern pike was also high in these nets. Baited slat traps were used with fair success in the main pool for large channel catfish.

Lake Red Rock was impounded in 1969 and the fish population density expanded rapidly for the first two years. Toward the end of the third year many biological characteristics of the fish populations appeared to stabilize. With initial flooding to an elevation greatly above normal conservation pool large populations of young commercial food fish developed. Growth was extraordinarily rapid and many entered the fishery by late summer. Estimated biomass of commercial food fish populations by late autumn was approximately 150 lbs per surface acre at conservation pool elevation. Biomass of each species was 112 lbs for carp, 22 lbs for river carpsucker, 8 lbs buffalo and 7 lbs channel catfish. The small average size from young age made about 80% of these fish unmarketable.

Although growth of fish in the second and third year was much slower than the first year, overall average weight of captured fish continued to increase each year. Carp increased from .35 lbs in 1969 to .76 lbs in 1971. River carpsucker weight increased from a mean of .59 lbs in the first year to 1.01 lbs in the last year. Mean weight of buffalo in the fishery increased from .36 lbs to 1.33 lbs in the three years. Channel catfish weight increased from .36 lbs in 1969 to 1.0 lbs in 1971, but part of this increase resulted from increased fishing with slat traps in the main pool. At present growth rates carp, carpsucker and buffalo would attain marketable size in four years, but channel catfish would require an additional year of growth.

Experimental exploitation by a net fishery during the second and third project segments yielded a harvest of 115,457 marketable food fish weighing 53,703 lbs. Market value of this fishery was estimated at $10,300. About 14 fish weighing 6 lbs per surface acre were exploited by the fishery, far below the expected potential.

Exploitation of commercial food fish populations had no perceptable affect on size distribution, length-weight relationship, body condition and growth, although true evaluations was partially masked by large variations in growth between years. Abnormally high water storage during initial impoundment for nearly 120 days resulted in production of fish populations far exceeding the carrying capacity at conservation pool elevation. Growth rates were exceptionally fast for all fish species in the first year, but when storage volume was lowered to authorized levels the fish were obviously stressed and growth rates slowed to nearly nothing. After water levels stabilized in the second and third years of impoundment growth returned to more normal rates.

Production of young gizzard shad was high during the second year of impoundment with an estimated biomass of 20 lbs per surface acre. Although shad have no value as a human food resource, they have considerable value for a protein base in pet foods. The main problem for utilization of shad from Lake Red Rock is developing suitable fishing techniques and apparatus to yield large catches of fish without catching small game-fish. 0-age gizzard shad also form the forage base for predatory game-fish species and surplus production would have to be estimated carefully before exploitation, otherwise overharvest could potentially limit game-fish production. In general, there appears limited potential for encouraging shad exploitation, particularly 0-age fish.

Abundance of other species of young food fish was quite low except for carp. By this criteria food fish populations closely resemble those at Coralville Reservoir where a single year class of fish, which was buffalo, dominated the age structure with low production in subsequent years (Mitzner, 1972). Exploitation by a net fishery would undoubtedly shorten the longevity of dominant year classes because cropping would lower the population density much faster than an unexploited population where mortality occurred from natural causes. These data are insufficient to speculate on the characteristics of the age structure following sustained harvest of surplus stocks at Lake Red Rock.

Within the next two years large quantities of commercial food fish should be of marketable size in Lake Red Rock. Currently about 88 lbs of every 100 lbs of fish captured in a net fishery has commercial food fish value and little sport value. This figure is expected to increase as the reservoir ages. Sustained harvest of carp, river carpsucker and buffalo could easily reach 200 lbs per surface acre each season or up to 1.5 million lbs of food fish. Total effort for this level of exploitation would require about 8,900 net days at the average catch effort in this study. Potential market value of the fishery could approach $150,000.

Competition between the sport fishery and commercial exploitation would be unimportant with proper management. Game-fish populations, with the exception of channel catfish and bullhead, are small. Environmental characteristics, especially sedimentary turbidity, in the lake offers slight potential for increasing game-fish populations. There is little chance walleye and northern pike can be sustained at present population densities because these populations resulted from initial fry plantings when competition from other fishes was low and survival high. Subsequent fry plantings have not been very successful. Most of the sport fishery is for crappie, channel catfish and bullhead. Sport fishery surveys in 1971 showed fishing pressure for the main pool was <1 fisherman per surface acre.

Based on results of this study it is recommended commercial fishing be allowed at Lake Red Rock by departmental rule commencing after 1 October, 1973. Presently, all types of net fishing should be prohibited in the tailwaters because of large concentrations of game-fish, especially walleye and northern pike. The main pool, including the headwaters should be opened to commercial fishing. Regulation of the fishery, including types of gear, seasons, species and catch reports should follow those previously established for flood control reservoirs and interior lakes.

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