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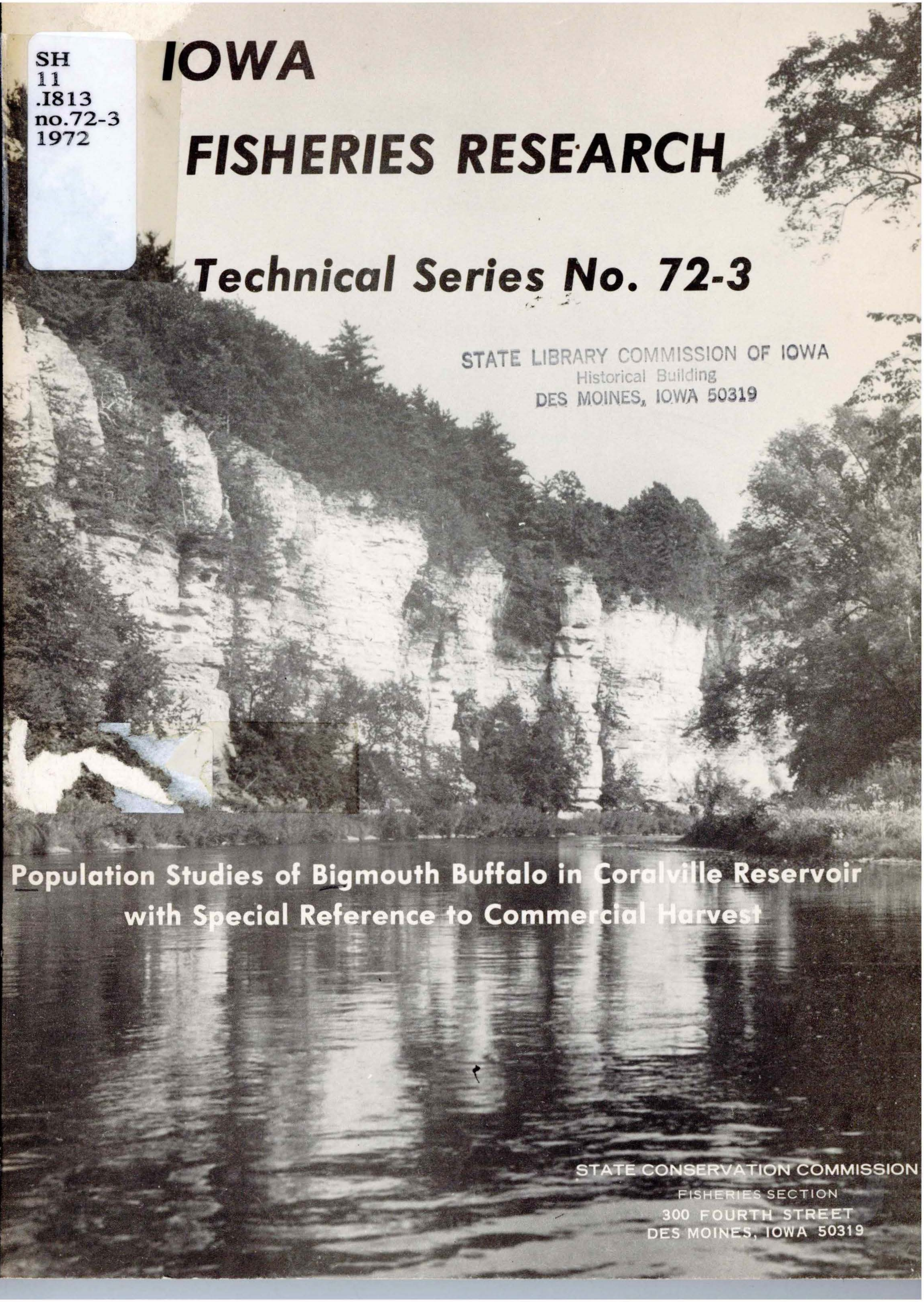

# Population Studies of Bigmouth Buffalo in Coralville Reservoir with Special Reference to Commercial Harvest

STATE CONSERVATION COMMISSION
FISHERIES SECTION
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DES MOINES, IOWA 50319

# POPULATION STUDIES OF BIGMOUTH BUFFALO IN CORALVILLE RESERVOIR WITH SPECIAL REFERENCE TO COMMERCIAL HARVEST[1]

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# ABSTRACT

Investigations to determine the magnitude of commercial fish populations and the rate they could be exploited were conducted at Coralville Reservoir during the 5 year period, 1966-1970. Population estimates indicated bigmouth buffalo were most abundant of any species with approximately 370 per acre and standing crop was estimated at 1,046 lbs per acre. An experimental net fishery was conducted in 1967 and 1968 to determine affects of exploitation. The fishery exploited 13 lbs per acre of carp, carpsucker, buffalo and channel catfish. Fish were removed by frame nets, slat traps, bait nets, and gill nets. Total gear effort was 5,616 net days. An additional 125 lbs per acre were lost by winter kill resulting from oxygen depletion in February, 1969. Life history and population statistics showed no change due to exploitation, even with the additional mortality from winter kill. Growth in body length of bigmouth buffalo expressed by the Walford line was .79. Mean instantaneous total mortality was .40. Length-weight relationships and condition factors were computed for comparison during each year of the investigation. Selectivity of gill nets was studied in 1970 to determine their feasibility for use in a commercial fishery. Total catch was 2,267 fish in 256 net days and was dominated by bigmouth buffalo. Catch success of buffalo in the 4, 5, 6 and 7 inch mesh size was 3.7, 4.6, 3.3 and 4.0 fish per net day. Catch from 12 May-14 August ranged from 6.9-1.4 fish per net day. Spawning activity in May and June resulted in highest catch rates. Location of net site revealed no difference in catch success, but net position in relation to shore showed significantly higher catches were made at off-shore areas. There was significant difference in size selectivity of 6 and 7 inch mesh over 4 and 5 inch mesh. Sixty-six sport fish or 3% of the total catch were taken in the gill nets. Potential equilibrium yield estimates were computed using the Beverton-Holt procedure. Yield ranged from 17-111 lbs per surface acre with mean recruitment of 100 fish per acre at age 2.5. Instantaneous fishing rates were adjusted from .1-1.6. Seven-inch mesh was most productive at fishing rate of 1.6, but most efficient rate was 1.2 which resulted in 70% exploitation. Recommendations for a commercial fishery with regulations for the fishery are presented and discussed.

# INTRODUCTION

A network of both existing and proposed flood control reservoirs in Iowa will make vast amounts of additional habitat available for fish populations. Approximately 30,000 surface acres of reservoirs will be operational within the near future. Much of this additional habitat is conducive to rough-fish species, but harvest of the resource is extremely low or absent. Low harvest usually results from disinterest of anglers for rough fish. Also, species such as buffalo or carpsucker are rarely taken on sport fishing gear. Low harvest was promoted because the Code of Iowa prohibited commercial exploitation or sale of any fish except from the Mississippi and Missouri Rivers or under special provisions of statute Chapter 109.17.

The US Congress passed Public Law 88:309 on 20 May, 1964, allowing federal funding for research and development of commercial fisheries. Iowa received approval for a 6-yr project to conduct research on inland streams and reservoirs upon filing proper application documents. The investigation was initiated in June, 1966.

Statewide investigations by Meek (1892) between 1889 and 1891 indicated abundant populations of catostamids. Records in the late 1930's by Aitken (1940) showed catostomids were abundant and European carp populations extremely abundant and ubiquitous in the state. Later investigations by Harrison (1949 and 1954) and Cleary (1953) showed populations of rough fish were common to abundant during 1948-1952. Biomass of carp, quillback and redhorse was estimated by Harrison (1956) at approximately 600 lbs per surface acre in the Humboldt impoundment of the Des Moines River. In the early 1950's Cleary (1954) found carp, quillback and sucker comprised 66% of trap net catches by weight in the Cedar River. Mayhew (1964) determined carp, buffalo and carpsucker in Coralville Reservoir contributed 86% by weight to the 1963 sample. The following year Helms (1964) found rough fish species comprised 80% of net samples by weight.

Although rough fish comprise a large biomass in Iowa waters they are often undesirable to anglers. The highest catches were recorded by Harrison (1962) who found carp contributed 36% to angler catch on the Des Moines River. Mayhew (1963) determined 9% of the catch at Coralville Reservoir was carp and 3% of the anglers preferred fishing for carp. Helms (1964) found 6% of the catch was carp and 2% of the anglers preferred carp. Harvest of rough fish species was continuously < 5 lbs per surface acre at Coralville Reservoir.

The present investigation was conducted at Coralville Reservoir because previous surveys by Mayhew (1964) showed the lake and tailwaters contained large populations of commercially valuable food fish. Overall objectives of the investigation were four fold. First, determine the magnitude and rate populations of commercial food fish could be exploited without jeopordizing established sport fisheries. Second, evaluate changes in life history statistics resulting

[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.

from increased harvest. Third, delineate factors affecting catch success of various types of fishing gear. Last, determine species selectivity of various types of fishing gear. Although equal emphasis was given to all species of food fish, this report deals mainly with bigmouth buffalo. Buffalo were the most abundant commercial food fish in the lake and had the highest market potential for profitable harvest. Carp and carpsucker were numerous but low market price precluded important commercial exploitation. Channel catfish have high market value, but their density in the reservoir was low and catfish are very important to the sport fishery. Detailed results for other species are discussed by Mayhew and Mitzner in Project Segment Completion Reports for 4-11-R-1, 4-11-R-2, 4-11-R-3, 4-11-R-4, and 4-11-R-5 (1967 through 1971).

The primary objectives were achieved by a systematic procedure outlined an integral part of the investigation. First, population estimates were made and biological statistics collected on age structure, growth, length-weight relationship, body condition, mortality rates and total catch for each type of gear. These parameters formed the baseline for comparison of changes resulting from exploitation and provided statistics for use in yield estimate models.

A controlled exploitation program was initiated in 1967 and 1968 to determine changes in population statistics resulting from population reduction. Harvest rate was not to exceed 20% of the 1966 population estimates. After exploitation, population estimates were repeated and vital statistics collected to evaluate the effects of exploitation.

Evaluation of gill nets was conducted in 1970 to determine the feasibility of this gear for a commercial fishery. Selectivity of species, body size and catch rate were measured and variation from important extrinsic sources were also measured to account for unexplained variation in catch rate.

## DESCRIPTION OF STUDY AREA

Coralville Reservoir is located near Iowa City in Johnson County, Iowa and impounds the Iowa River 83 miles from its confluence with the Mississippi River. It was built by the US Army Corps of Engineers, Rock Island District and became operational in 1958. The primary purpose of operation is downstream flood control and navigational release for barge traffic in the upper Mississippi River basin. Recreational benefits are of secondary importance to flood control.

The summer conservation pool is 680 ft mean sea level (MSL) and contains 4,900 surface acres. At this level mean depth is 14 ft with 38,610 acre-ft storage capacity (Plate 1). This level is maintained from 15 June-1 September except when flood waters are temporarily stored. From 1 September-15 December the level is raised to 683 ft MSL for waterfowl management. It is then reduced to 680 ft MSL until 1 February when it is drawn down to 670 ft MSL in anticipation of spring floods. At low level the pool contains 1,820 surface acres with 7,979 acre-ft storage and mean depth of 4.3 ft. Flood pool elevation is 712 ft MSL with potential storage capacity of 24,800 surface acres and mean depth of 16.3 ft. Excess storage is released at no more than 10,000 CFS nor less than 150 CFS depending on storage volume.

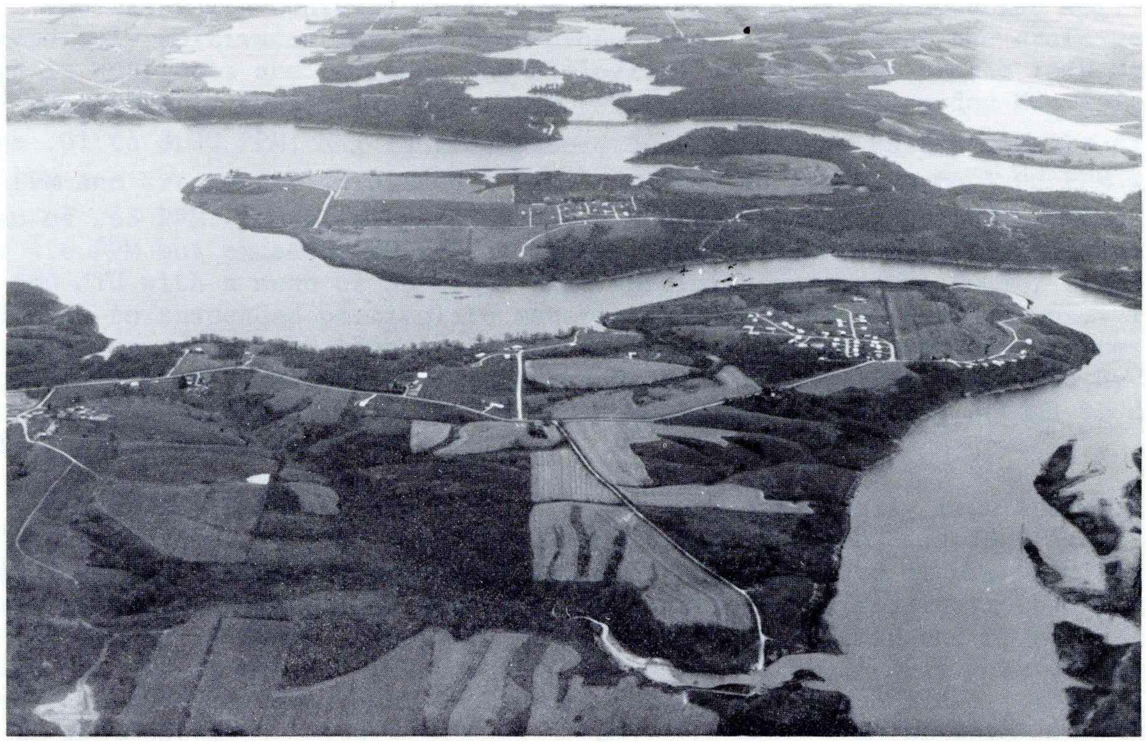

Plate 1. Coralville Reservoir at study area.

The watershed contains 3,115 square miles of highly productive soil intensively cultivated for row crop production. Runoff from the drainage is high in nutrients and enriches the biological productivity of the Iowa River and consequently Coralville Reservoir. McDonald (1971) recorded $NO_2$ ranging from .01 to 3.90 PPM; $NH_4$ ranged up to 4.65 PPM. These values usually exceeded .1 PPM and frequently surpassed 1 PPM. $PO_4$ ranged from .04 to 1.90 PPM with mean of .63 PPM. Total alkalinity had a seasonal mean of 201 PPM. Mean BOD was 4.6 PPM but exceeded 30 PPM at times. Turbidity was also high, ranging up to 600 JTU with a mean of 58 JTU. High turbidity during the summer season was due both to suspended particulate material and high algal populations. Temperature varied no more than $5^{o}$ F from surface to bottom, even during summer months. When thermal stratification started to form it was destroyed by wind and current. Storage ratio is .03 and normal flow was strong enough to dissipate thermal stratification.

Water levels during the study did not vary drastically from operational objectives except in 1969 when flood conditions occurred. In 1965 and 1969 during spring floods elevations of 708.5 ft MSL and 711.9 ft MSL were recorded. Heavy rainfall in June 1969 caused a rapid increase in reservoir level to 691 ft MSL by 10 June. Abnormal, heavy rainfall persisted and by 9 July water stage was 704 ft MSL and increased to 711.9 ft MSL by 21 July. Water level gradually receded throughout the summer and did not reach elevation 683 ft MSL until mid-September. A gradual and steady increase of water level in 1968 caused optimum conditions for growth of rooted aquatic vegetation, dominated by smartweed. This dense growth made it difficult to find productive netting sites.

A partial fish-kill occurred during February and March, 1969. High discharge into the reservoir in late January from melt-water caused an increase in BOD and subsequent decline in DO to 2.6 PPM, but no fish loss was observed at this time. Similar conditions occurred in late February and early March after winter drawdown. Recurrent thawing and runoff were again accompanied by high BOD values. At this time many dead and dying fish were observed. On 26 February, all BOD levels were > 30 PPM and DO decreased to 1.4 PPM. DO was .2 PPM on 6 March and gradually increased to 6.8 PPM on 11 March. Estimates of fish loss at ice-off, based on observation of fish floating and dead on shore, were 20% for tolerant species such as carp, and 40% for species such as crappie and walleye.

Commercial food fish lost because of the 1969 winter kill could not have been marketed, but biologically they were extracted from the population. This unexpected depletion of fish stocks was considered a unique type of exploitation and was included in evaluation of population dynamics. Population parameters were analyzed to detect causal effects occurring from the net fishery and the additional depletion by winter kill. Netting removed 6.2 and 6.8 lbs per surface acre in 1967 and 1968, respectively. Mortality due to low DO accounted for approximately 125 lbs per acre.

## METHODS AND PROCEDURES

Sampling was conducted on a bi-weekly basis with the last week in March the initial period. Subsequent periods were numbered consecutively from this period. Scale samples, body lengths and weights were collected in each bi-weekly period. Approximately 400 buffalo were measured every year. Each sample was selected from a randomly chosen piece of gear and all fish were measured to avoid size selectivity in the sample. Catch statistics by weight and number were recorded for each type of gear.

Sampling gear consisted of frame trap nets, baited hoop nets, slat traps and gill nets. Frame nets had 50-ft leads with two, 2 1/2 x 5-ft frames ahead of a hoop net 2 1/2-ft in diameter and 8-ft long. A wing throat was formed by the frames and the hooped portion of the net contained two funnel throats. The entire net was constructed of 2-inch stretch measure web. Leads were always set perpendicular to shore at a depth sufficient to cover the hoops. Baited hoop nets were constructed identically to the hooped portion of the frame nets except they had 2-ft hoops and were made of 1 1/2-inch stretch measure web. These nets were baited with cheese trimmings or soybean meal and set in flowing water. Nets were anchored in the current so fish attracted upstream were exposed to the throated end of the net. Slat traps were constructed of 1 1/2 x 1/4-inch oak slats separated by an opening of approximately 3/8-inch to form a box with overall dimensions of 1 x 1 x 5-ft. One end was open and contained a pyramidal oak slat throat. A door was located on the opposite end for fish removal. This gear was baited, but could be set in either flowing or standing water. Gill nets were 6-ft deep by 100-ft long and fished perpendicular to shore. Mesh size was 4-inch stretch measure. Description of experimental gill nets will be given in the section on gill net selectivity.

Each type of gear was used when it was most effective. Deployment in this manner allowed for maximum catches and better personnel efficiency. Frame netting was initiated during the first period and terminated after Period 10, while slat traps were used from Period 4-14. Bait netting was conducted during Periods 6-7 and continued in Periods 12-14. Most effort was expended on gill netting during 1970 to evaluate the efficiency and selectivity of this type of gear.

## GEAR UTILIZATION, SPECIES COMPOSITION AND CATCH STATISTICS

During the study 139,079 fish weighing 138,754 lbs were captured with 10,136 net days (ND) of effort. Carp (*Cyprinus carpio*) were most numerous and contributed 38,642 to the catch followed by channel catfish, (*Ictalurus punctatus*) 31,166; buffalofish (*Ictiobus cyprinellus* and *bubalus*), 31,056; and carpsucker (*Carpiodes carpio* and *cyprinus*), 19,996. Other species included northern pike (*Esox lucius*), northern red horse (*Moxostoma aureolum*), silver red horse (*M. anisurum*), flathead catfish (*Ictalurus olivaris*), bullhead (*Ictalurus spp.*), white bass (*Roccus chrysops*), yellow bass, (*R. mississippiensis*), largemouth bass (*Micropterus salmoides*), white crappie (*Pomoxis annularis*), black crappie (*P. nigromaculatus*), green sunfish (*Lepomis cyanellus*), bluegill (*L. macrochirus*), pumpkinseed (*L. gibbosus*) and walleye (*Stizostedion vitreum*) contributing the remaining 28,219.

## GEAR EFFORT

Each type of gear was selective to certain species and distribution of effort for each gear influenced the overall species composition. Frame nets were utilized 2,094 ND with most intensive use in 1968 and 1969 when gear was set 675 and 583 ND (Table 1). In 1966, frame nets were set 296 ND followed by 437 and 103 ND for 1967 and 1970. Baited slat traps were used 6,196 ND during the investigation. Most intensive use was during years of exploitation with 1,988 and 1,562 ND. Effort for 1966, 1969 and 1970 was 1,122, 983 and 541 ND, respectively. Baited hoop nets were used 1,683 ND for sampling and exploitation. In 1966, the conservation pool was near flood stage and with no flowing water within the study area; hoop nets were set only 12 ND. Conditions were near optimum in 1970 and hoop nets were used 576 ND. During the exploitation phase 469 and 475 ND were expended while in 1969 bait nets were set 151 ND. Buffalo nets and gill nets were used 73 and 163 ND.

Table 1. Distribution of effort for commercial fishing gear in net days (ND)

| Year | Slat trap | Frame net | Bait net | Gill net |
|---|---|---|---|---|
| 1966 | 1,122 | 296 | 12 | 5 |
| 1967 | 1,988 | 437 | 469 | 5 |
| 1968 | 1,562 | 675 | 475 | 5 |
| 1969 | 983 | 583 | 151 | 20 |
| 1970 | 541 | 103 | 576 | 128 |
| Total | 6,196 | 2,094 | 1,683 | 163 |

## SPECIES COMPOSITION

Frame net samples produced 101,872 fish weighing 117,016 lbs. Distribution of catch was 10,697 lbs in 1966 and 21,801 lbs, 33,159 lbs, 27,658 lbs and 8,557 lbs in 1967-1970. Numerical species composition was always dominated by carp. They contributed 45.2%, 37.9%, 26.6%, 36.0% and 33.3% to the catch in 1966-1970 (Table 2). Carpsucker ranked second, comprising approximately 25%, except in 1969 and 1970 when buffalo became more important. Bigmouth buffalo were not effectively captured by frame nets and they contributed 3.5%, 5.5%, 21.1%, 34.4% and 18.2% to the catch in 1966-1970. Channel catfish never contributed more than 1%. Crappie was most numerous of other species comprising 9-26% of the catch.

Combined slat trap effort yielded 14,698 fish weighing 8,843 lbs. Highest catch was in 1967 with 5,515 followed by 1966, 3,493; 1968, 2,431; 1969, 2,086; and 1970, 1,173. Channel catfish were more vulnerable to baited slat traps than frame nets and always dominated catches. In 1967 they contributed 95.7% to the catch followed by 93% in 1970 and 86%, 81.1% and 86.7% in 1966, 1968 and 1969 (Table 3). Carp were second most abundant comprising 12.2%, 2.9%, 13.8%, 3.9% and 3.4% of the catches in 1966-1970. Other species never contributed > 5% to the catch.

Table 2. Catch and species composition in frame nets

| Species | 1966 N | 1966 % | 1967 N | 1967 % | 1968 N | 1968 % | 1969 N | 1969 % | 1970 N | 1970 % |
|---|---|---|---|---|---|---|---|---|---|---|
| Carp | 4,828 | 45.2 | 8,266 | 37.9 | 8,800 | 26.6 | 9,957 | 36.0 | 2,867 | 33.3 |
| Carpsucker | 2,731 | 25.6 | 5,183 | 23.8 | 7,397 | 22.3 | 3,587 | 12.9 | 552 | 6.4 |
| Buffalo | 377 | 3.5 | 1,202 | 5.5 | 6,970 | 21.1 | 9,533 | 34.4 | 1,569 | 18.2 |
| C catfish | 67 | .6 | 141 | .6 | 378 | 1.1 | 154 | .6 | 14 | .2 |
| Other | 2,677 | 25.2 | 7,016 | 32.1 | 9,577 | 29.0 | 4,440 | 16.1 | 3,589 | 41.6 |
| Total | 10,680 | | 21,808 | | 33,122 | | 27,671 | | 8,591 | |

Table 3. Catch and species composition in slat traps

| Species | 1966 N | 1966 % | 1967 N | 1967 % | 1968 N | 1968 % | 1969 N | 1969 % | 1970 N | 1970 % |
|---|---|---|---|---|---|---|---|---|---|---|
| C catfish | 3,005 | 86.0 | 5,277 | 95.7 | 1,972 | 81.1 | 1,810 | 86.7 | 1,091 | 93.0 |
| Carp | 427 | 12.2 | 159 | 2.9 | 336 | 13.8 | 82 | 3.9 | 40 | 3.4 |
| Carpsucker | 0 | 0 | 0 | 0 | 2 | .1 | 1 | .1 | 0 | 0 |
| Buffalo | 0 | 0 | 9 | .2 | 2 | .1 | 3 | .1 | 1 | .1 |
| Other | 61 | 1.7 | 70 | 1.3 | 119 | 4.8 | 190 | 9.1 | 41 | 3.5 |
| Total | 3,493 | | 5,515 | | 2,431 | | 2,086 | | 1,173 | |

Baited hoop nets were also dominated by channel catfish. Species composition was 79.6% channel catfish and 18.6% carp.

## EXPLOITATION

Exploitation of buffalo could be expected to alter vital statistics of the population. Removal of carp, carpsucker and channel catfish would also have an indirect effect on the buffalo population. These effects could change growth rate, recruitment and mortality rate.

During years of exploitation 55,343 lbs of carp, carpsucker, buffalo and channel catfish were removed with frame nets (Plate 2). Carp contributed 11,247

Plate 2. Experimental exploitation of buffalo, carp, and carpsucker.

lbs to the catch in 1967 and 12,121 lbs in 1968. Carpsucker catch was 9,762 lbs in 1967 and 12,121 lbs in 1968. Buffalo harvest was 2,245 and 7,261 lbs in 1967 and 1968. Channel catfish contributed 97 and 489 lbs to the catch in the same years. Total removal by this gear was 10.9 lbs per surface acre.

Exploitation of channel catfish, carp, carpsucker and buffalo by slat traps accounted for 3,010 lbs in 1967 and 1,423 lbs in 1968. Channel catfish contributed 3,443 lbs for the two-year program while 940 lbs of carp, 47 lbs of buffalo and 3 lbs of carpsucker were exploited. Total removal by this gear was 4,433 lbs or .9 lbs per surface acre.

Exploitation by bait nets in 1967 accounted for 3,161 lbs of channel catfish, 2,111 lbs of carp, 12 lbs of carpsucker and 3 lbs of buffalo. Total exploitation was 5,287 lbs or slightly more than 1 lb per surface acre.

Buffalo nets and gill nets accounted for removal of 760 lbs of carp, carpsucker, channel catfish and buffalo. Combined gear effort resulted in total exploitation of 65,823 lbs of fish in 1967 and 1968 or 13 lbs per surface acre.

## CATCH PER UNIT EFFORT

Relative abundance described by Rounsefell and Everhart (1953:64) indicated catch success values can be used to detect change in population density. Catch per unit of effort is usually the most immediate and noticeable of all parameters affected by exploitation.

An evaluation was made of catch in frame nets for bigmouth buffalo to relate their abundance to exploitation. Mean catch rates within sampling years 1967-1970 were compared by two-way analysis of variance during Periods 4, 6, 7, 9 and 10.

Mean catch of bigmouth buffalo ranged from .02 fish per net hour (FNH) in Period 4, 1967 to 1.26 FNH in Period 9, 1970 (Table 4). Buffalo catches in 1967 were lowest with a mean of .09 FNH. Highest catch rates were achived in 1969 with .69 FNH followed by 1968 and 1970 with .45 and .57 FNH, respectively. High catches in 1969 and 1970 were obviously due to recruitment of the abundant 1966 year class into the fishery. Mean catch for Periods 4, 6, 7, 9 and 10 were .36, .69, .54, .45, .22 and .45 FNH showing no distinct seasonal trend. Analysis of variance showed no difference between years or within sampling periods ($P > .05$).

Table 4. Catch of bigmouth buffalo in frame nets expressed as FNH

| Netting period | Sample year 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|
| 4 | .02 | .53 | .70 | .18 |
| 6 | .08 | .79 | 1.25 | .64 |
| 7 | .12 | .54 | 1.04 | .46 |
| 9 | .09 | .13 | .30 | 1.26 |
| 10 | .12 | .25 | .16 | .33 |
| $\overline{X}$ | .09 | .45 | .69 | .57 |

## LIFE HISTORY OF BUFFALO

Knowledge of life history was essential to evaluate change in population density due to exploitation. Fisheries biologists have used trends in rate of growth, length-weight relationship, body condition, mean weight and age structure to relate corresponding changes in population density (Ricker, 1958; Rounsefell and Everhart, 1953). A large change in abundance will tend toward equilibrium and become evident in altered life history statistics. Computations involving yield equations also require this basic information. In addition, maximum attainable length and weight, instantaneous growth, total and natural mortality and age of recruitment to gear are necessary for estimating yield. These statistics were determined for bigmouth buffalo throughout the investigation and were used to compare original and exploited populations.

### LENGTH-WEIGHT RELATIONSHIP

Measurements of total body length and weight were taken from 1,492 bigmouth buffalo in Periods 1-12 of each study segment. Length-weight relationships were computed independently for each year using the linear regression model

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

where W is weight in lbs and L is total length (TL) in inches.

The following constants were computed from paired observations.

1966: $\log_{10}W = -3.0019 + 2.8099 \log_{10}L$

1967: $\log_{10}W = -3.4108 + 3.1364 \log_{10}L$

1968: $\log_{10}W = -3.2226 + 2.9790 \log_{10}L$

1969: $\log_{10}W = -3.3126 + 3.0541 \log_{10}L$

Correlation coefficients for all regressions were $\geq$ .998.

Paired intercepts (a) and slopes (b) were compared by Students t-distribution. Differences in a and b values were significant at the 95% level between 1966 and all other years, and 1967 and 1968. All other year combinations had common values.

The difference between 1966 and 1967 showed small buffalo in 1966 were in better condition than those in 1967 with the inflection occurring at 17.9 inches (Table 5). Condition factors (C) for fish above and below the inflection point in 1966 were 62 and 55 compared to 61 and 53 for 1967 samples.

Table 5. Condition factors of bigmouth buffalo

| 1966 | | 1967 | | 1968 | | 1969 | |
|---|---|---|---|---|---|---|---|
| Observed length | C | Observed length | C | Observed length | C | Observed length | C |
| 8.2 | 60 | 6.5 | 51 | 7.6 | 52 | 4.2 | 81 |
| 9.2 | 60 | 7.3 | 54 | 8.4 | 61 | 5.8 | 51 |
| 10.1 | 65 | 8.0 | 51 | 9.4 | 58 | 9.4 | 52 |
| 11.1 | 68 | 8.8 | 47 | 10.4 | 56 | 10.4 | 55 |
| 12.0 | 64 | 9.5 | 54 | 11.4 | 56 | 11.4 | 56 |
| 13.0 | 64 | 10.3 | 53 | 12.4 | 56 | 12.4 | 56 |
| 14.5 | 63 | 11.1 | 56 | 13.4 | 58 | 13.4 | 56 |
| 16.1 | 57 | 11.8 | 52 | 14.4 | 56 | 14.4 | 56 |
| 17.1 | 58 | 12.5 | 56 | 15.4 | 46 | 15.4 | 55 |
| 18.6 | 55 | 13.3 | 55 | 16.4 | 51 | 16.5 | 61 |
| 19.6 | 57 | 14.0 | 54 | 17.4 | 47 | 18.0 | 55 |
| 20.5 | 57 | 16.3 | 49 | 18.4 | 54 | 19.2 | 56 |
| 21.5 | 56 | 17.8 | 56 | 19.4 | 55 | 20.2 | 56 |
| 22.5 | 54 | 18.5 | 58 | 20.4 | 59 | 21.2 | 56 |
| 23.7 | 53 | 19.3 | 58 | 21.4 | 59 | 22.2 | 56 |
| 26.0 | 52 | 20.0 | 58 | 22.4 | 62 | 23.2 | 60 |
| | | 20.8 | 59 | 23.4 | 60 | 24.1 | 64 |
| | | 21.5 | 60 | 24.4 | 61 | 25.0 | 58 |
| | | 22.3 | 59 | | | 25.9 | 65 |
| | | 23.0 | 63 | | | 26.4 | 64 |
| | | 23.8 | 58 | | | 29.0 | 64 |
| | | 24.4 | 61 | | | | |
| | | 25.0 | 62 | | | | |
| | | 26.3 | 65 | | | | |

Differences between 1966 and 1968 occurred on either side of 20 inches TL. Buffalo < 20.2 inches were in better condition in 1966 than those in 1968. In 1966 C values for fish above and below 20.2 inches were 54 and 61 and in 1968, these values were 60 and 54.

Buffalo < 18.8 inches were in better condition in 1966 than fish of the same size in 1969. Condition factors for fish of these sizes were 61 and 58 in 1966 and 1969, respectively. For buffalo > 18.8 inches condition factors were 54 and 60 in 1966 and 1969.

The difference between length-weight regression in 1967 and 1968 was apparent at an inflection of 15.7 inches. Condition factors in 1967 for the two size classes were 53 and 59 for smaller and larger sizes, respectively. Comparable values in 1968 were 55 and 56.

## BODY-SCALE RELATIONSHIP

Body-scale relationship was determined from 348 samples collected in 1967. TL of the sample ranged from 5.8-24.5 inches. Scale measurements and body lengths were grouped by paired observations. Scales were magnified (17X) and measured from the focus to the scale edge along the first primary radius between the lateral and posterior fields. The relationship appeared to be linear and the model

$$L = a + bS$$

was used to describe the realtionship where L denoted TL in inches and S was the scale radius in inches (X17).

The regression was best described by the equation $L = 1.24 + 2.81S$. Correlation coefficient for this regression was .995. The equation was used to construct a nomograph for calculation of TL at each annulus.

## ESTIMATED TL AT EACH ANNULUS

Predicted TL at each annulus was combined by year class regardless of the year collection was made and grand average TL was computed (Table 6). TL at the end of the first 10-yrs of life were estimated at 7.2, 11.7, 15.0, 17.4, 19.3, 20.8, 22.3, 23.8, 24.9 and 27.7 inches. Growth during the first year of life varied from 5.4-8.6 inches. Growth was greatest in the first year of life and diminished at a systematic rate as age increased.

Examination of the increments of growth indicated in certain years growth was greater than others for all ages regardless of year the collection was made. A growth index for calendar years 1959-1967 was computed by measuring the percentile deviation of growth in one year from the grand average increment. The resulting values were subtracted from 100 and adjusted so their sum was zero. The 0 value indicated average growth while plus and minus values denoted above and below average growth.

Growth indices were 0, 11, 17, 13, 0, -15, -8, 20 and -56 for the calendar years 1959-1967. Buffalo growth was extremely poor in 1967 while best growth occurred the previous year. The poor growth in 1967 was mostly attributed to the extreme abundance of the 1966 year class.

Table 6. Estimated total body length of the end of each year of life for bigmouth buffalo

| Year class | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Growth index |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Year of life | | | | | | | | | | |
| 1967 | 5.4 | 8.6 | | | | | | | | | -56 |
| 1966 | 5.7 | 8.8 | 11.1 | | | | | | | | 20 |
| 1965 | 5.8 | 11.0 | 13.4 | 15.3 | | | | | | | - 8 |
| 1964 | 6.4 | 10.8 | 14.4 | 16.5 | 19.4 | | | | | | -15 |
| 1963 | 8.6 | 13.2 | 15.9 | 17.8 | 17.9 | 20.1 | | | | | 0 |
| 1962 | 8.6 | 13.3 | 16.7 | 17.8 | 19.6 | 20.3 | 21.7 | | | | 13 |
| 1961 | 8.2 | 13.3 | 16.1 | 17.6 | 19.0 | 20.7 | 21.2 | 22.7 | | | 17 |
| 1960 | 8.4 | 13.5 | 16.1 | 17.7 | 19.0 | 20.6 | 22.6 | 22.5 | 23.9 | | 11 |
| 1959 | 7.5 | 12.6 | 16.6 | 19.3 | 21.1 | 22.2 | 23.4 | 26.1 | 25.9 | 27.7 | 0 |
| $\overline{X}$ TL | 7.2 | 11.7 | 15.0 | 17.4 | 19.3 | 20.8 | 22.3 | 23.8 | 24.9 | 27.7 | |
| $\overline{X}$ inc. | 7.2 | 4.5 | 3.0 | 1.8 | 1.7 | 1.4 | 1.3 | 1.4 | .7 | 1.8 | |

GROWTH IN LENGTH AND WEIGHT

One requirement for computation of yield and production estimates is a mathematical description of growth. A convenient method of mathematical representation for growth is a Walford line (Walford, 1946) computed by the equation

$$\ell_{t+1} = \ell_\infty(1 - k) + k\ell_t$$

where k was a function of the rate of change in length between $\ell_{t+1}$ and $\ell_t$. The variable $\ell_t$ was length of a fish at annulus t while $\ell_{t+1}$ was length of fish after 1 year of growth. The constant $\ell_\infty$ denoted the maximum attainable length of fish from the population.

Emperical determination of k for bigmouth buffalo by regression was .79 and $\ell_\infty$ was 29.4 inches. The coefficient of determination ($R^2$) was .98 (Figure 1, segment A). Further evaluation and validation of the Walford line was achieved by plotting $\log_e(\ell_\infty - \ell_t)$ against age (Figure 1, segment B). The relationship was linear indicating $\ell_\infty$ was a valid estimate. Asyptotic lengths by both estimates agreed closely with actual lengths of buffalo caught in fishing gear. Largest buffalo taken was 28.4 inches which was 1-inch shorter than the computed maximum length.

Growth in weight was derived as the product of length for each age and mean weight computed from length-weight relationship. By using the 1969 length-weight relationship, growth in weight for ages 2-10 was .90, 1.92, 3.02, 4.15, 5.12, 6.35, 7.74, 8.94 and 12.31 lbs.

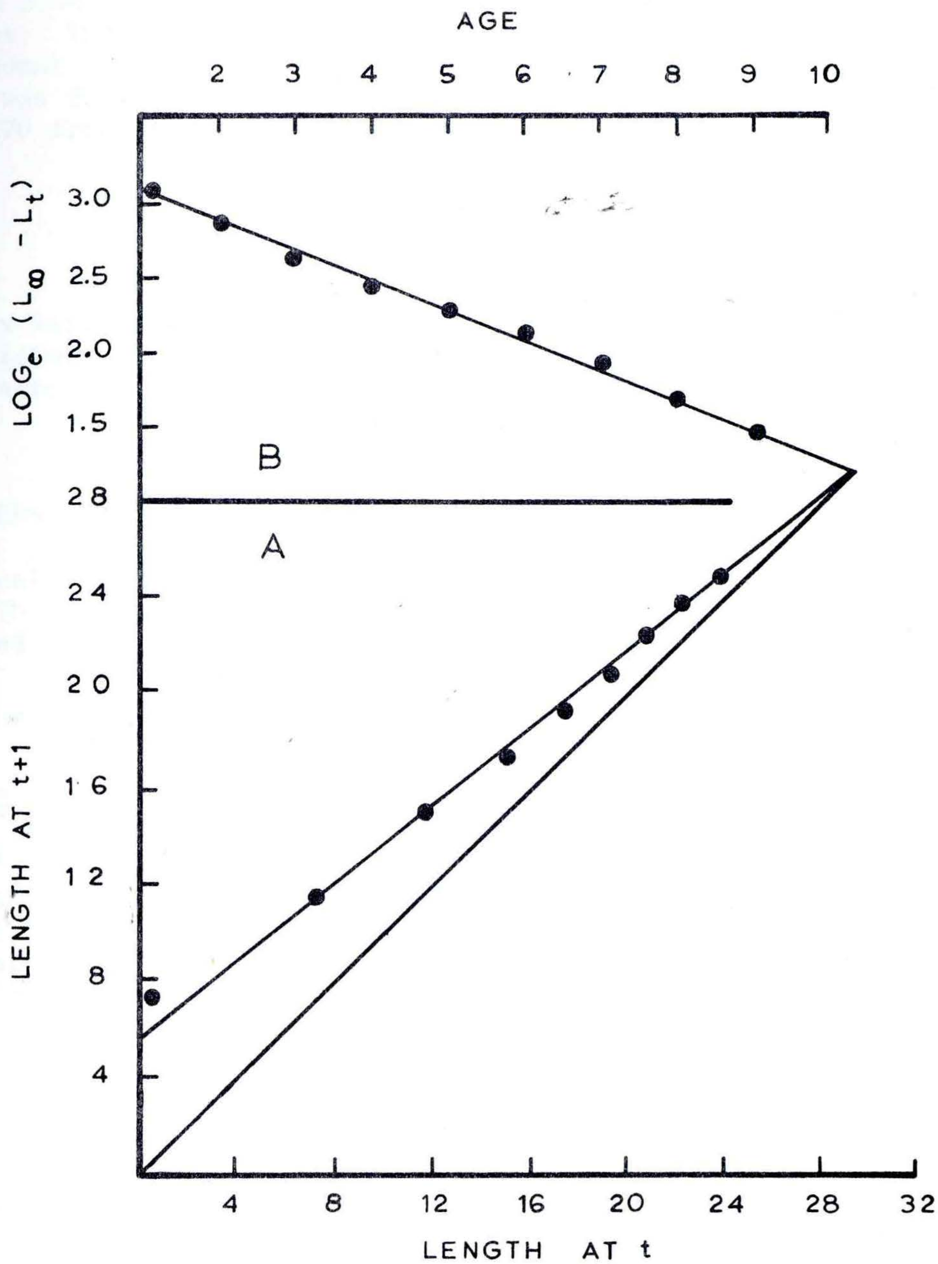


Figure 1. Walford growth transformation of estimated TL at age t + 1 and t for bigmouth buffalo.

There was a change in mean weight of bigmouth buffalo during the investigation. In 1966, mean weight was 3.46 lbs followed by a decline to 1.87 lbs in 1967 and 1.04 lbs in 1968. There was an increase in 1969 and 1970 to 1.25 and 1.90 lbs. The systematic decline and recovery in mean weight was a result of the abundant 1966 year class becoming vulnerable to gear during 1967. The year class was fully recruited by 1968 and mean weight of buffalo increased in 1969 and 1970 from growth.

## POPULATION DYNAMICS

Factors influencing population change are not totally evident by measuring only life history statistics. Population density, movement, age structure, mortality rates and biomass are also essential to determine impact of exploitation.

### POPULATION DENSITY

Numerical estimates of bigmouth buffalo populations were conducted in 1966 and 1969. The estimate was based on the Schnabel method of multiple sampling and estimated by

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

where

$\hat{N}$ = estimated number in the population
$M_t$ = total number of marked fish available at sampling interval t
$C_t$ = total sample collected in interval t
$R_t$ = total number of marked fish in $C_t$.

These estimates yielded both cumulative and independent values at each sampling interval. Confidence intervals for the 95% level were determined from the equation

$$\hat{s} = \frac{R}{(\Sigma C_t M_t)^2}$$

where $\hat{s}$ is the standard error of $1/\hat{N}$.

Buffalo were marked over the entire conservation pool in 1966. During the project segment 440 buffalo were captured, 366 marked and 2 were recaptured. The estimated population density was 80,520 ± 3,360,000 bigmouth buffalo or 16 per surface acre. Confidence intervals were extremely great because of the small number of recaptures and the estimate was considered unreliable.

Method of estimation was changed in 1969 because of the difficulty to mark enough fish in one season and yet expect an adequate recapture sample for reliable population estimates. A sub-sampling area was used to avoid this ineffectiveness, but this method allowed movement of marked fish out of the study area causing over-estimation error of the population. An evaluation of movement was made to account for emmigration, and population estimate computations were adjusted accordingly. Details of the study area and methods of movement evaluation are given by Mitzner (1971).

Fish marked for movement studies were also used as a sub-population from which recaptures were sampled to determine population estimates. Fish were marked and captured continuously and estimates were made for each period in addition to cumulative estimates. Sampling was initiated on 8 April and terminated on 12 August. Frame nets were used exclusively for sampling and records were kept on number caught, marked and recaptured.

Marked fish were recaptured during all netting intervals. In all, 52 fish were recaptured during the season. Greatest recapture rate occurred in Period 7 when 1.5% were marked (Table 7). Individual estimates varied from 69,643 to 1,887,578 in Periods 2 and 6. Cumulative estimates were less variable and ranged from 69,643 in Period 2 to 566,957 in Period 6. Final cumulative estimate was 435,182 or 366 buffalo per surface acre with 95% confidence limits of 281-526 per surface acre. An adequate approximation of the final estimate was reached by Period 5 with some variation in the sixth period, but values were stable until termination of the estimate.

Table 7. Independent and cumulative estimates of bigmouth buffalo in 1969

| Period | N Captured | $N'$ Marked* | N Recaptured | Independent $\hat{N}$ | Cumulative $\hat{N}$ |
|---|---|---|---|---|---|
| 1 | 626 | 0 | 0 | 0 | 0 |
| 2 | 1,511 | 507 | 11 | 69,643 | 69,643 |
| 3 | 750 | 1,722 | 0 | ------ | 187,050 |
| 4 | 736 | 2,330 | 2 | 857,400 | 290,180 |
| 5 | 715 | 2,924 | 2 | 1,045,300 | 390,874 |
| 6 | 1,078 | 3,502 | 2 | 1,887,578 | 566,957 |
| 7 | 2,038 | 4,374 | 30 | 297,100 | 394,730 |
| 8 | 150 | 6,000 | 1 | 900,000 | 405,260 |
| 9 | 397 | 6,121 | 4 | 607,509 | 420,818 |
| 10 | 116 | 6,439 | 0 | ------ | 435,182 |

*Adjusted for marked fish leaving study area.

## MORTALITY RATES

Mortality rates were determined from the age structure of the buffalo population. Standard aging techniques were used from random samples collected from frame net catches since 1966. Approximately 50 individuals were sampled bi-weekly. Mortality rates were computed for fish age II and older because younger fish were not captured with the sampling gear. Some of the estimates might be questionable because of large variation in year class strength (Table 8).

Table 8. Age structure of bigmouth buffalo population expressed as per cent frequency

| Age | 1966 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|
| II | 3.4 | 12.2 | 85.6 | 3.9 | 3.5 |
| III | 4.9 | 3.0 | 2.1 | 83.6 | .1 |
| IV | 15.7 | 19.6 | 2.5 | 2.1 | 84.0 |
| V | 28.9 | 14.3 | 2.6 | 1.2 | 7.0 |
| VI | 22.5 | 6.7 | 3.2 | 3.7 | 1.0 |
| VII | 4.9 | 3.0 | 2.9 | 3.6 | 1.3 |
| VIII | 1.5 | .9 | .8 | 1.8 | 1.3 |
| IX | .3 | .2 | .2 | .6 | .6 |
| X | .3 | 0 | 0 | .2 | 1.3 |
| XI | 0 | 0 | 0 | .2 | 0 |

Regardless of possible unreliable estimates the analysis was completed for individual years and compared by analysis of variance to test the validity of the estimates.

Age structure was transformed and fitted to the linear model

$$\log_e(10)Y = a + bX$$

where Y is per cent of occurrence in the sample and X is the corresponding age class. Coefficient b was an estimate of instantaneous (i) mortality rate. Annual (a) mortality rate was determined from the function

$$a = 1 - e^{-i}.$$

Regressions for individual years were

$$1966: \log_e(10)\hat{Y} = 6.051 - .409X$$
$$1967: \log_e(10)\hat{Y} = 6.314 - .490X$$
$$1968: \log_e(10)\hat{Y} = 6.286 - .555X$$
$$1969: \log_e(10)\hat{Y} = 5.853 - .452X$$
$$1970: \log_e(10)\hat{Y} = 3.783 - .143X.$$

Correlation coefficients were > .66 except in 1970 when it was .21. Analysis of variance of the b values for individual years showed common slope and instantaneous mortality rate. Yearly regressions were pooled and yielded the regression equation

$$\log_e(10)Y = 5.616 - .400X$$

with correlation coefficient of .63.

The standard deviation from regression was used to establish 95% confidence limits for i. For the pooled regression they were ±.15. Annual mortality rate was .33 ± .14 (Figure 2).

## ESTIMATED BIOMASS

Harvestable biomass of bigmouth buffalo was defined as the difference between growth and recruitment which would increase standing crop and total mortality which would reduce biomass. These factors were measured for five consecutive years and used to estimate mean standing crop. A single biomass estimate would not adequately describe a population on an instantaneous basis because of seasonal and yearly fluctuation of the parameters inherent in the model. The purpose of the following estimates was not to determine instantaneous values but reconstruct mean biomass estimates characteristic of the steady state population. This makes the estimates more applicable to a long term fishery. Errors inherent for these computations were minimized by establishing 95% confidence intervals around the estimates.

Biomass estimates were determined by systematically reducing the estimated population density by mean annual mortality rate starting at age II. Total weight for each age group was computed from the product of density and mean weight. Total biomass was the sum of age groups II-X.

Numerical means for ages II-X was 124, 83, 56, 37, 25, 17, 11, 8 and 5 fish per surface acre with corresponding weights of .89, 1.91, 3.00, 4.12, 5.15, 6.41, 7.81, 8.92 and 12.40 lbs. Product of mean weight and estimated density was 110, 159, 168, 152, 129, 109, 86, 71 and 62 lbs per surface acre (Figure 3). Total standing crop of fish age II and older was 1,046 lbs per surface acre. The minimum estimated biomass based on a population density of 280 buffalo per acre was 118, 134, 111, 81, 54, 35, 23, 13 and 10 lbs per surface acre for ages II-X. Total standing crop was 579 lbs per acre (Figure 3).

It is likely these were valid estimates particularly when compared with the reported estimated biomass from other areas. Carlander (1955) summarized standing crop of buffalofish from 17 mid-western reservoirs from Texas to Illinois, and 20 rough-fish lakes in Minnesota. Reservoirs had mean standing crop of 161 lbs per surface acre and ranged from .5-1,016. Minnesota lakes had a mean of 167 lbs per surface acre and ranged to 1,144.

Determination of the critical size within the buffalo population was essential to establish size restriction or mesh limitations. Critical size was defined as the point where biomass of a year class starts to decrease and occurs when total mortality surpasses growth in weight. Fish should be harvested slightly prior to this mode for greatest efficiency. Once critical size has been determined the type of gear and maximum intensity of the fishery can be adjusted to maximize harvest. Mean standing crop estimates of buffalo indicated critical size was approximately 17 inches or 2.8 lbs. Critical size based on minimum standing crop was 14.5 inches or 1.7 lbs.

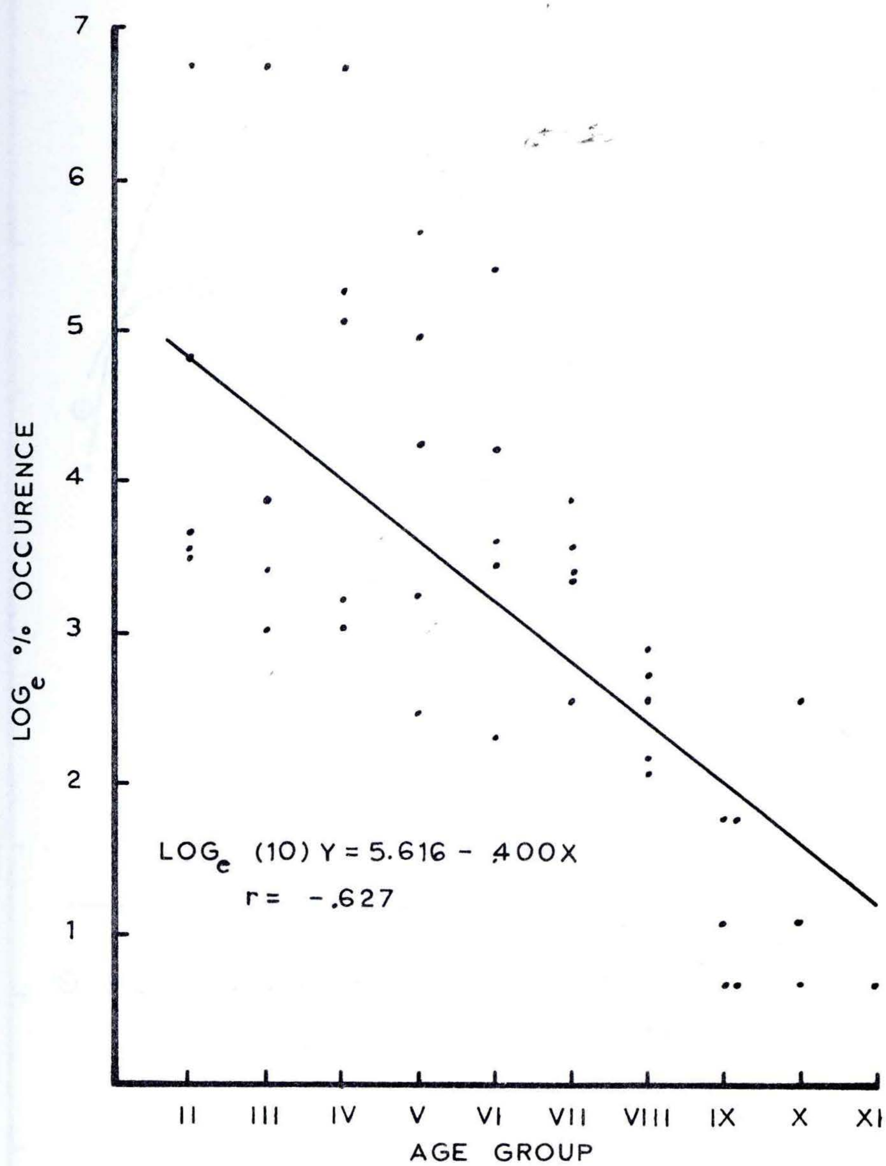


Figure 2. Pooled regression of instantaneous mortality rates (i) for bigmouth buffalo.

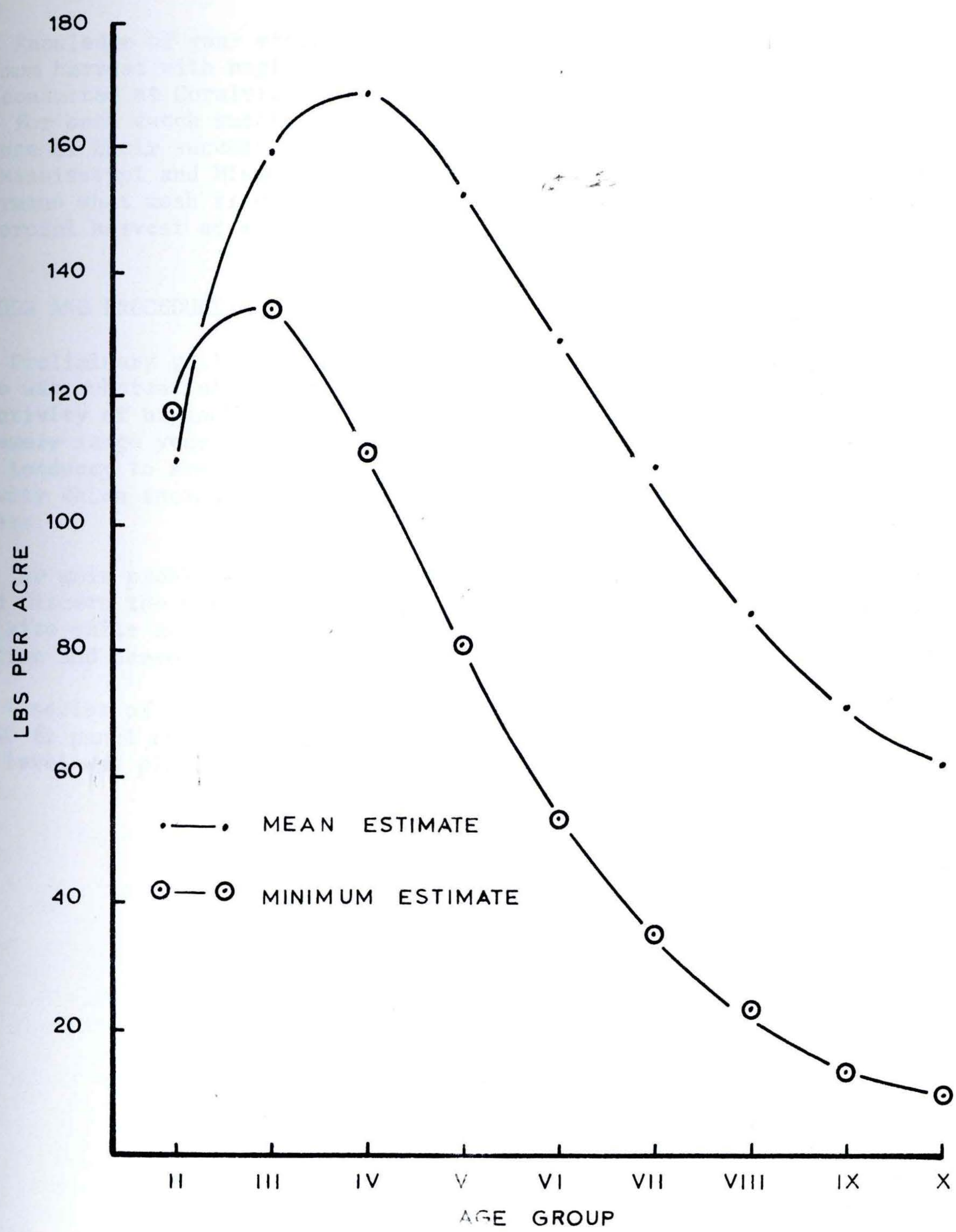


Figure 3. Minimum and mean estimated biomass of bigmouth buffalo.

## SELECTIVITY OF EXPERIMENTAL GILL NETS

Knowledge of gear efficiency and selectivity was essential to control maximum harvest with negligible affect upon sport fish populations. A study was conducted at Coralville Reservoir in 1970 to evaluate selectivity of gill nets for both catch success and body size of fish. Gill nets were chosen because of their success in established commercial fisheries, particularly at the Mississippi and Missouri Rivers. The objective of this segment was to determine what mesh size and quantity of gear would be necessary to regulate commercial harvest at a sustained level without jeopardizing the sport fishery.

### METHODS AND PROCEDURES

Preliminary gill netting during the third and fourth study segments showed there was substantial seasonal and locality variation in catch success and size selectivity of bigmouth buffalo. The population was not only dominated by an extremely large year class, which influenced size distribution, but buffalo showed some tendency to school particularly during periods of spawning activity. Any activity which increased movement of fish proportionately accelerated catch success.

The main problem of the experiment was to develop a sampling design which would discern the unique effects of different mesh size on catch success and body size while accounting for variations due to extrinsic factors. Of these, location and season were paramount.

A series of four experimental gill nets were constructed, each containing one 50-ft panel of 4-, 5-, 6- and 7-inch stretch mesh. Position of each treatment level was placed according to the following Latin-square design

| | | POSITION | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| NET | 1 | A | B | C | D |
| | 2 | B | C | D | A |
| | 3 | C | D | A | B |
| | 4 | D | A | B | C |

where A, B, C and D denoted mesh sizes 4-, 5-, 6- and 7-inch. Position of the mesh size was defined by its lateral distance from shore with Position 1 the closest. Individual nets were numbered 1 through 4 depending upon the array of mesh sizes. As an example, the inshore end of Net 1 contained 4-inch mesh and increased by 1-inch intervals as net position increased toward mid-water. Randomization of position and net number was impossible because it would require complete reconstruction of nets upon conclusion of the series. Web material was No. 208 multi-strand nylon twine hung to sink with braided leadcore and poly-float lines.

Each net was fished at two different locations due to unequal horizontal distribution of fish. The sites were located about 200 yds apart, 8 miles up-stream from the damsite. Each site was sampled daily over a four-day period without particular selection of net sequence.

Seasonal variation in catch success and body size were measured by replicating each series at weekly intervals during May, June, July and August. In all, 8 netting experiments were completed during the season.

Sets were made at a minimum depth of 11 ft between 3-4 PM and lifted the following morning between 8-11 AM. Each period was defined as one net-day. Captured fish were counted and measured separately at each site and position.

The overall experiment consisted of 8 discrete experiments at 2 netting sites. Since the experimental design was a factorial classification, analysis of variance procedure in a completely randomized model was used with the level of significance set at the .05 level. Deviations mean squares due to experimental units were cross classified at all levels of sites x replications. Variations due to position and net number were nested within the experimental units. Treatments sums of squares were sub-divided into a response curve by orthogonal contrasts. All counts were transformed by $\sqrt{x + 1/2}$ to stabilize variance due to non-normality in distribution of residuals and eliminate zero counts. Examination of the emperical cumulative distribution of residuals by probability plotting indicated this transformation was satisfactory.

## CATCH SUCCESS OF GILL NETS

Total catch of fish in gill nets was 2,267 fish, of which 999 was bigmouth buffalo (Plate 3). Carp was second most numerous with 859; followed in importance by 343 carpsucker, 32 crappie, 18 channel catfish, 11 bullhead, 3 walleye and 2 northern pike. One of the most important results of these experiments showed when mesh sizes of 4-inch stretch measure of larger were used < 3% of the catch was game-fish species. Catch of game-fish was < .5% in 6- and 7-inch mesh.

Analysis of variance (Table 9) showed highly significant differences ($P < .01$) in catch success between mesh sizes. The 5-inch and 7-inch mesh was most effective with 4.6 and 4.0 FND compared to 3.7 FND with 4-inch mesh and 3.3 FND with 6-inch mesh (Figure 4). Extension of the analysis of treatment sum of squares by orthogonal contrasts indicated the response of catch success to increased mesh size was not linear, but could be best described by cubic regression. This fact further supported the observed instability of year class strength with the predominant 1966 year class causing significant inflections in the catch curve. The high catch rate in 7-inch mesh was rather unexpected because these fish were not sampled by frame nets. This segment of large-sized buffalo were far more abundant than previously estimated.

Plate 3. Bigmouth buffalo was most effectively taken with gill nets.

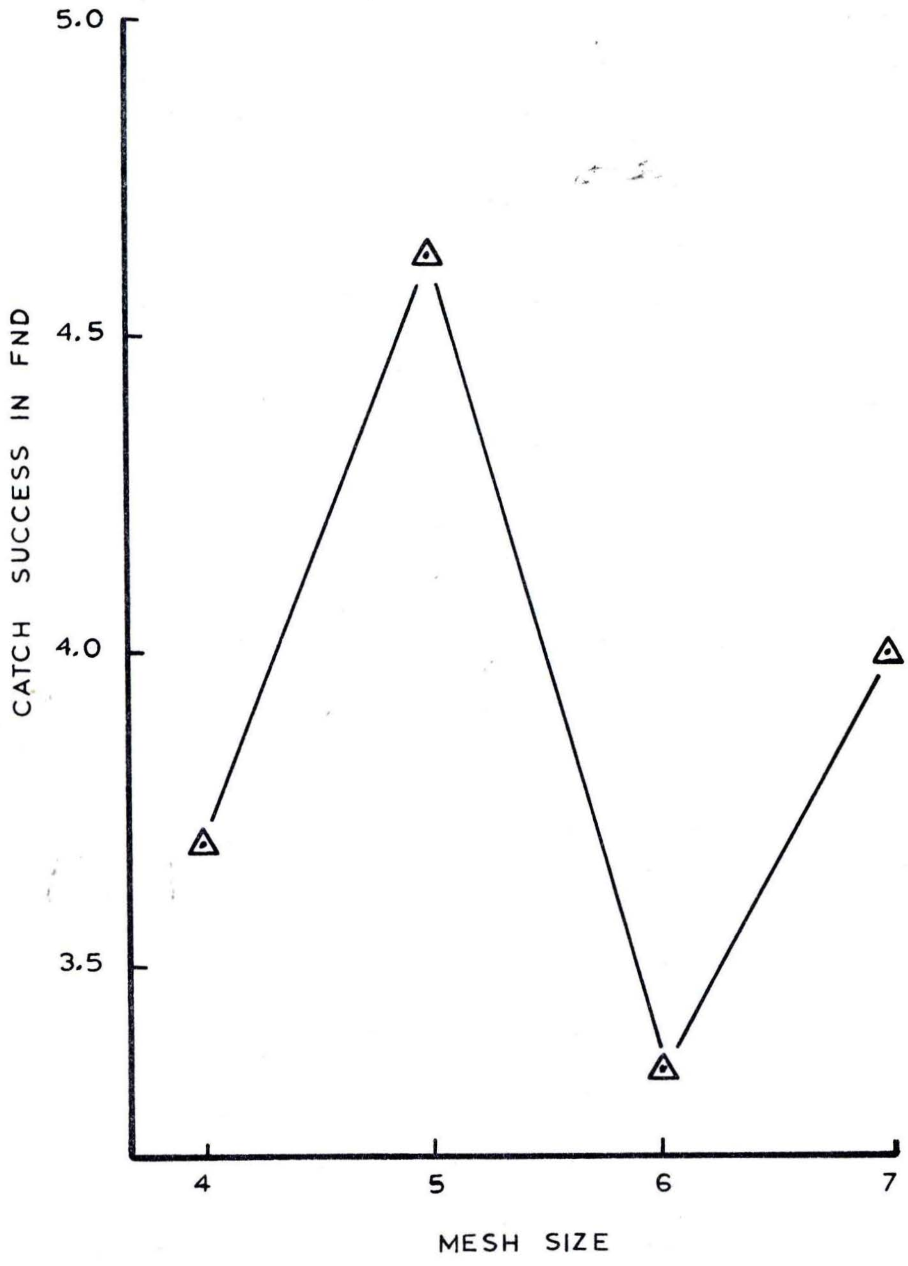


Figure 4. Catch success of bigmouth buffalo in experimental gill nets containing different mesh sizes.

Table 9. Analysis of variance in mean catch success of bigmouth buffalo in experimental gill nets

| Source of variation | df | SS | MS | F |
|---|---|---|---|---|
| Experiments | (15) | 59.59 | | |
| Sites | 1 | .85 | .85 | 2.36 |
| Periods | 7 | 55.88 | 7.98 | 22.16** |
| Sites x Periods | 7 | 2.86 | .41 | 1.13 |
| Nets within experiments | 48 | 67.22 | 1.40 | 3.88** |
| Positions within experiments | 48 | 21.85 | .45 | 1.25* |
| Treatments | (3) | 4.39 | 1.46 | 4.05** |
| Linear | 1 | .02 | .02 | .05 |
| Quadratic | 1 | .06 | .06 | .16 |
| Cubic | 1 | 4.31 | 4.31 | 11.97** |
| Residuals | 141 | 52.13 | 0.36 | |
| Total | 255 | 205.18 | | |

*Significant at .05 level.

**Significant at .01 level.

Mean catch success of buffalo was 3.6 FND at Site 1 and 4.1 FND at Site 2, slightly below the 95% level of significance. First order interaction between sites and netting periods was also non-significant.

Seasonal catch success of buffalo in the gill nets showed bi-modal distribution (Figure 5). Mean catch success in the first weekly period was 6.09 FND and decreased to 2.13 in Period 2. During the next two periods catch reached maximum values of 6.91 FND and 6.50 FND followed by a systematic decline to the lowest value of 1.38 FND in the last biweekly interval. The difference in these values was highly significant ($P < .01$).

Variations in catch rate attributable to the position each mesh treatment occupied in the net, which represented the distance each treatment was located from the shoreline was significant ($P < .05$). Mean catch success values showed an increasing systematic trend from inshore toward midwater. Lowest catch success value was recorded at Position 1 with 3.74 FND, which increased to 3.86 FND at Positions 2 and 3 and reached a maximum value of 4.16 FND at Position 4.

There was highly significant differences ($P < .01$) in catch success between net numbers resulting from non-randomization of net x position in the two-way table.

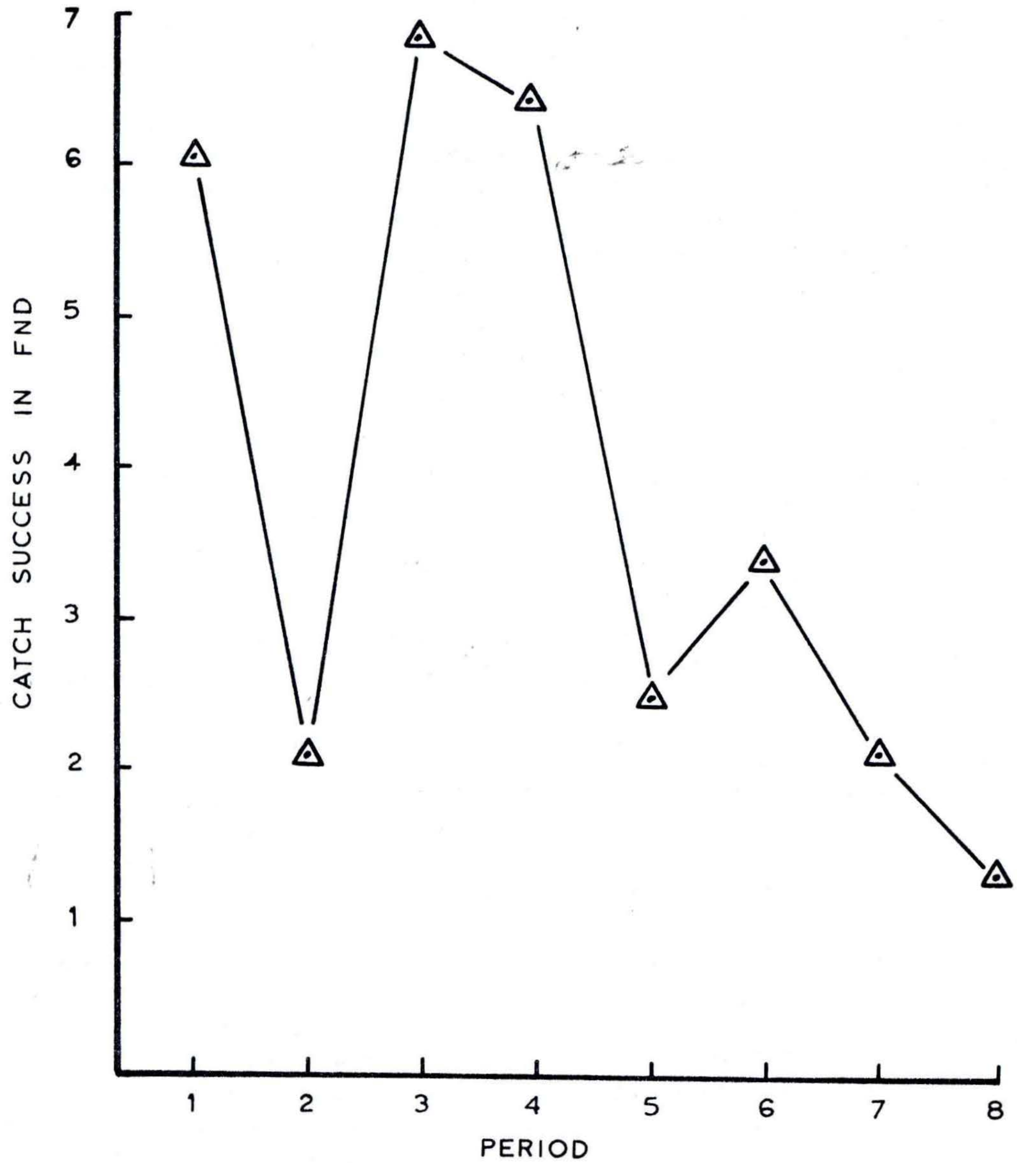


Figure 5. Catch success of bigmouth buffalo in experimental gill nets by week-period.

## SIZE SELECTIVITY OF GILL NETS

Body size selectivity of mesh treatments showed disproportionate abundance due to the 1966 year class. This segment of the population was vulnerable in both 4- and 5-inch mesh, but capture in the latter weighted the sample with smaller individuals. Mean lengths at 4-inch and 5-inch treatment levels were 16.6 and 16.5 inches, respectively. Mean lengths increased in 6-inch and 7-inch mesh to 21.3 and 22.5 inches (Figure 6). Standard deviations ranged from ±1.59 inches in 7-inch mesh to ±3.17 inches in 4-inch mesh. Distribution of body size was homogeneous in relation to treatment position, and although more fish were found in the off-shore area the size distribution was identical to in-shore area because all meshes had identical means regardless of position.

## POTENTIAL EQUILIBRIUM YIELD

One of the important objectives of this investigation was to determine the rate populations of commercial food fish could be exploited without interferring with sport fisheries. Foregoing sections of this report adequately defined the magnitude of the buffalo population. Satisfactory exploitation rate was to be established by experimental exploitation, but two major problems precluded completion of this phase of the project. Fish could not be exploited to levels where changes in population statistics were expected and it was impossible to establish sustained differences during the project. Even mortality of 125 lbs per surface acre from winter kill showed no differences in catch success, growth, condition, mean weight or population density. If major differences occurred they were not measured because of the nearly instantaneous, resilient nature of the populations. Sustained trends in established commercial fisheries are usually present after many years of intensive exploitation. Long-lived commercial species may require up to 10 years before populations reach equilibrium, even though there are drastic changes immediately following initial exploitation. Baranov (Ricker, 1958:217) described the theory of initial and sustained yield and Thompson (1934) documented changes occurring in an actual fishery.

Equilibrium yield models developed by fisheries biologists since 1910 were designed to predict sustained annual harvest. These models contain variables of recruitment, growth, natural mortality, fishing mortality and stock density. These parameters were measured during the investigation at Coralville Reservoir and were applied to existing models.

The method used by Beverton and Holt (1957) is one of the most comprehensive, and was used in the abbreviated expression (10.18 of Ricker) for estimates of potential equilibrium yields of buffalo at Coralville Reservoir.

Statistics required for the yield equation were

$T_0$ = 0 years = age at 0 length

$T_Q$ = 2.5 years = age when fish become acceptable as food or have market value

$T_R$ = 3-7 years depending on mesh size = age of recruitment

$Q$ = 100 per surface acre = number of individuals that reach age $T_Q$

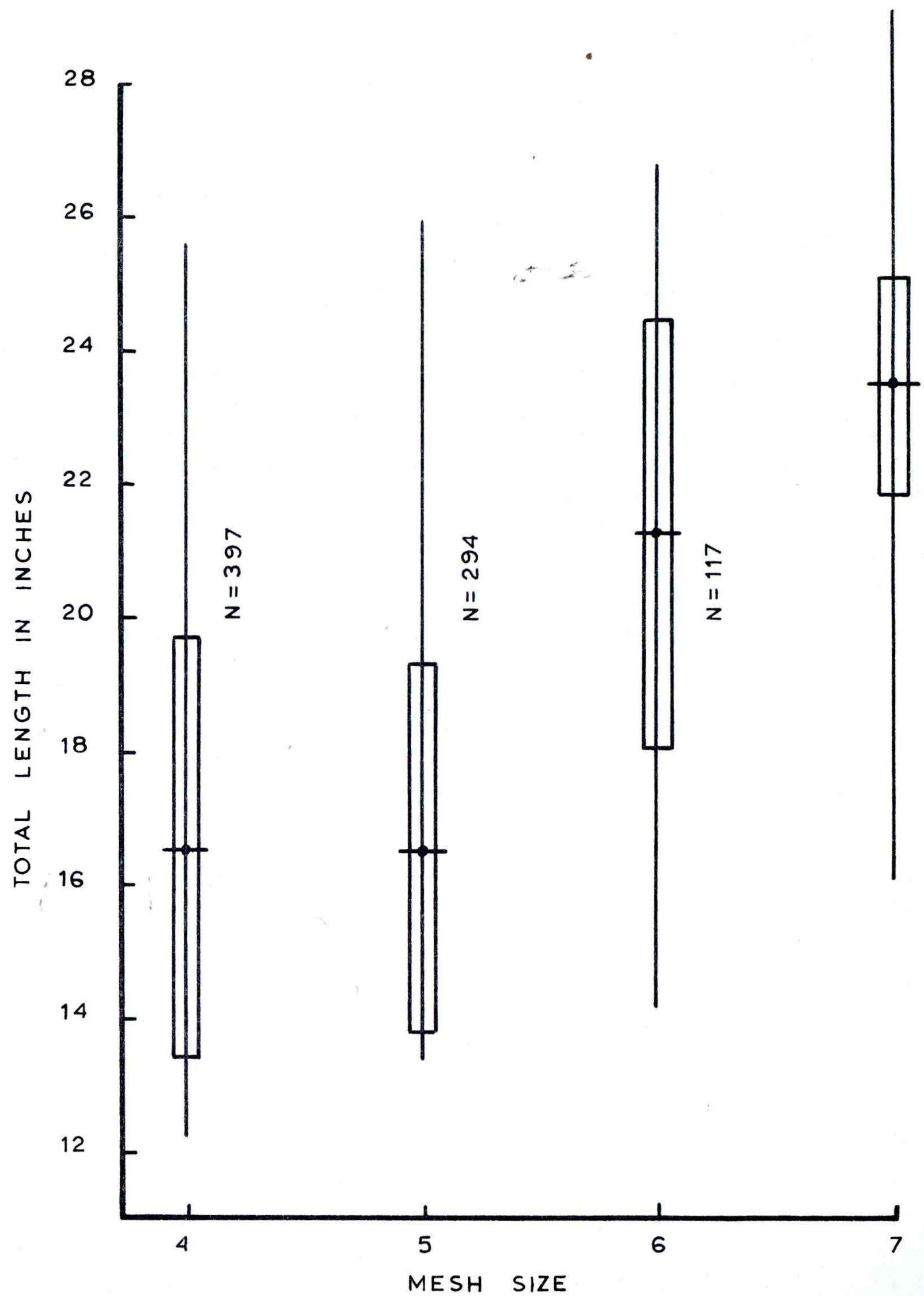


Figure 6. Size distribution of bigmouth buffalo in experimental gill nets. Horizontal lines are means, vertical lines are ranges and bars are one standard deviation.

$R$ = 84-20 per surface acre depending on mesh size = yearly number of recruits which enter the fishery at age $T_R$
$p$ = .10-1.60 = instantaneous fishing rate
$q$ = .36-.07 = instantaneous natural mortality rate
$i$ = .46-1.67 = instantaneous total mortality rate
$\ell_\infty$ = 29.4 inches = maximum attanable size of stock as determined by the Walford equation
$W_\infty$ = 2.78-10.20 lbs = mean weight of stock when its length was $\ell_\infty$ or when fish are no longer vulnerable to gear
$K$ = .24 = $-\log_e k$ where k is slope of the Walford line
$Y$ = yield in lbs.

The realtionship between fishing and natural mortality was not documented, but total annual mortality (a) was determined at .33 when fishing mortality (m) was 0. When mortality due to exploitation was imposed at different levels the per cent of fish taken in the fishery which otherwise would be included as natural mortality, would be a x m. This value was subtracted from total mortality at m = 0 to produce equilibrium natural mortality ($\hat{n}$), or $\hat{n} = a - am$. For $p = .20$, $m = .18$ and $a = .33$ then $\hat{n} = .33 - (.33)(.18) = .27$ or instantaneous natural mortality (q) would be .31. From the equation $i = p + q$, instantaneous total mortality was .51. These relationships provided instantaneous total and natural mortality with varied fishing intensity (Table 10).

Table 10. Relationship of total instantaneous mortality (i) to instantaneous fishing mortality (p) and natural mortality (q)

| p | m | q | i | $\hat{n}$ |
|---|---|---|---|---|
| .1 | .10 | .36 | .46 | .30 |
| .2 | .18 | .31 | .51 | .27 |
| .3 | .26 | .28 | .58 | .24 |
| .4 | .33 | .25 | .65 | .22 |
| .5 | .39 | .22 | .72 | .20 |
| .6 | .45 | .20 | .80 | .18 |
| .8 | .55 | .16 | .96 | .15 |
| 1.0 | .63 | .13 | 1.13 | .12 |
| 1.2 | .70 | .11 | 1.31 | .10 |
| 1.4 | .75 | .09 | 1.49 | .08 |
| 1.6 | .80 | .07 | 1.67 | .07 |

Stock loss from $T_Q$ to $T_R$ by natural mortality was determined from the equation

$$R = Qe^{-q(T_R - T_Q)}$$

and (R) varied with mesh size and age at recruitment. Mean recruitment rate for the individual mesh treatments were 84, 58, 35 and 20 buffalo per acre from an estimated density of 100 per acre at $T_Q$.

Estimated yield was computed independently for each mesh size. Mean ages at recruitment ($T_R$), for these meshes were 3, 4, 5.4 and 7 years and had asymptotic weights ($W_\infty$) of 2.78, 4.57, 7.23 and 10.20 lbs (Table 11).

Table 11. Variable statistics of bigmouth buffalo for selected mesh size

| Mesh size | $T_R$ Age of recruitment | R Rate of recruitment | $W_\infty$ Maximum attainable wgt |
|---|---|---|---|
| 4 | 3.0 | 84 | 2.78 |
| 5 | 4.0 | 58 | 4.57 |
| 6 | 5.4 | 35 | 7.23 |
| 7 | 7.0 | 20 | 10.20 |

The model for equilibrium yield computations was expressed by

$$Y = pRW_\infty \left( \frac{1}{i} - \frac{3e^{-K(T_R-T_0)}}{i + K} + \frac{3e^{-2K(T_R-T_0)}}{i + 2K} - \frac{e^{-3K(T_R-T_0)}}{i + 3K} \right)$$

using the previously defined notations. Compuation of yield using 4-inch mesh varied from 17 lbs per surface acre with p at .1 to 46 lbs per surface acre with p at 1.0. Yield decreased slightly to 42 lbs per acre when instantaneous fishing rate was increased to 1.6 (Table 12).

Table 12. Estimated equilibrium yield in lbs per surface acre for 4-, 5-, 6- and 7-inch mesh with varied exploitation rates (p)

| | Mesh size in inches | | | |
|---|---|---|---|---|
| p | 4 | 5 | 6 | 7 |
| .1 | 17 | 25 | 30 | 30 |
| .2 | 29 | 43 | 54 | 52 |
| .3 | 38 | 54 | 69 | 68 |
| .4 | 41 | 62 | 80 | 81 |
| .5 | 43 | 67 | 88 | 88 |
| .6 | 45 | 70 | 92 | 94 |
| .8 | 45 | 73 | 99 | 102 |
| 1.0 | 46 | 74 | 102 | 107 |
| 1.2 | 45 | 73 | 104 | 109 |
| 1.4 | 44 | 73 | 105 | 111 |
| 1.6 | 42 | 72 | 104 | 111 |

Yield increased when values for 5-inch mesh were used in the computation with p at .1, yield was 25 lbs per surface acre while p at 1.6 provided a yield of 72 lbs per surface acre. Maximum yield was achieved at 74 lbs per surface acre with p at 1.0.

Six-inch mesh was more productive than 4- or 5-inch mesh and maximum yield was 105 lbs per surface acre with p at 1.4. Range was 30-104 lbs per surface acre at minimum and maximum levels of fishing.

Yield estimates decreased for 7-inch mesh at the .1-.3 levels of fishing when compared with 6-inch mesh, but were greater than 4- or 5-inch mesh. Loss of yield at lower fishing intensity was due to natural mortality without compensatory gain in biomass of stock by growth. Maximum yield was 111 lbs per surface acre and occurred at fishing rate of approximately 1.5.

Yield computations were plotted with instantaneous fishing rate as the independent variable and mesh size the dependent variable. The relationship (Figure 7) showed isopleth contours in lbs per surface acre based on an entry of 100 bigmouth buffalo. Combinations of mesh size and fishing intensity to achieve desired exploitation level, are obtained from this relationship. Line AA represents a response surface for maximum harvest with the most productive mesh size. For instance, if 90 lbs per surface acre sustained harvest was desired the most efficient combination would be an instantaneous fishing rate of .5 with about 6 1/2-inch mesh.

## DISCUSSION OF RESULTS

Bigmouth buffalo is the most important commercial species of food fish at Coralville Reservoir because of its large biomass and market demand. For this reason commercial fishing regulations should be derived for harvest of surplus stocks of bigmouth buffalo. Carp and carpsucker populations comprised approximately 230 and 40 lbs per acre, but market demand and price are substantially less than for buffalo. Carp and carpsucker will provide small commercial value, and will be of secondary importance compared to bigmouth buffalo.

Changes in populations can be expected at Coralville when a commercial fishery is established and bigmouth buffalo will be affected more than any species. An equilibrium fishery will not be established until nearly 5 years after origination because a single year class requires this time to move through the fishery. Initial exploitation will provide greater yields than equilibrium estimates, but the reduced population will produce a stable fishery. Stock density can also be expected to decline until equilibrium is achieved.

Change in stock density may indirectly effect sport-fish populations. The initial yield of bigmouth buffalo should be high so forage species such as *Notropis* and gizzard shad may expand into the biological void and provide sport-fish populations with a larger forage base. If commercial fishermen were restricted so they could not operate profitably the initial high harvest may not be great enough to create an adequate void for forage species.

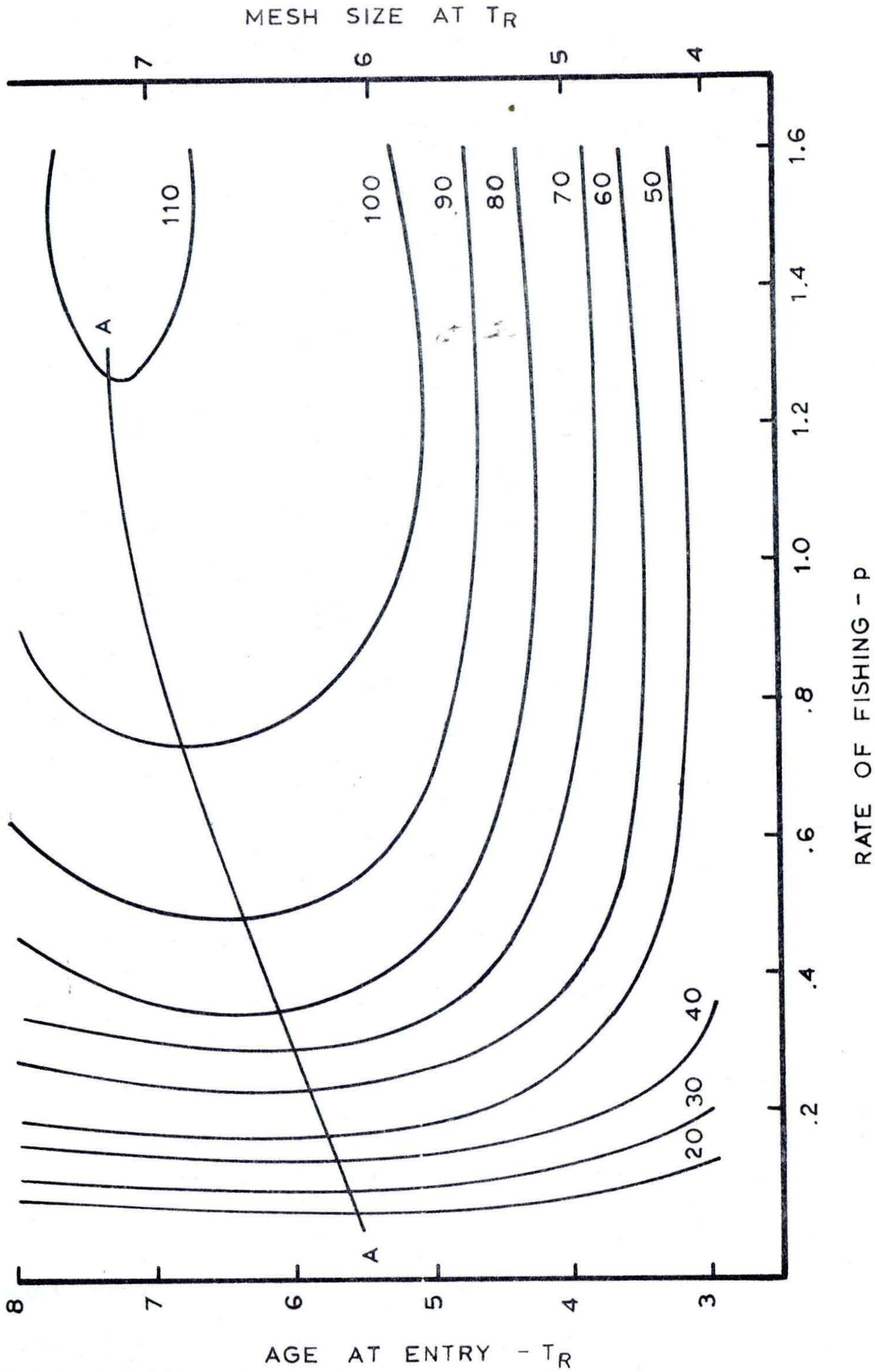


Figure 7. Yield isopleth contours of bigmouth buffalo expressed as lbs per acre and based on 100 per acre when $T_Q$ is 2.5 years.

Regardless of benefits to sport fishing the buffalo, carp and carpsucker populations are a wasted, renewable resource and could be more efficiently utilized. At sustained yields of 100 lbs per surface acre and average market prices of 20¢, bigmouth buffalo would provide a gross value of $100,000 per year to the fishery. The fishery might be valued several times greater during initial exploitation. Carp and carpsucker would also increase the value of the fishery.

There is little need to regulate the fishery for maximum sustained yield if benefit to the sport fishery is the sole objective. Over-exploitation of commercial populations would be required to enhance the sport fishery, but this probably would not occur, even with unrestricted harvest of food fish. As stocks diminished, yield would decline to a level where profitable exploitation would cease, causing the fishery to become self-regulatory at a level below maximum sustained yield. Unnecessary restrictions on commercial fishermen would tend to reduce total annual yield and contradict management of the sport fishery.

There is some inherent danger to sport fish by accidental death in commercial gear. This situation can be minimized by proper selection of mesh size and lessen the incidence of illegally kept sport fish.

An important aspect of the commercial fishing potential at Coralville Reservoir is excessive Dieldrin concentrations in fish flesh. Routine monitoring of pesticide concentration in water indicated chlorinated hydrocarbons were carried into rivers by soil erosion and high concentrations were associated with intensive row crop farming. This prompted a study to determine pesticide levels in edible portions of fish from major drainages. Bigmouth buffalo at Coralville Reservoir contained Dieldrin concentration of 900 PPB, three times greater than Food and Drug Administration guidelines. Buffalo > 20 inches had concentrations ranging up to 1,200 PPB. Carp and carpsucker were below FDA guidelines. The guidelines pertain to interstate marketing of edible food fish. Iowa has the same standards for Dieldrin content in fish flesh.

Fish kills caused by low DO have occurred in 1965, 1969 and 1972. Run-off in January-March causing high BOD and subsequent decline in DO will continue and periodic fish loss can be expected in the future. The buffalo population is resilient and survival of eggs and larval fish should be excellent following the decline in populations. After the winter kill in 1965 there was high survival of the 1966 year class. The fishery might decline briefly after a winter kill but shall recover as new year classes are recruited. When equilibrium is established some variation in catch can be expected because of erratic year class strength.

The results of this investigation are of value to help appraise commercial fish populations in other waters. Although the study was specifically designed to evaluate commercial species at Coralville, statistics such as growth and mortality rates should be similar to buffalo from other waters. Stock density and recruitment rate of buffalo at other waters might be entirely different and some indication of abundance should be available before applying the results of this investigation. Caution should be used especially when making comparisons with other waters having greatly different physical and chemical characteristics.

# RECOMMENDATIONS

Results of this investigation have proved a commercial fishery is biologically feasible at Coralville Reservoir. Based on predicted yield estimates and average market prices the fishery is also economically feasible. The value of the fishery was estimated at $100,000 yearly depending on interest by commercial fishermen and exploitation. The fishery may also provide population control for rough fish thereby enhancing the sport fishery. Regardless of the justification for a commercial fishery there will be more efficient use of a wasted resource.

The following recommendations should be considered to implement the results of this investigation.

1. A commercial fishery should be developed at Coralville Reservoir.

2. Regulations should be flexible during the first years of the fishery. Commercial fishermen should not be discouraged from fishing during the initial phase of exploitation by cumbersome regulations. If the sport fishery can be enhanced the maximum harvest should occur during the first 5-years of the fishery. Catch statistics would also tend to be more reliable and easier to evaluate from a fishery with brief and concise regulations.

3. The fishery should be evaluated yearly. If more restrictive or liberal regulations are required they can be more effectively implemented.

4. Geographic limits should be from the dam to Johnson County Road "O". The area below the dam should be from the boat ramp on the northeast side of the tailwaters, downstream to abandoned US Highway 218.

5. Commercial fishing season should be from 1 October through 30 April. A conflict of commercial fishing and water-related recreation should be avoided at least until the fishery becomes established.

6. The initial fishery should be restricted to trammel and gill net with a minimum size mesh of 6-inch stretch measure.

7. Each piece of gear should have an identification tag attached listing the operator's name and address.

8. Permits for gear should be consistent with those required at the Mississippi and Missouri Rivers.

9. Only fish from the families *Catostomidae* or *Cyprinidae* may be kept.

10. Constant attendance of gear should be required in the tailwaters area. Gear in Coralville conservation pool should be attended daily.

11. Records should be kept monthly by the permit holder and returned no later than 10 days after the month has ended. If he fails to return monthly records his permit should be revoked. Statistics should be obtained independently for both tailwaters and pool with aggregate weight of each species for each type of gear. Permit holders should be encouraged by field personnel to return accurate records.

12. Warning on Dieldrin content of bigmouth buffalo and its implications should be specified on each permit.

13. Warning on adjacent waterfowl refuge violation should also be written on the permits.

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## LITERATURE CITED

Aitken, W. W.
1940. A preliminary report of the fishes of the upper Des Moines River basin in Iowa. Ia. Acad. Sci., Vol. 47, p. 387-392.

Beverton, R. J. H. and S. J. Holt
1957. On the dynamics of exploited fish populations. U. K. Min. Agr. and Fish., Fish. Invest., Ser. 2, 19, 533 pp.

Carlander, K. D.
1955. The standing crop of fish in lakes. J. Fish. Res. Bd. Canada, Vol. 12, No. 4, p. 543-570.

Cleary, R. E.
1953. An annotated check-list of the fishes of the Iowa-Cedar drainage basin in Iowa. Ia. Acad. Sci., Vol. 60, p. 626-635.

________
1954. Summary of trap net surveys on northeastern Iowa streams, 1949 to 1954. Quart. Biol. Rpts., Ia. Cons. Comm., Vol. 6, No. 3, p. 36-39.

Harrison, H. M.
1949. An annotated list of the fishes of the upper Des Moines River basin in Iowa. Ia. Acad. Sci., Vol. 56, p. 333-342.

______ 1956. An experimental treatment of a segment of the Des Moines River in Iowa to increase desirable fish by suppressing undesirable forms. Quart. Biol. Rpts., Ia. Cons. Comm., Vol. 8, No. 3, p. 11-15.

______ 1962. Creel census of Des Moines River fishermen in Boone, Dallas, and Polk Counties, Iowa. Ia. Acad. Sci., Vol. 69, p. 277-285.

______ and E. B. Speaker
1954. An annotated list of the fishes in the streams tributary to the Missouri River in Iowa. Ia. Acad. Sci., Vol. 61, p. 511-523.

Helms, D. R.
1964. Coralville Reservoir and Lake MacBride creel census - 1964. Quart. Biol. Rpts., Ia. Cons. Comm., Vol. 16, No. 3, p. 13-20.

______ 1964. 1964 annual survey of the Coralville Reservoir fish population. Quart. Biol. Repts., Ia. Cons. Comm., Vol. 16, No. 4, p. 32-38.

Mayhew, J.
1963. Coralville Reservoir and Lake MacBride fisheries investigations, 1963, Part 1: creel census. Quart. Biol. Rpts., Ia. Cons. Comm., Vol. 15, No. 4, p. 28-32.

______ 1964. Coralville Reservoir fisheries investigations, 1963, Part 2: liminology and fish populations. Quart. Biol. Rpts., Ia. Cons. Comm., Vol. 16, No. 1, p. 25-31.

______ and L. R. Mitzner
1967. Report on the first year study of commercial fish species in the Des Moines River and Coralville Reservoir. Biol. Section, Commercial Fish. Rpt., Project 4-11-R-1, Ia. Cons. Comm., Des Moines. 60 p.

______ and ______
1968. Report on the second year study of commercial fish species in the Des Moines River and Coralville Reservoir. Biol. Section, Commercial Fish. Rpt., Project 4-11-R-2, Ia. Cons. Comm. 76 pp.

______ and ______
1969. Report on the third year study of the Des Moines River and Coralville Reservoir. Biol. Section, Commercial Fish. Rpt., Project 4-11-R-3, Ia. Cons. Comm. 87 p.

__________ and __________
1970. Report on the fourth year study of Red Rock (Des Moines River) and Coralville Reservoirs. Biol. Section, Commercial Fish. Rpt., Project 4-11-R-4, Ia. Cons. Comm. 73 p.

__________, __________ and G. L. Wunder
1971. Large flood control reservoir studies. Fisheries Section, Commercial Fish. Rpt., Project 4-11-R-5, Ia. Cons. Comm. 99 p.

McDonald, D. B.
1971. Coralville Reservoir water quality study. Coll. of Eng., Univ. of Ia., Rpt. No. 71-1, 50 p.

Meek, S. E.
1892. Report upon the fishes of Iowa, based upon observations and collections made during 1889, 1890 and 1891. Bull. U. S. Fish. Comm., 10(1890), p. 217-248.

Mitzner, L. R.
1969. Accidental mortality of crappie in pound nets fished for rough fish species. Proc. Ia. Acad. Sci., Vol. 76, pp. 211-216.

__________
1971. Movement of bigmouth buffalo in Coralville Reservoir, Iowa. Proc. Ia. Acad. Sci., Vol. 78, pp. 34-35.

Rounsefell, G. A. and W. H. Everhart
1953. Fishery science; Its methods and applications. John Wiley and Sons, Inc., New York. 444 p.

Ricker, W. E.
1958. Handbook of computation for biological statistics of fish populations. Fish. Res. Bd., Canada, Bull. 19. 200 p.

Thompson, W. F. and F. H. Bell
1934. Biological statistics of the Pacific halibut fishery. (2) Effects of changes in intensity upon total yield and yield per unit of gear. Rpt. Int. Fish Comm., No. 8, 49 pp.

Walford, L. A.
1946. A new graphic method of describing the growth of animals. Biol. Bull., Vol. 90, No. 2, p. 141-147.