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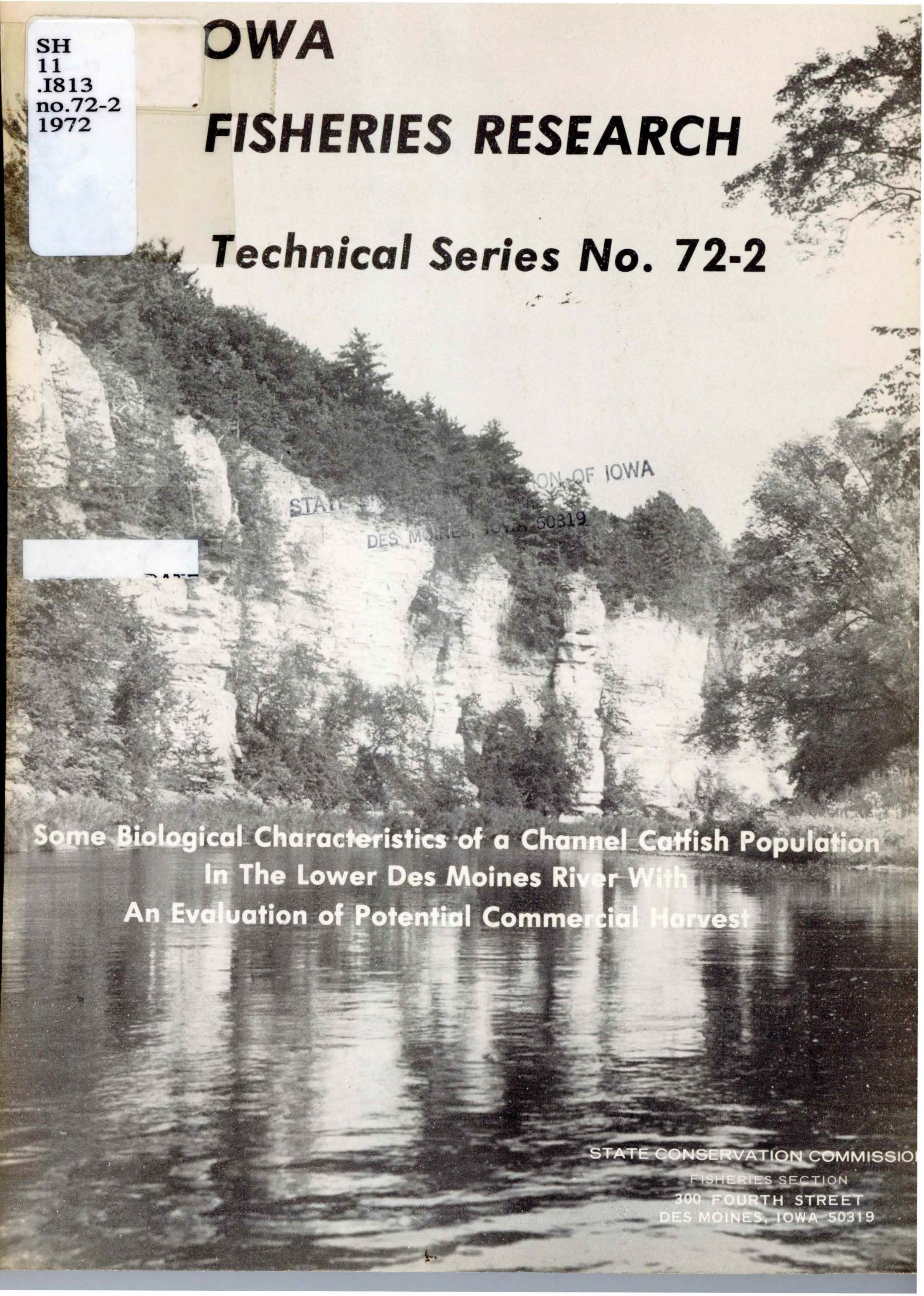

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Some Biological Characteristics of a Channel Catfish Population In The Lower Des Moines River With An Evaluation of Potential Commercial Harvest

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SOME BIOLOGICAL CHARACTERISTICS OF A CHANNEL CATFISH POPULATION IN THE LOWER DES MOINES RIVER WITH AN EVALUATION OF POTENTIAL COMMERCIAL HARVEST[1].

By

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ABSTRACT

Studies were conducted on the biological characteristics of the channel catfish population in a 20-mile stretch of the lower Des Moines River. The population was experimentally exploited by a net fishery for evaluation of the commercial fishing potential during the three years from 1966-69. Baited hoop nets and slat traps were fished for 4,615 net days and single-wing fyke nets were fished for 542 net days. During the study 43,272 channel catfish with a combined weight of 17,845 lbs were captured. An additional 12,268 fish of other species weighing 11,712 lbs were also caught. Numerical composition of catfish in the catch ranged from 53.9% to 88%. Population density was estimated at 101,774 fish in 1966 and 107,240 in 1969. Net exploitation removed about 20% of the numerical population in 1967. Late in project year 1967-68 a winter kill reduced the population density by about 55%. Total instantaneous mortality was estimated at .64 and total annual mortality was .42. The sport fishery accounted for about .10 of the annual mortality. Growth of channel catfish was slow and the fish were in rather poor body condition. Nearly 3.8 years of growth was required for fish to reach 10-inches TL. Length-frequency, growth and body condition showed no preceptable reaction to exploitation, but the winter kill caused quite large shifts in length-frequency distribution. The length-weight relationsip was nearly equal in all years. Mean annual standing crop of catfish was estimated at 3,508 fish per mile with a combined biomass of 2,769 lbs. The effects of exploitation rate and several environmental factors on catch success are examined by multiple regression analysis. Spawning activity was the most important factor influencing catch success. Equilibrium yield models using the Beverton and Holt procedure indicated potential harvest of catfish ranged from 296 to 998 lbs per mile with W_∞ at 6.12 lbs and 474 to 1,597 lbs per mile at 9.79 lbs when the minimum size limit was 10-inches TL. At a 13-inche TL size limit maximum yield was estimated at 885 lbs per mile. Recommendations for a fishery which would extend the sport fishery harvest in the lower Des Moines River are presented. Necessary controls for the fishery are included in the recommendations.

INTRODUCTION

Channel catfish (Ictalurus punctatus) is the most important species of fish in the interior streams of Iowa. Popularity of this fish among sport fishermen has been well documented in research studies by the State Conservation Commission and Fisheries Research Unit, Iowa State University. Surveys by Harrison in the late 1950's and early 1960's (State Conservation Commission, Quarterly Biology Reports, Volume IX through XV) revealed from 60% to 90% of the fishermen contacted in the upper Des Moines River basin were seeking channel catfish. Although there was rather wide seasonal and geographical variation in species preference by anglers during the nearly eight years of census, the amount of time spent fishing for catfish usually ranked first and never lower than second. Similar surveys in other major stream drainages of Iowa, such as the Cedar, Iowa, Skunk, Raccoon and Little Sioux Rivers showed nearly equal results. Sport fishermen in navigation pools 9 and 18 of the Mississippi River indicated somewhat lower preference for channel catfish, but they were still quite popular, particularly in the set-line fishery (UMRCC Annual Report, 1967).

Schmulbach (1958) estimated total fishing pressure was about 85,000 hours per year in a 7-mile stretch of the upper Des Moines River from the Fraser Dam to the Boone Waterworks. There was no breakdown given for individual species of fish, but applying values from Harrison's surveys it was estimated fishing pressure for channel catfish was about 7,500-10,000 hours per mile annually. Fishing access along the river in the Fraser-Boone area was somewhat greater than usual which may account for the high public use, but even if these were considered maximum values the recreational benefits offered anglers by this species were of substantial importance.

Channel catfish are not only the most sought after game-fish species in Iowa streams, but as expected from their popularity they also make up a large portion of the pole-and-line harvest. The censuses by Harrison showed species composition of fishermen catches averaged 54% channel catfish and ranged from 35% to 81%. Schmulbach (1958) reported channel catfish comprised 30% to 48% of the anglers catch.

Catch success of channel catfish seemed to vary greatly depending upon numerous physical characteristics of the habitat and time of the year. Schmulbach (1958) stated river stage and flow were the most important factors with highest catch rates reported in late June and early July. Catch success in Harrison's censuses ranged from .13 to .33 with a mean of .25 channel catfish per hour. Fishermen specializing in channel catfish commonly had a much higher catch rate of up to 1.5 catfish per hour.

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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.

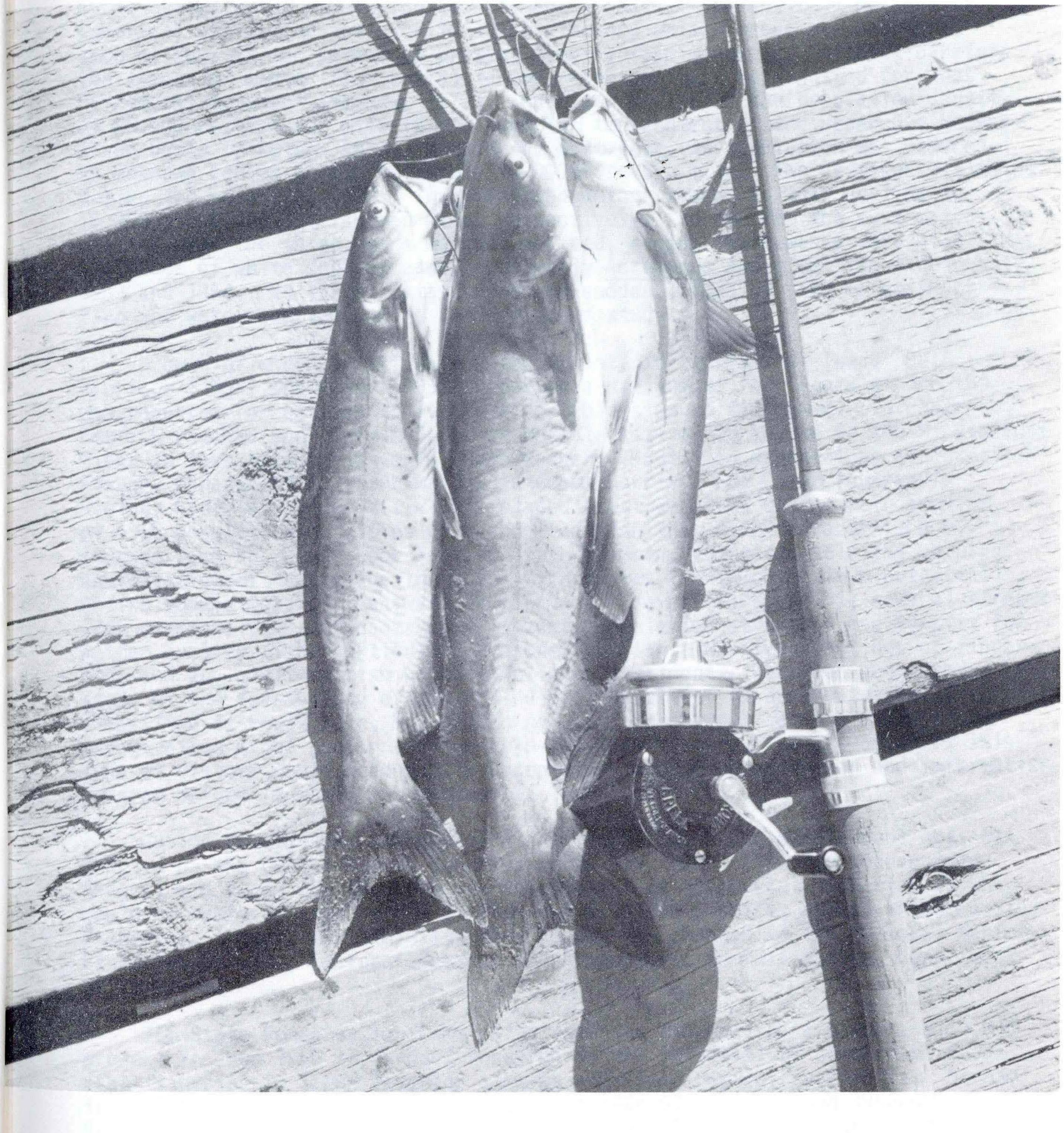

Plate 1. Channel catfish are the most important species of fish in Iowa streams.

One of the most neglected areas of catfish research in streams seemed to be in estimates of population density and biomass. Conventional methods of numerical estimation are usually unsatisfactory unless there are barriers, such as dams in the stream to prevent lengthy fish movement. Without barriers the number of marked fish available for recapture must be adjusted for loss by natural movement (Mayhew, 1971). Harrison estimated the population density at 20,000 catfish per mile in the Humboldt impoundment of the upper Des Moines River basin in autumn 1953. Within the next year the population was reduced by unknown causes to approximately 11,000 fish per mile. Two Peterson estimates during the next year (1955) in spring and autumn showed further decline to 10,000 and 6,400 catfish per mile, respectively. Source for the systematic decline over the three years was not defined, except there was a very high incidence of white spot disease, presumably Aeromonus among catfish throughout 1953 and 1954. No large, catastrophic or sudden losses of fish by death or flooding were observed during the period of study.

Growth of channel catfish is slow in interior streams of Iowa. Both Harrison (1957) and Muncy (1958) reported a minimum of four years of growth was required for catfish to attain acceptable size to fishermen. In contrast, catfish reached the minimum legal marketable size of 13 inches in the Mississippi River in less than three years (Schoumacher, 1963). In discussions of sport fishery management in interior Iowa streams Harrison and Clear (Quarterly Biology Reports, Volume VIII-XIII) placed great emphasis on the main problem of high population densities of channel catfish that were characterized by stunted fish in rather poor body condition. Both biologists held the opinion exploitation of catfish by the sport fishery was far below maximum potential. Entire populations of fish were eradicated or severely reduced in several streams with chemical fish toxicants to manipulate population structure and density for better quality fish, particularly channel catfish. Massive plantings of fingerling and sub-adult catfish usually followed treatment. Harrison suggested a study of the feasability of controlled net harvest of fishes statutorally classified as rough fish, but he did not include channel catfish because over exploitation might jeopardize the pole-and-line fishery. Legalization of this type of fishery would need public acceptance through an education and information program before it would be successful.

Public Law 88-309, Commercial Fisheries Research and Development Act, was enacted by the United States Congress on 20 May, 1964. The act appropriated federal aid funds for research and development of commercial fisheries which would be administrated by the US Fish and Wildlife Service, Bureau of Commercial Fisheries. Later, the administrative agency was changed to the National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Department of Commerce.

The State Conservation Commission received approval of a 6-year, $160,000 project in June 1966 to conduct research on the potential of commercial food-fish fisheries in large interior streams and flood control reservoirs. Stream investigations would include project years 1966-67, 1967-68 and 1968-69. Primary objectives of the study were four-fold. The first was to determine if populations of valuable food fish existed in these waters in sufficient quantity to support some sort of commercial exploitation or at least a net fishery which extended the sport fishery. Second, if results of the first objective were affirmative, what potential would these populations offer for commercial harvest. Third, what effects a net fishery might exert upon established sport fisheries. Last, to develop methods of orderly exploitation with necessary controls for a net fishery so the sport fishery would not be jeopordized. Since all types of commercial fisheries are statutorally prohibited in interior waters, enactment of necessary legislation for both fishing and marketing would also be necessary.

Although the fishery would be substantially smaller than those existing in the Mississippi and Missouri Rivers bordering Iowa, a cursory review of these fisheries might indicate their economic importance. Harvest of channel catfish from the Mississippi River has ranged between 300,000 and 600,000 lbs each year for the past decade. Monetary value of this catch ranged between $100,000 and $200,000. Total poundage of buffalofish and carp is higher than catfish, but the latter has greater cash value because of market price. Commercial channel catfish catch from the Missouri River ranged between 4,900 and 10,400 lbs from 1958 through 1963 (Quarterly Biology Reports by Robinson and Welker, Volume X through XV). This fishery has steadily declined in importance because of widespread channelization and water level stabilization.

The first step of this investigation was to measure the biological impact of experimental exploitation with entrapment gear on a channel catfish population. Because of its proximity to Red Rock Reservoir, a 20-mile stretch of the lower Des Moines River near Knoxville, was chosen. Pre-impoundment studies had been conducted in this region during two preceding summers, and portions of these results were applicable to catfish investigations.

Preliminary data were collected for various biological parameters of the channel catfish population by intensive netting. Parameters included species composition of the catch, estimates of numerical population abundance, age structure, length-weight relationship, and rates of growth and mortality. Since fish movement would preclude accurate population estimates unless marked: unmarked ratios were adjusted, much of the project segment was used for marking catfish and measuring intra-stream distribution and movement.

Experimental exploitation was initiated in project year 1967-68. Size or daily catch restrictions were not placed on the fishery, but the maximum harvest limit was 20% of the preceding population estimate. Concurrent measurements of biological parameters were continued to determine if the net fishery caused any changes in those previously established. The fishery would also provide information on overall and seasonal catch success rate with different types of entrapment gear.

Between the second and third project segments (1968-69) a large fish kill occurred throughout the entire study area from low DO concentrations. The Des Moines Sewage Treatment Plant was given permission to by-pass all municipal and industrial waste water for six weeks because of plant reconstruction and enlargement. Release of untreated waste water began in February followed by the fish kill soon after. Fish populations were so drastically reduced by this incidence further scheduled experimental exploitation was postponed until the impact of the fish kill could be evaluated. A chronological documentation of the fish kill can be reviewed in the Commercial Fisheries Investigation Report No. 3 (Mayhew and Mitzner, 1969). Third year research concentrated on repeating numerical population estimates, evaluating changes in species composition, age structure, size distribution, rates of growth and mortality following the fish kill.

Toward the end of the third year Red Rock Reservoir was impounded. Abnormal flooding raised the water level in the lake 38 ft above conservation pool level completely inundating the study area. About one-half of the original area was located in the middle and upper portion of the reservoir, while the remainder formed a large segment of the reservoir headwaters. Further channel catfish investigations in the stream ceased except for those relating to reservoir headwaters.

This report is a summarization of some of the biological characteristics of the channel catfish population within the boundaries of the study area and the effects of controlled experimental exploitation. The period of study covered three seasons from April 1966 through June 1969. Models for theoretical equilibrium yield for this population of catfish by a net fishery are also presented.

DESCRIPTION OF THE STUDY AREA

The Des Moines River study area was located in Marion County from Bennington's Bridge near Swan (R22W, T77N, Sec 9) to County Road P near Pella (R18W, T76N, Sec 30), a length of nearly 20 river miles (Figure 1). Throughout this geographical region the river valley is quite broad ranging up to a maximum of about two miles and lies in an almost straight Northwest-Southeasterly direction. The stream course winds in a series of sharp bends from bluff to bluff producing alternating deep cut banks and large exposed sand bars (Plate 2). Habitat diversity varied from large, deep, sluggish pools to faster flowing riffles over exposed sandstone outcroppings and sand deposits. Width of the stream ranged from 75 to 250 ft. Maximum pool depth within the study area at average flow was about 16 ft. Side channels contained numerous drifts of fallen trees and agricultural debris.

Near the upper portion of the study area there was considerable strip mining for coal within the past two decades. At two locations scouring by flood waters exposed two shallow coal deposits in the flood plain. Large outcroppings of soft sandstone form sheer cliffs along two stretches of the stream. Small grain croplands bordered the river along the entire length of the study area. Little timberland was present in the flood plain because a majority had been cleared for cropland.

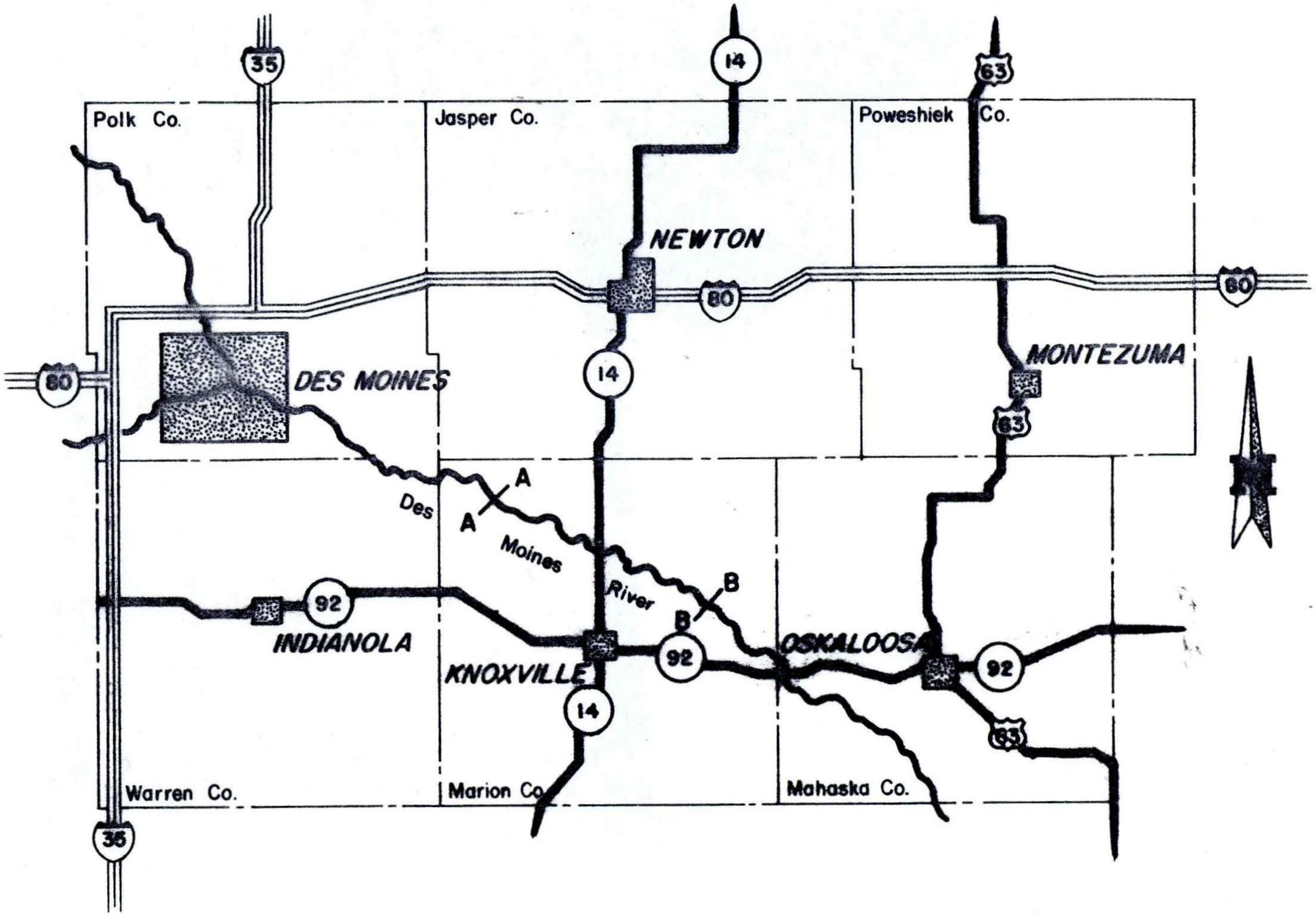

Figure 1. Map of the study area in the lower Des Moines River basin. A designated approximate location of upper boundary and B designated lower boundary.

Plate 2. Des Moines River near the center of the study area showing sandstone bluff, high cut bank and sandbar development.

Metropolitan Des Moines is located only a short distance upstream from the upper boundary of the study area, and the effluent from its waste water treatment plant had profound enriching influence on water quality and chemical composition. Table 1 lists ranges in 15 water quality parameters from 26 biweekly samples from January through December 1969 at a sampling station near the center of the study area. Capacity of the waste water treatment plant was enlarged in 1967-68 and water quality immediately improved, although there were periods when untreated wastes were bypassed. Maximum values listed in the table were somewhat higher during much of the catfish investigations since sampling commenced after construction of the dam.

Table 1. Annual ranges for 15 water quality parameters based on biweekly collections from the Des Moines River study area in 1969

Parameter	Range for sampling period
DO	3.4 - 14.2 ppm
BOD (5 day)	2 - 10 ppm
COD	18.2 - 45.5 ppm
PO_4	.2 - 2.4 ppm
Total PO_4	.2 - 2.5 ppm
Organic N	.76 - 8.4 ppm
NH_3	< .01 - 1.6 ppm
NO_2	.01 - 6.2 ppm
NO_3	.02 - .31 ppm
pH	7.2 - 8.25
Turbidity	24 - 1,200 JTU
Total alkalinity	108 - 346
Total solids	420 - 835
Hardness	9.3 - 26.9 g/gal
Coliform bacteria	< 10 - 12,000 N/100 ml

GEAR UTILIZATION, SPECIES COMPOSITION AND CATCH STATISTICS

The experimental fishery in the Des Moines River relied wholly upon hoop nets, slat traps and single-wing fyke nets for population sampling and exploitation (Plate 3). Hoop nets were constructed with 24-inch circular metal frames using 1½ and 2-inch-mesh (stretch) nylon web. Overall length of the nets was 10-12 ft depending on mesh size. Slat traps were constructed with thin oak slats over a 1 x 1 inch oak frame with about 3/8 inch spacings between slats. Outside dimensions of the trap were 1 x 1 x 6 ft. A throated opening of tapered slats was placed in one end of the trap and other end was closed. Fish were emptied through a small door in the top of the trap. Both hoop nets and slat

Plate 3. Hoop nets were the principal gear used in the catfish investigations.

traps were fished in deep pool habitat and baited with cheese clippings and soybean cake. Gravid females were also used as attractors during the spawning season. Single-wing fyke nets were constructed with 3 ft circular steel hoops using 3-inch stretch measure nylon web. A single 30 ft lead with cork floats was attached to the hooped section of the net. Fish entering the heart of the net were trapped by a single crowfoot throat on the second hoop. Fyke nets were set vertical to the shoreline in shallow water immediately downstream from sandbars in slow flowing waters.

Hoop nets and slat traps were fished continuously from 6 June through 28 September for 1,410 net days in 1966, from 10 May through 3 November for 1,101 net days in 1967 and from 18 May through 4 November for 2,104 net days in 1968. Fyke nets were used for 139 net days in 1967 and 403 net days in 1968. Catch statistics were recorded for daily net raises, but for this report all statistics were compiled at biweekly intervals.

During the 3-year study period 43,272 channel catfish with a combined weight of 17,845 lbs and 12,268 fish of other species weighing 11,712 lbs were captured (Table 2). Other species included carp (*Cyprinus carpio*), river carpsuckers (*Carpoides carpio* and *cyprinus*), flathead catfish (*Ictalurus olivaris*), bullheads (*Ictalurus melas* and *natalis*), crappie (*Promoxis annularis* and *nigro-maculatus*), bluegill (*Lepomis machrochirus*), green sunfish (*Lepomis cyannelus*), largemouth bass (*Micropterus salmoides*), walleye (*Stizostedion vitreum*), eel (*Anguilla rostrata*), bigmouth buffalo (*Ictiobus cyprinellus*), white sucker (*Catostomus commersonii*), gizzard shad (*Dorosoma cepedianum*), northern red horse (*Moxostoma macrolepidotum*), white bass (*Roccus chrysops*) and yellow bass (*Roccus mississippiensis*).

Table 2. Catch statistics of the intensive net fishery in the Des Moines River

	1966			1967			1968		
Species	N	Lbs	$\overline{X}$ wgt	N	Lbs	$\overline{X}$ wgt	N	Lbs	$\overline{X}$ wgt
C catfish	14,371	8,437	.55	19,908	5,296	.26	8,593	4,112	.47
Fl catfish	307	227	.76	45	68	.98	64	27	.42
Carp	1,865	3,182	1.70	1,457	2,921	2.03	1,517	1,528	1.06
R carpsucker	88	93	1.05	1,053	1,030	.98	2,484	2,163	.87
Other	11	19	1.75	126	45	.36	3,271*	409	.12
Total	16,642	11,958		22,589	9,360		15,936	8,239	

*Catch contained more than 3,000 bullhead.

Numerical composition of channel catfish in the fishery was 86%, 88% and 53.9% for 1966, 1967 and 1968. By weight, they comprised 70%, 56.5% and 49.9% of the catch, respectively. Carp and river carpsucker usually ranked second and third in numerical importance. Carp were second most important in 1966 when only baited hoop nets and slat traps were used and in 1967 when fyke nets were used periodically. With increased use of fyke nets numerical occurrence of river carpsucker increased systematically from < 1% in 1966 to 15.6% two years later.

Species composition of the fishery was not greatly influenced by experimental exploitation in 1967 or the winter kill in the following year, except for the large catch of bullhead in 1968. During the first two years bullhead made up < 1% of the catch both in number and weight. Following the fish kill they comprised 19% of the numerical catch and 3.7% of the total weight. Bullhead are notoriously tolerant of low DO levels and presumably survived in greater proportion than any other species of fish.

The most important change in fish population characteristics following the winter kill was in mean weight. Mean weight increased for flathead and channel catfish, declined for carp and remained about the same for river carpsucker. Bullhead occurred so infrequently in catches prior to the fish kill valid comparisons were impossible.

Fluctuations in mean weight of fish in the catch could conceivably result from two sources. First, from non-randomized selection of samples, and second, from disproportionate mortality of different age and sized fish. Mean weight of channel catfish captured in 1966 was .55 lbs, but this value was computed from catfish > 10 inches total body length (TL) because of a tagging program. Randomized samples in the two subsequent years produced mean weight values of .26 and .47 lbs. Since it is unlikely an experienced fishery research crew would select larger fish for samples in 1968, it was most logical to attribute most of the change to disproportionate mortality. In this instance smaller channel catfish died in greater proportion than larger catfish. Mortality in flathead catfish showed the identical trend, but carp was the opposite with losses of larger fish most significant. Mean weight of carp was 2.03 lbs in 1967 compared to 1.06 lbs the following season.

ESTIMATED POPULATION DENSITY

Numerical estimates of the channel catfish population within the boundaries of the study area were completed during the first and third project years. Method of estimating the population density was Chapman's modification of the Schnabel equation for multiple sample censuses

$$\hat{N} = \frac{\Sigma(C_t\ M_t)}{(\Sigma R_t) + 1}$$

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

Estimates using short-term intensive fishing with replacement, simultaneous marking and recapture yielded both independent estimates for each biweekly netting interval and cumulative totals. Confidence interval at the 95% level were set around the estimates in the usual fashion for Poisson distribution (Ricker, 1958). Adjustment of numbers of marked channel catfish available for recapture within the study area at any interval was achieved by the procedure outlined by Mayhew (1971).

Low water stages throughout a majority of the first season precluded netting of the entire study area so population estimates were made for a 10-mile segment and expanded by a factor of two for the total estimate. The total number of catfish marked and released for the eight biweekly intervals was 14,371. Loss of marked fish by movement outside the study area reduced the number available for recapture to 14,098. Slightly more than 12% (1,742) were recaptured. As shown in Table 3, independent biweekly estimates ranged from 14,203 in the first period to 95,762 in the last interval. Cumulative yields of estimated population density ranged from 13,504 to 50,887. Although the latter value increased systematically with greater numbers of marked fish in the population it was considered the most accurate. Total channel catfish population estimate was 101,774 which varied no more than ±17,993 at the 95% level.

Table 3. Independent and cumulative estimates of the channel catfish population in 1966

Sample interval	Marked fish* at large at interval	N fish captured at interval	N recaptured	Independent $\hat{N}$	Cumulative $\hat{N}$
1	419	419	3		
2	2,835	1,966	58	14,203	13,504
3	4,046	1,661	146	27,133	23,117
4	7,213	3,167	285	44,960	35,770
5	9,506	2,293	440	37,589	36,628
6	10,454	948	238	37,864	36,880
7	12,067	1,613	273	61,766	41,588
8	14,098	2,031	299	95,762	50,887**

*Number is adjusted for movement of marked fish from boundaries of study area.

**$\hat{N}$ for study area = 101,774 ± 17,993.

Estimates were repeated in the 1968 season because of winter fish mortality. Methods were the same as 1966, using the identical boundaries for data expansion. During 10 biweekly intervals 8,593 catfish were marked and released in the 10-mile segment (Table 4). Loss of marked fish reduced the number available for recapture to 7,859. From a total sample of 10,497 fish, 753 or about 8% were recaptured. Biweekly estimates ranged from 27,666 to 292,136. Most fluctuation occurred in the early sample periods which probably was related to an unmixed marked population or movement of fish in from other areas to fill the void created by the fish kill. Cumulative yields of estimated population density varied from 4,368 to 72,198, and were of greatest magnitude in early sampling periods. After the fourth period estimates remained nearly constant. Using the cumulative estimate for the tenth interval and expanding as before, the catfish population was estimated at 107,240 fish which would vary no more than ±7,840 at the 95% level.

Table 4. Independent and cumulative estimates of channel catfish population in 1968

Sample Interval	Marked fish* at large at interval	N fish captured at interval	N recaptured	Independent $\hat{N}$	Cumulative $\hat{N}$
1	756	904	16		
2	1,016	318	3	27,666	4,368
3	1,841	1,077	4	292,136	54,414
4	3,369	1,842	61	78,904	72,198
5	4,826	1,985	214	37,752	47,461
6	5,696	1,215	147	40,830	45,271
7	5,915	321	35	47,315	45,420
8	6,808	1,172	93	76,268	50,427
9	7,510	1,329	153	59,535	52,346
10	7,859	334	27	87,866	53,620**

*Adjusted for movement outside of boundaries of study area.

**$\hat{N}$ for study area = 107,240 ± 7,840.

Despite the winter kill the 1968 estimate showed little difference from the previous estimate. At the 95% level confidence intervals of the estimates overlap, and final cumulative estimates vary by slightly less than 4,000 fish. These findings would indicate minor loss of fish from the 1968 winter mortality, or if there was substantial loss, complete repopulation occurred before the final estimate. More than 9 months elapsed between the fish kill and the final cumulative estimate making the latter the most appropriate explanation.

CATCH CURVE AND MORTALITY RATE

Age structure of channel catfish catches was represented by plotting the natural logarithm of the percent frequency for each age class on age (Figure 2). Only fish collected in project years 1967 and 1968 were used because samples from 1966 were tagged fish with a TL 10 inches or greater. In both years fish older than 8 years were combined as one class because of low frequency occurrence. The difference in transformed values between age i and age i + 1 was the instantaneous mortality rate, and the mean of all age groups was considered the total instantaneous mortality rate (i). Annual mortality rates were obtained from a table of exponential functions where $a = 1 - e^{-i}$ (Ricker, 1958). Survival rate was the compliment of annual mortality rate ($s = 1 - a$).

Age distribution of the 1967 catch based on a sample of 230 catfish was 6.9%, 18.5%, 23.8%, 27.7%, 7.7%, 8.6%, 4.6% and 2.2% for age groups I through VIII+, respectively. In the following year from a sample of 630 fish, age distribution of the catch was 4.6%, 21.5%, 29.6%, 18.5%, 12%, 10.9%, 3.6% and 0.3%. Comparison of paired age distributions by transformed percent frequency in a t distribution rejected the null hypothesis of significant difference ($P > .05$) and the two years were pooled. Age distribution after pooling was I, 5.7%; II, 20%; III, 26.6%; IV, 23%; V, 9.8%; VI, 9.7%; VII, 4% and VIII+, 1.2%.

Mortality rate was computed for catfish age III and older with younger ages excluded because they were not fully vulnerable to the gear. As shown in Table 5, instantaneous mortality rate between individual age classes ranged from .01 for ages V-VI to 1.204 for ages VII-VIII+. Total instantaneous mortality rate was estimated at .637 with annual mortality rate for the population estimated at .418. No more than .10 of the total annual mortality rate ($i = .11$) was attributed to the sport fishery with the remainder considered death from natural causes.

Table 5. Pooled instantaneous (i), annual (a) mortality rates and survival (s) rates of channel catfish

Age	% composition	$\log_e$	i	a	s
III	26.6	3.281			
			.146	.131	.869
IV	23.0	3.135			
			.853	.573	.427
V	9.8	2.282			
			.010	.010	.990
VI	9.7	2.272			
			.886	.585	.415
VII	4.0	1.386			
			1.204	.699	.301
VIII+	1.2	.182			
			$\bar{i}$ = .637	$\bar{a}$ = .418	

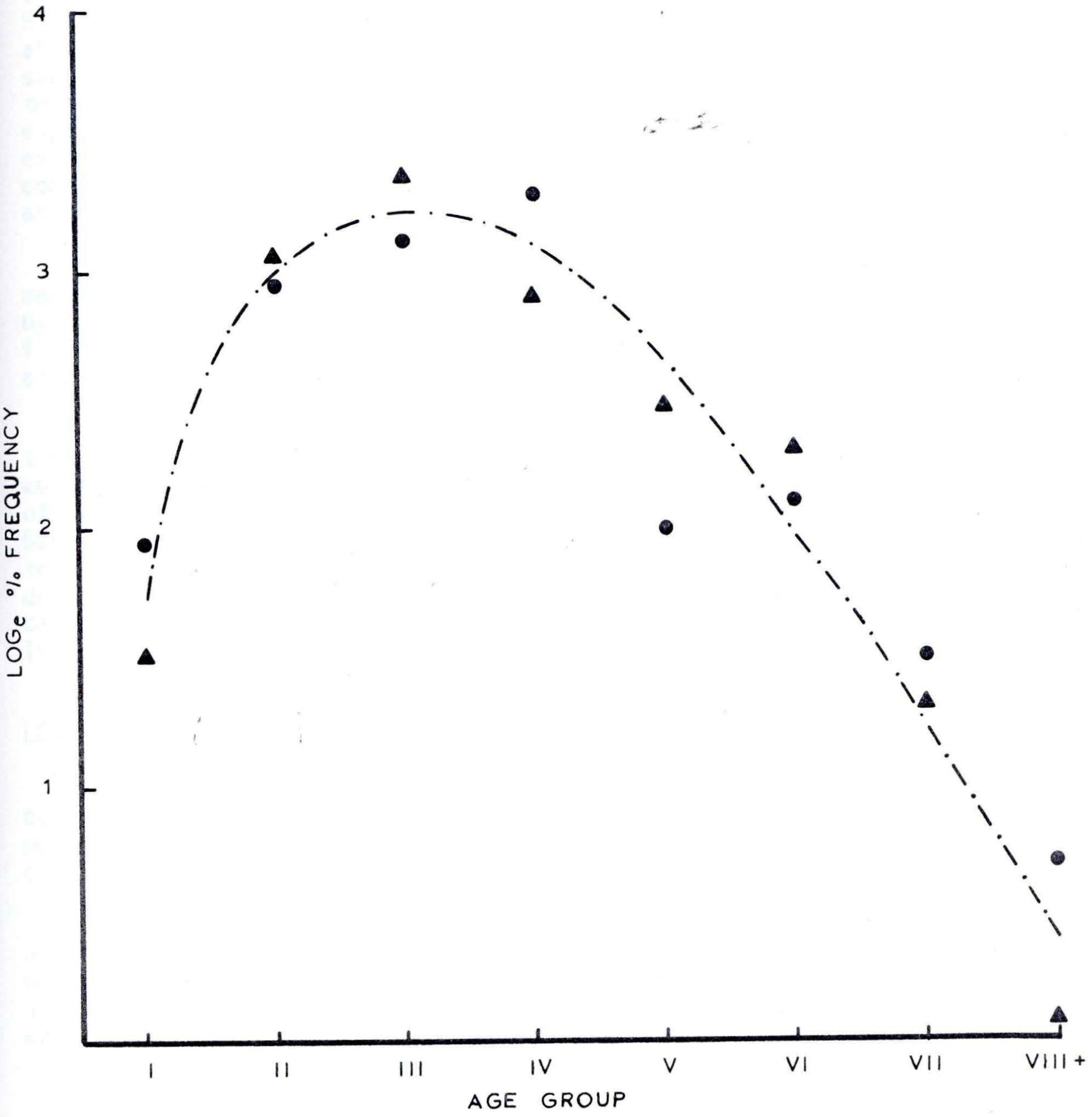

Figure 2. Catch curve of the percent frequency distribution for age groups of channel catfish. Dots are 1967 samples and triangles are 1968 samples. The plotted line represents smoothed pooled years.

LIFE HISTORY OF CHANNEL CATFISH

The initial year of this investigation was used primarily for collection of vital statistics for channel catfish life history pretaining to age and growth. Ricker (1954) and Rounsefell and Everhart (1958) pointed out decline in exploitable stock at significant rates usually results in compensation by forcing factors such as growth and recruitment. Since there is considerable interaction between these factors it is doubtful their unique contribution to the dynamics of exploited fish populations are readily discernable. With scheduled experimental exploitation in the second year it was expedient to establish a baseline for comparison of life history parameters even though they would be measured in aggregate rather than singularly.

Loss of channel catfish by the winter kill was unforseeable, but was of the magnitude which required evaluation. Catastrophic reduction in fish populations by the abrupt mortality did not resemble the sustained mortality from the net fishery in many respects, but it was helpful in assessing the impact of mortality at a level unattainable by controlled exploitation.

Life history parameters of most consequence were length frequency distribution, length-weight relationship, body condition and growth history in length and weight. These statistics were comparable between project years and were indicators of shifts in the structure of catfish populations. Integral portions of these basic parameters were also used in determination of growth indices, Walford growth transformations for body length and weight and potential yield models. Methods of data collection and analysis were identical for all project years and the results can be reviewed in Annual Project Completion Reports (Mayhew and Mitzner 1967, 1968 and 1969).

LENGTH FREQUENCY DISTRIBUTION

Distribution of TL was determined by measuring body length of all catfish captured in a randomly selected net on one day in each biweekly period. Measurements of individual fish were grouped by .5 inch intervals. The total number of observations by project year was 540 in 1966, 441 in 1967 and 456 in 1968.

Total length distribution of the samples showed the typical polymodal arrangement (Table 6). In 1966 the range in body length was 6.0-20.7 inches with a median of 15.5 inches. Most prevalent modes of 7% each occurred at the 11.5-11.9 and 14.0-14.4 inch intervals. Nearly 23% of the catfish in the sample were < 10 inches in length. TL of fish in the 1967 catch ranged from 5.5-25.3 inches with a median of 17 inches. The 10.0-10.4 and 14.0-14.4 inch groups were most important again with 6.5% and 6.8% frequency. Over 33% of the catfish captured were < 10 inches long. In 1968 size ranged from 4.7-21.4 inches and median length of the sample was 17 inches. Fish in the 11.0-11.4 size interval comprised 12.1% of the sample. The 10.0-10.4 group, which was most common in the previous two years, increased to 9% frequency, but occurrence of the 14.0-14.4 inch interval declined to < 2% frequency. Nearly 50% of the catfish captured in 1968 were < 10 inches in body length.

Table 6. Length frequency distribution in number and percent occurrence by .5 inch size intervals from random samples of channel catfish

Length range	1966		1967		1968	
	N	%	N	%	N	%
4.5- 4.9					1	.2
5.0- 5.4						
5.5- 5.9			2	.5	3	.6
6.0- 6.4	1	.2	5	1.1	7	1.5
6.5- 6.9	1	.2	8	1.8	15	3.3
7.0- 7.4	6	1.1	14	3.2	12	2.6
7.5- 7.9	24	4.4	20	4.5	8	1.8
8.0- 8.4	19	3.5	24	5.4	20	4.4
8.5- 8.9	21	3.9	24	5.4	29	6.3
9.0- 9.4	14	2.6	19	4.3	35	7.7
9.5- 9.9	17	3.1	18	4.0	45	9.9
10.0-10.4	19	3.5	29	6.5	41	9.0
10.5-10.9	23	4.3	24	5.4	40	8.8
11.0-11.4	23	4.3	23	5.2	55	12.1
11.5-11.9	38	7.0	17	3.8	33	7.2
12.0-12.4	16	3.0	19	4.3	30	6.6
12.5-12.9	35	6.5	19	4.3	14	3.1
13.0-13.4	22	4.1	18	4.0	14	3.1
13.5-13.9	31	5.7	14	3.2	13	2.8
14.0-14.4	38	7.0	30	6.8	8	1.8
14.5-14.9	36	6.7	11	2.5	6	1.3
15.0-15.4	27	5.0	12	2.7	2	.4
15.5-15.9	29	5.4	17	3.8	3	.6
16.0-16.4	25	4.6	11	2.5	5	1.0
16.5-16.9	21	3.9	22	5.0	2	.4
17.0-17.4	14	2.6	15	3.4	1	.2
17.5-17.9	13	2.4	5	1.1	2	.4
18.0-18.4	6	1.1	6	1.4	3	.6
18.5-18.9	8	1.5	5	1.1	1	.2
19.0-19.4	6	1.1	3	.7	2	.4
19.5-19.9	5	.9	3	.7	1	.2
20.0-20.4	1	.2	4	.9	3	.6
20.5-20.9	1	.2			1	.2
21.0-21.4			1	.2	1	.2
21.5-21.9						
22.0-22.4						
22.5-22.9			1	.2		
23.0-23.4						
23.5-23.9						

Table 6. (Continued)

Length range	1966 N	1966 %	1967 N	1967 %	1968 N	1968 %
24.0-24.4						
24.5-24.9						
25.0-25.4			1	.2		
Total N	540		441		456	

There were obvious changes in size structure of the catfish population between all years. Length frequency distribution during the first year was partially based on fish captured in slightly larger mesh nets, and would bias the frequency distribution toward somewhat larger fish. Evidence of this factor can be gleaned from the fact nearly three-quarters of the catch was 10 inches TL or greater.

Most change in size distribution of catfish occurred between 1967 and 1968 following the winter kill. Although the median size remained constant at 17 inches both years nearly one-third more fish were < 10 inches in 1968. This could only result from recruitment of a weak year class into the fishery or disproportionate loss of different size fish during winter mortality. The former was eliminated because there was lack of evidence of year class failure in the 1966 sample. Further evidence to support this supposition was gained by examination of changes in the frequency at different size intervals.

LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR

Many fisheries workers have reported changes in the relationship between body length and weight from events in fish life history (LaCren, 1951; Beckman, 1951; Hile, 1954). Temporal fluctuation from spawning activity are normally expected, particularly in females because of ovarian development. Variability in food abundance often results in related changes of the length-weight relationship. Although changes in length-weight relationships resulting from increased exploitation of fish populations have not been well documented, compensation in growth for both length and weight from increased harvest has been reported many times and should be reflected in this relationship when it is allometric. Diversity in channel catfish length-weight relationships between years was determined by body measurements from randomly chosen sub-samples. Sexes were combined because of difficulty in accurately separating males and females except during ovarian and gonadal development prepatory to spawning. From a combined sample of 1,438 catfish, statistics were collected from 540 in 1966, 443 in 1967 and 446 in 1968.

The general parabola $W = aL^b$, where W represents weight in .01 lbs, L represents TL in .1 inches and a and b are empirically determined constants was used for mathematical expression of the relationship. Length-weight relationships for individual years were as follows:

1966 $W = .34 \times 10^{-5} L^{3.09}$
1967 $W = .22 \times 10^{-5} L^{2.93}$
1968 $W = .29 \times 10^{-5} L^{2.93}$

Regression coefficients were tested for statistically common values of a and b by analysis of covariance. Significant difference ($P < .05$) occurred for the 1967 intercept compared to the other two years, but 1966 and 1968 had common a values. Slope in all years was identical at the .05 level and coefficients were combined to form the pooled regression equation

$$W = .28 \times 10^{-5} L^{2.99}$$

Testing of the pooled b value for isometric growth ($b = 3.0$) in a t distribution rejected the null hypothesis ($P > .05$).

Plotting of predicted weight values at mean TL for ages III, V and VII by collection year revealed little change in length-weight relationships following increased harvest (Figure 3). Predicted weight of age III catfish was .20 lbs in 1966, .21 lbs in 1967 and .18 lbs in 1968. For age V estimated weight of fish in the three years of study were .70, .79 and .81 lbs, respectively. The predicted weight for age VII catfish was 1.92 lbs in 1966, 1.90 in 1967 and 1.68 lbs in 1968. The latter value was based on only two observations and might well be biased because of sample size.

Calculated weights were prepared for each sample year for .5 inch intervals in body length (Table 7). Predicted weight differed only slightly from emperical values with the most fluctuation resulting from few observations at extreme length ranges. The maximum variation of TL for fish reaching 1-lb was 14.2 inches in 1966 to 14.8 inches in 1967. For catfish reaching 2-lbs the low was 17.9 inches for 1966 and the high was 18.5 inches in 1968.

Condition factors for each group were computed by $C_F = (1/L)^3 (W \times 10^5)$, where W and L are the same as before. Mean C_F for 1966 was 35 with a range of 31-40 in 1967 C_F ranged from 29-46 with a mean of 33. Condition factors for individual size groups ranged from 27-40 in 1968 and averaged 34. There was no tendency for systematic increase or decrease in C_F with changes in body length.

ESTIMATED LENGTH AT EACH YEAR OF LIFE

Total body length of catfish at the end of each year of life (NAGE) was back calculated by mathematical extrapolation of the body-spine relationship. Randoml chosen sub-samples of pectoral spines were processed for aging in the usual fashion (Sneed, 1951) and aged by microprojection of the spine cross section. Al measurements of annuli and spine radii were made to the nearest .1 inch. Plots o TL on spine radius were made by computer and a line fitted by the polynomial mode

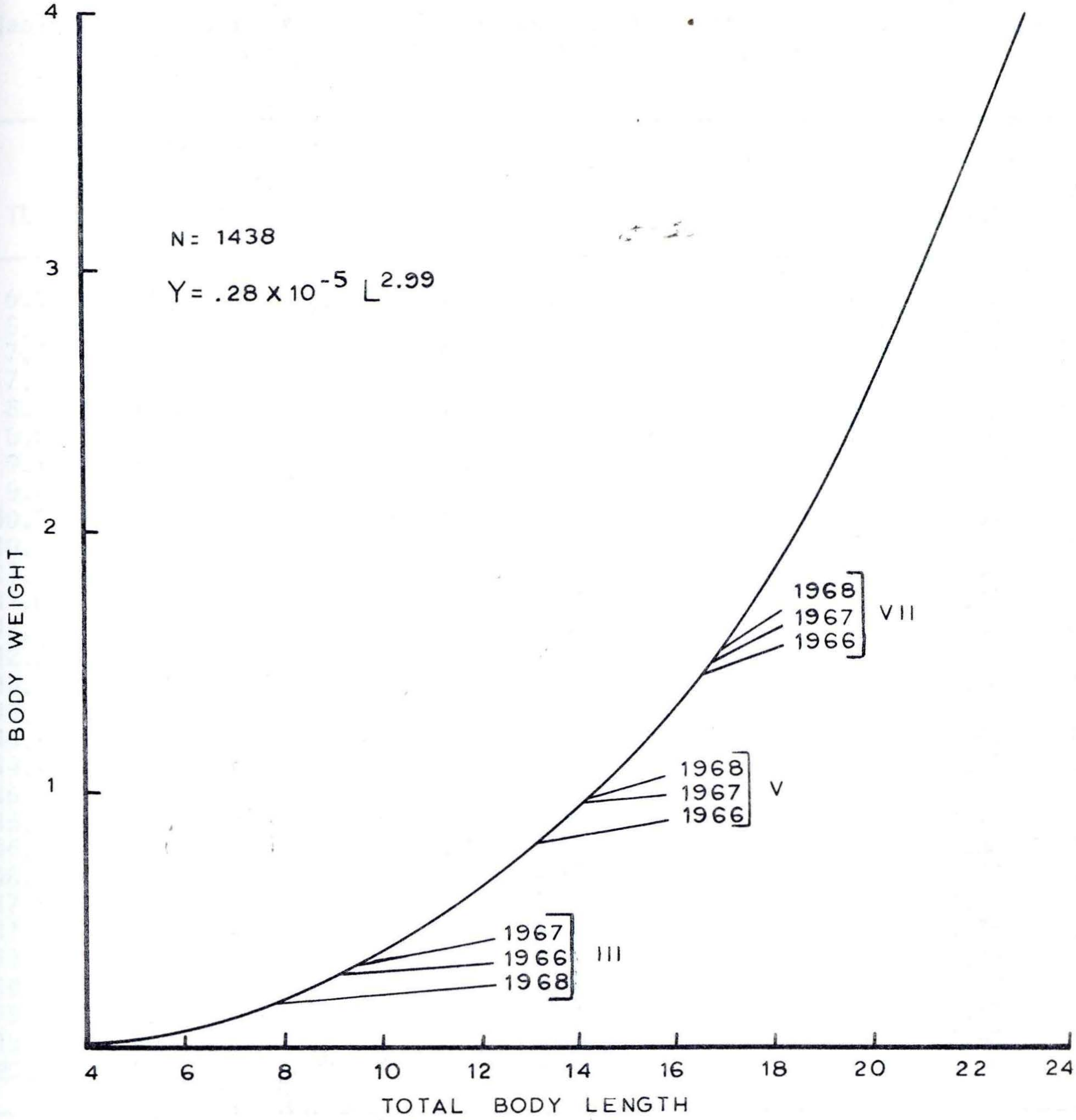

Figure 3. Pooled length-weight regression of channel catfish for 1966, 1967 and 1968 with mean length-weight values of age groups III, V and VII.

Table 7. Predicted weight of channel catfish at .5 inch total length intervals using regression coefficient for individual years

1966			1967			1968		
TL	Wgt	N	TL	Wgt	N	TL	Wgt	N
6.4	.10	1	6.2	.09	5	6.2	.09	1
6.8	.12	1	6.7	.11	8	6.7	.10	15
7.2	.13	6	7.2	.17	14	7.2	.11	12
7.7	.17	24	7.7	.18	20	7.8	.14	8
8.1	.19	19	8.2	.21	24	8.3	.17	20
8.6	.20	21	8.7	.22	24	8.7	.20	29
9.1	.25	14	9.2	.26	19	9.2	.22	35
9.7	.31	17	9.6	.28	18	9.7	.26	45
10.2	.34	19	10.2	.34	29	10.2	.31	41
10.7	.41	23	10.7	.40	24	10.7	.34	40
11.2	.46	23	11.2	.45	23	11.2	.40	55
11.6	.51	38	11.7	.53	17	11.7	.46	33
12.2	.61	16	12.2	.56	19	12.2	.50	30
12.7	.70	35	12.8	.65	19	12.7	.58	14
13.2	.80	22	13.2	.71	18	13.2	.67	14
13.6	.86	31	13.7	.77	16	13.8	.79	13
14.2	1.01	38	14.2	.84	30	14.2	.81	8
14.7	1.11	36	14.6	.93	11	14.6	.97	6
15.2	1.29	28	15.2	.96	12	15.2	1.08	4
15.7	1.42	29	15.7	1.24	17	15.8	1.19	3
16.2	1.56	25	16.1	1.35	13	16.2	1.36	5
16.6	1.69	21	16.7	1.57	22	16.7	1.60	2
17.2	1.98	14	17.1	1.67	15	17.2	1.67	1
17.7	2.07	13	17.7	1.90	5	17.7	1.78	2
18.1	2.19	6	18.1	2.10	6	18.2	2.19	3
18.5	2.56	8	18.7	2.55	5	18.7	2.32	1
19.1	2.68	6	19.3	2.77	3	19.2	2.59	2
19.6	2.92	5	19.7	3.20	3	19.6	2.88	1
20.1	3.23	1	20.4	3.28	4	20.0	3.17	3

$$L = \Theta + \Theta_1 S + \Theta_2 S_2 + \cdot \cdot \cdot + \Theta_n S^n + \varepsilon$$

where L represented TL and S represented spine radius in a step-wise regression procedure (Mayhew, 1971). Polynomials were computed to the sixth degree and progressively reduced to the lowest significant term (Chamberlin and Jowett, 1969). For the sample data the cubic regression term

$$\hat{\ell} = -.76 + 8.21S - 3.42S^2 + .98S^3$$

best described the relationship. Coefficient of determination for this regression was 98%.

Estimation of total body length at NAGE was computed for individual project years, but showed little variation and were combined for presentation (Table 8). Sample number for project years were 445 in 1966, 368 in 1967 and 130 in 1969, for a total sample of 943 catfish.

Grand average calculated TL at each annulus for the first 10 years of life was 3.5, 6.6, 8.9, 11.6, 14.2, 16.0, 18.0, 19.9, 22.2 and 24.2 inches, respectively. By successive summation of mean increments at ages 1 through 10 mean TL was 3.5, 6.5, 8.7, 11.2, 13.9, 15.0, 17.4, 19.1, 20.4 and 21.3 inches. The latter was considered the best estimation. Calculated body weight of catfish at NAGE by using the pooled length-weight regression was .015, .09, .22, .47, .89, 1.12, 1.75, 2.3, 2.79 and 3.12 lbs.

Growth history by year class (Figure 4) showed greatest growth occurred in the first year and generally declined at a systematic rate throughout life. Noticeable exceptions, mostly attributed to small sample size, occurred in the 1966 and 1968 samples for the 1959 year class and in the 1967 samples for the 1961 year class.

In comparison with catfish growth from other locations in the Des Moines River basin the present study differed considerably depending mostly on geographical region but generally it was rather slow. Harrison (1955) showed slightly slower growth in early years of life in the Humboldt impoundment, but in later years TL at NAGE was much less. Catfish growth reported by Muncy (1959) in the middle Des Moines River was quite similar to this study.

Studies by Schoumacher and Ackerman (1965) showed very rapid and constant growth of commercially caught catfish in the Mississippi River. Estimated TL at each annulus was greater in streams located in southern and eastern United States (Davis, 1959; Sanderson, 1958; Hall and Jenkins, 1954). Kimsey, Hagy and McCammon (1957) reported similar growth of catfish from the lower Colorado River in California.

A growth index for calendar years was computed by the percent deviation of mean increments for combined age groups transposed to a base of 100 (Table 8). All values < 100 would represented below normal growth and values > 100 represented above normal growth. Growth indices for the combined years ranged from 97 in 1966 to 154 in 1958. Calendar year of above normal growth were 1967, 1963, 1960, 1959 and 1958. There was no clear trend for systematic changes in the growth indices.

RATE OF GROWTH IN LENGTH

The rate of growth in length was computed by the method outlined by Ricker (1958) from the Walford growth transformation where TL at time interval t is given by

Table 8. Calculated length and mean growth increments for channel catfish sampled during three consecutive years

Year class	N in years sampled 1968,	1967,	1966	Total N samples	Estimated TL at NAGE 1	2	3	4	5	6	7	8	9	10	Growth index
1967	9	**	***	9	3.4										107
1966	24	17	***	41	3.5	5.6									87
1965	31	79	40	150	3.5	5.8	8.8								94
1964	36	109	62	207	3.3	6.8	8.7	12.3							112
1963	10	68	73	151	3.3	6.6	10.0	13.1	16.4						92
1962	11	44	76	131	3.1	6.0	8.4	10.0	13.6	16.4					98
1961	6	40	86	132	3.8	6.6	8.2	10.5	13.1	14.9	17.4				98
1960	3	6	68	77	3.7	6.2	8.3	10.9	13.4	14.8	17.0	18.3			125
1959	*	1	36	37	3.8	7.2	8.3	11.2	13.7	16.1	17.6	19.4	a		120
1958	*	3	4	7	3.8	7.8	10.5	12.7	14.5	16.6	18.9	20.7	21.2	a	154
1957	*	1	***	1	3.8	7.8	9.2	12.1	14.8	16.9	19.2	21.1	23.1	24.2	b
Gr. $\overline{X}$ cal. length					3.5	6.6	8.9	11.6	14.2	16.0	18.0	19.9	22.2	24.2	
Gr. $\overline{X}$ increment					3.5	3.1	2.3	2.7	2.6	1.8	2.0	1.9	1.3	2.0	
Gr. $\overline{X}$ cal. increment					3.5	3.0	2.2	2.5	2.7	2.1	2.4	1.7	1.3	0.9	
Sum of increments					3.5	6.5	8.7	11.2	13.9	15.0	17.4	19.1	20.4	21.3	
Est. wgt. at annulus					.015	.09	.22	.47	.89	1.12	1.75	2.30	2.79	3.18	

[a] Age group absent from sample.

[b] Not calculated because no age IX taken in 1968 samples.

*Year class absent from 1968 sample.

**Year class absent from 1967 sample.

***Year class absent from 1966 sample.

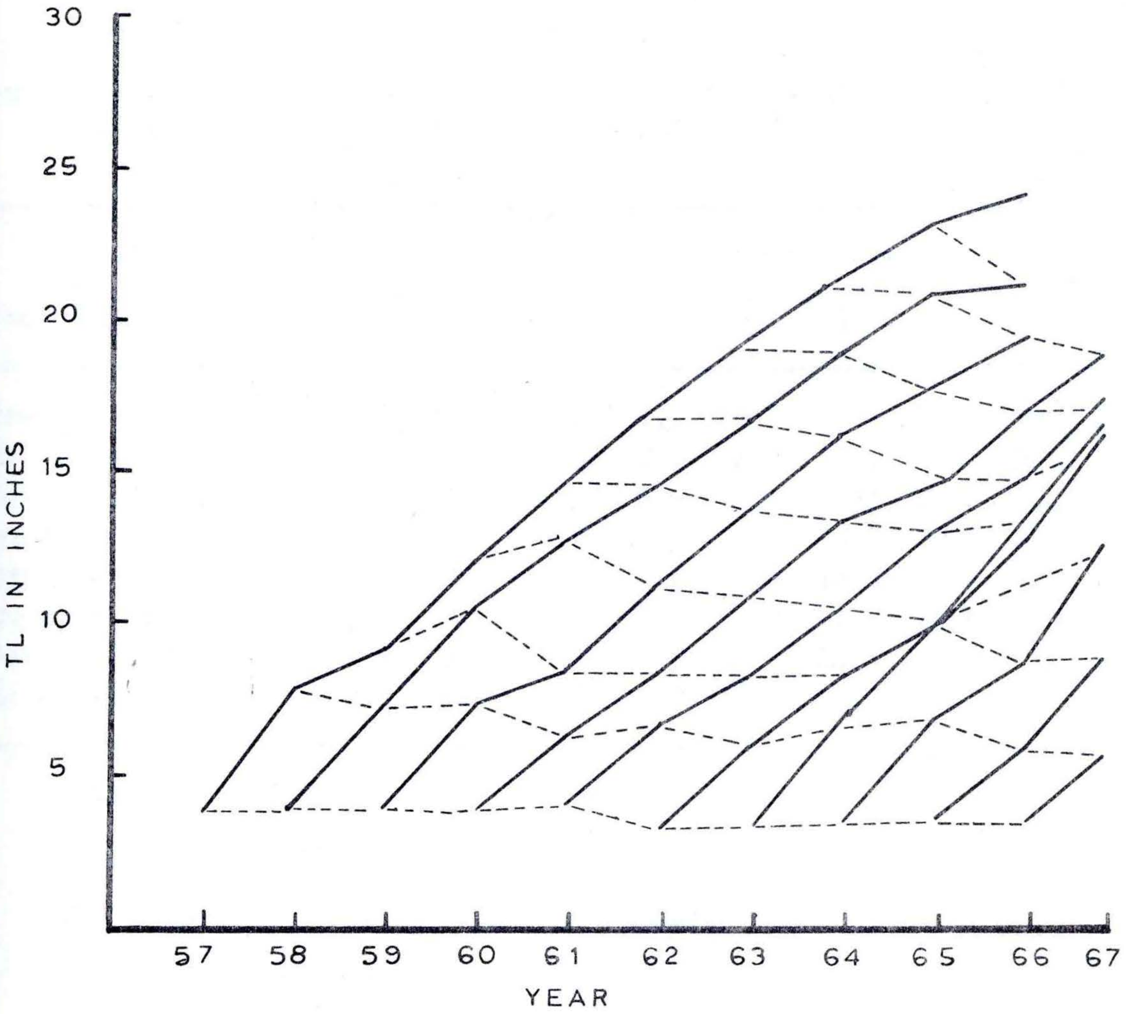

Figure 4. Growth history of channel catfish by year class from combined 1966-1968 samples. Solid lines are successive summations of mean TL increments. Dotted lines represent estimated increments.

$$\ell_t = L_\infty[1-e^{-k(t-t_o)}]$$

using notations

L_∞ = maximum attainable TL in the sample population
k = rate at which TL approaches L_∞
t_o = time at which TL would equal 0 in the equation.

Table 9. Comparison of TL at each year of life for channel catfish from the Des Moines River and other selected streams

	TL at annulus									
Location	1	2	3	4	5	6	7	8	9	10
Present study	3.5	6.5	8.7	11.2	13.9	15.0	17.4	19.1	20.4	21.3
Des Moines, IA[1]	.8	4.9	7.7	10.1	12.3	15.0	17.4	19.3	21.5	24.3
Des Moines, IA[2]	3.0	5.5	7.0	8.6	9.4	11.9	12.1	13.6	14.3	14.5
Mississippi, IA[3]	6.6	9.2	12.6	15.4	16.8	18.1	20.4	21.3	20.7	
Streams (6), KS[4]	2.6	7.1	10.7	11.2	13.2	16.6	21.1	21.5		
Streams (3), OK[5]	5.6	8.5	11.5	17.3	19.9	22.6	25.6	27.0	28.5	
Potamac, MD[6]	7.7	10.5	13.0	15.7	18.1	20.5				
Colorado, CA[7]	2.8	6.9	9.3	12.0	15.2	18.4	20.9			

[1] Muncy, R. (1959).

[2] Harrison, H. (1955).

[3] Schoumacher, R. and G. Ackerman (1965).

[4] Davis, J. (1959).

[5] Hall, G. and R. Jenkins (1954).

[6] Sanderson, A. (1958).

[7] Kimsey, J., R. Hagy and G. McCammon (1957).

From the equation the rate of increase in TL by interval t is

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

which in affect is plotting TL of catfish at age 2 on age 1, age 3 on 2 and so on until all age groups are included (Figure 5, segment A). The slope of the fitted line, k, is a measure of the rate of growth in length and where it intercepts a 45^o diagonal line drawn from the origin is the maximum attainable length, ℓ_∞, of fish in the population.

Refinement of the rate of increase in TL by intervals of time was obtained by the procedure from Beverton (1954) where

$$\log_e(\ell_\infty - \ell_t) = \log_e \ell_\infty + (kt_o - k_t).$$

Again, the procedure yielded an estimate of ℓ_∞ by plotting logarithmic transformed values of $\ell_\infty - \ell_t$ on t (Figure 3, segment B). The author suggested fitting the line for estimating ℓ_∞ by hand to the point where it intersects with the Walford line. A least squares procedure was used for fitting the line in this study. Best estimation of maximum attainable length of the sample population was 30.9 inches which represented an estimate 15 years of growth. Maximum observed TL for an individual catfish was 27.6 inches. It is doubtful if a catfish with a TL of 30.9 inches could enter throats of the hoop nets used in the study.

RATE OF GROWTH IN WEIGHT

The rate of growth in weight was derived from the same procedure as length, except weight values were substituted in the equation

$$W'_t = W_\infty[1 - e^{-k(t' - t'_o)}]^3$$

where

W_∞ = maximum attainable weight at L_∞
k = rate at which weight approaches W_∞
t'_o = time at which weight would be 0 in the equation.

Rate of increase in weight at intervals of t' can be expressed by the equality

$$W'_{t+1} - W'_t = (1 - e^{-k})(W_\infty - W'_t)$$

Maximum attainable weight was estimated at 9.79 lbs. The heaviest individual catfish captured during the study was 6.12 lbs. Predicted weight of a fish with TL set at 30.9 inches and extrapolating through the length-weight regression was 10.1 lbs, which agrees quite well with the Walford estimation.

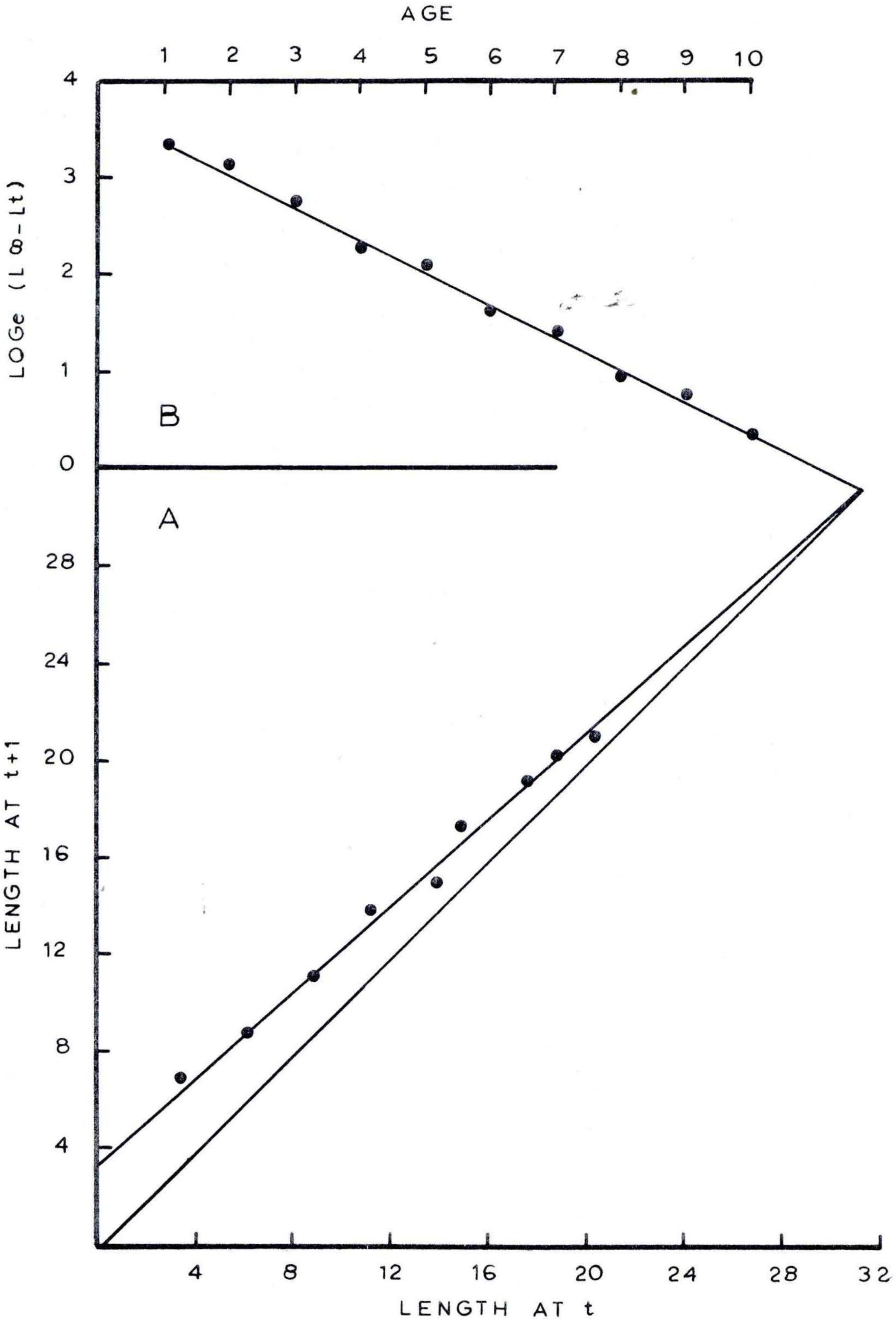

Figure 5. Walford growth transformation of body length at age t + 1 and age t for channel catfish.

CHANGES OF GROWTH RATE IN LENGTH

Rate of growth was one of the most important parameters monitored for changes due to the experimental exploitation. Many studies on population dynamics of reduced stock show acceleration in rate of growth following exploitation or manipulation. Bennett (1962) lists several methods of population reduction to improve growth and overall quality of fish in small ponds. Although changes in growth rate in a sustained yield fishery is somewhat reduced compared to suddenly induced mortality it should accelerate when exploitation reaches or surpasses surplus yield.

Changes in the rate of growth between project years 1966 and 1967 were measured by comparing growth increments for individual age groups during both years and ages in which growth occurred. Growth increments in this array appeared quite similar with the greatest diversity at ages IV and VII (Table 10). Rate of growth within both years was nearly constant without anticipated acceleration with the advent of the sustained fishery.

Table 10. Mean annual TL increments for channel catfish in the sample years preceding (1966) and during (1967) experimental exploitation by the net fishery (number of paired observations in parenthases)

	Year in which growth occurred								
Age	1966	1965	1964	1963	1962	1961	1960	1959	1958
1	3.6 (17)	3.1 (79)	2.0 (109)	2.5 (68)	2.2 (44)	1.9 (40)	1.4 (6)	2.2 (1)	2.3 (4)
2	3.5 (119)	4.2 (171)	3.1 (140)	1.8 (120)	2.4 (126)	1.8 (74)	1.5 (37)	2.3 (7)	
3	3.1 (171)	3.8 (140)	2.6 (120)	2.3 (126)	2.3 (74)	2.4 (37)	1.9 (7)		
4	3.0 (140)	3.5 (120)	1.5 (126)	2.5 (74)	2.5 (37)	2.0 (7)			
5	3.8 (120)	3.7 (126)	2.4 (74)	2.4 (37)	1.5 (7)				
6	3.5 (126)	3.5 (74)	1.6 (37)	2.5 (7)					
7	3.5 (74)	3.8 (37)	2.7 (7)						
8	3.5 (37)	4.3 (7)							
9	3.5 (7)								

Statistical evaluation of changes in growth rate between successive years was somewhat complicated by large variation in sample size between age groups primarily from different frequency distribution of age classes within the population. The influence of these variations can be minimized by transforming paired values to equalize variance by

$$x_i = \frac{x_1 - x_2}{\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where x_i is the transformed value of the difference between original paired growth increments and n_1 and n_2 are the associated number of paired observations. Resulting transformed values of x_i had equal variance and comparisons were made between years by the t distribution procedure outlined by Snedecor and Cochran (1967:94). The differences in paired growth increments was not significant at the 95% level ($t = 1.201$, 1215 df).

MEAN ANNUAL STANDING CROP AND PRODUCTION

Estimated biomass of channel catfish within the confines of the study area was based on age frequency of the sampled population and the estimated population density. Age frequency of the 1968 sample was 4.6% from age I, 21.5% from II, 29.8% from III, 18.5% from IV, 12% from V, 10.9% from VI, 1.8% from VII and < 1% from VIII and older. The numerical estimate was 5,354 fish per river mile with a total weight of 2,408 lbs. As shown in Table 11, ages III through VI contained the bulk of the biomass with 352, 466, 583 and 655 lbs per mile, respectively.

Table 11. Net changes in biomass of channel catfish per mile by age group based on a total population density of 5,354

Age	$\hat{N}$ population	Est. total biomass (W)	Instantaneous growth (g)	Instantaneous mortality (i)	Annual mean wgt ($\overline{W}$)	Biomass change [$\overline{W}$(g-i)]
I	247	4	1.848	*		
II	1,153	104	.872	*		
III	1,598	352	.755	.146	231	141
IV	992	466	.645	.853	306	-64
V	645	583	.227	.010	383	83
VI	584	655	.442	.884	430	-190
VII	97	170	.227	1.204	112	-109
VIII	38	74	.162	.637**	49	-23
Total	5,354	2,408			1,511	-162

*Value not computed because age group was not fully vulnerable to the gear.

**i value is the mean instead of $\log_e$ percent occurrence.

Annual mean number ($\overline{N}$) and weight ($\overline{W}$) was computed by the method suggested by Robson and Chapman (1951) where $\overline{N} = \frac{Na}{i}$ and $\overline{W} = \frac{Wa}{i}$. The a value represented annual mortality and i represented the instantaneous mortality rates used before. Net change in biomass for individual age groups was calculated as $\overline{W}$ adjusted for growth and mortality. Instantaneous growth was the coefficient of the function

$$G_{\ell} = \log_e \ell_2 - \log_e \ell_1.$$

$\overline{W}$ values for fish age III and older was as follows: III, 231 lbs per mile; IV, 306 lbs; V, 383 lbs; VI, 430 lbs; VII, 112 lbs and VIII+, 49 lbs.

Biomass gained was greatest for age III with +141 lbs and age V with +83 lbs. Loss in biomass for other age group was as follows: IV, -64 lbs; VI, -190 lbs; VII, -109 lbs and VIII+, -23 lbs per mile. Overall loss in biomass was -162 lbs per mile, but this value would be compensated for by ages I and II not included in the sampled population. Mean annual standing crop ($\overline{W}$) of channel catfish per mile of stream was estimated at 2,769 lbs (Table 12). Mean annual number of catfish in the population was estimated at 3,508 fish per mile.

Table 12. Estimated number and biomass of channel catfish per mile in Des Moines River during 1968

Statistic	Total study area
N of miles in study area	20
Mean number of channel catfish in entire study area in 1968 ($\overline{N}$)*	70,158
Mean N per mile	3,508
Mean weight ($\overline{W}$) of catfish in study area during 1968	55,224
Lbs of catfish per mile	2,769

*$\overline{N}$ value is based on the function $\overline{N} = \frac{Na}{i}$ where a = .418 and i = .70 and values are from Robson and Chapman (1951).

EXPERIMENTAL EXPLOITATION AND CATCH SUCCESS

During project year 1967 channel catfish were experimenally exploited by a sustained net fishery at approximately 20% of the previous estimated density of 102,000 fish. Actual cumulative harvest during 10 biweekly netting intervals was 19,908 fish weighing over 5,296 lbs. Harvested fish were removed daily without restrictions on size or number. Netting commenced on 18 May and continued only one period before flooding delayed further fishing until 7 July. After this date netting was continuous except for a 5-day delay in September for equipment repair.

Rounsefell and Everhart (1953:64) stated downward trends in catch per unit effort is useful in determining declining fishery stock. Sudden drops should be regarded with suspicion because they may be temporary phenomenon unrelated to actual declining population numbers or from interference between pieces of gear. Of most importance in a sustained fishery is a gradual systematic decline over a long period of time.

Catch success was defined as the ratio between numbers of fish captured in all gear in a 24-hour interval and the combined effort within the netting period. It was expressed in terms of fish per net day (FND). A catch success curve (Figure 6) of the mean FND showed biomodal seasonal distribution. Success rate increased rapidly from 8.7 FND in the first period to 43.5 FND in the third period reaching the maximum rate of 44.4 FND during the fourth interval. The following two periods were characterized by sharply declining fishing success reaching a low of 4.4 FND in the sixth period. Catch success increased gradually in the seventh and eighth periods until a secondary mode of 23.5 FND was achieved in the ninth interval. In the last period catch success declined again to 10.4 FND.

Expolitation rate within individual periods ranged from .64% of the estimated numerical population at P in the tenth period to 4.66% in the fourth period (Table 13). The rate of exploitation was based on original population estimates rather than progressively reducing estimates by cumulative catch. Recruitment into the exploitable stock by growth would nearly balance the constant loss by the net fishery.

Harvest would not normally influence catch success unless mortality from all sources exceeded replacement of fish into available stock. When this level was reached continued harvest would theoretically result in declining catch success proportional to remaining density. Annual mortality rate of the catfish population was estimated at .42 before experimental harvest. Of this, < .10 was attributable to sport fishing. Total annual mortality from all fisheries did not exceed .30 during the year. Potential yield of the population will be discussed later in this report.

The nearly constant recruitment of catfish into the exploitable stock from growth would greatly reduce the effects of the fishery on catch success. Channel catfish were not fully vulnerable to mesh size used in the gear until about 8-inches TL. Age at this size was about 2.6 years. Annual estimated TL increment for fish of this size was approximately 2.4 inches. All fish between 5.6 and 7.9 inches TL would become vulnerable during the netting season if growth rate remained constant. Length frequency distribution of the sample population showed this size range contained 16.5% of the stock. By exploiting 19.6% of the population > 8-inches TL during the year, harvest barely exceeded normal recruitment.

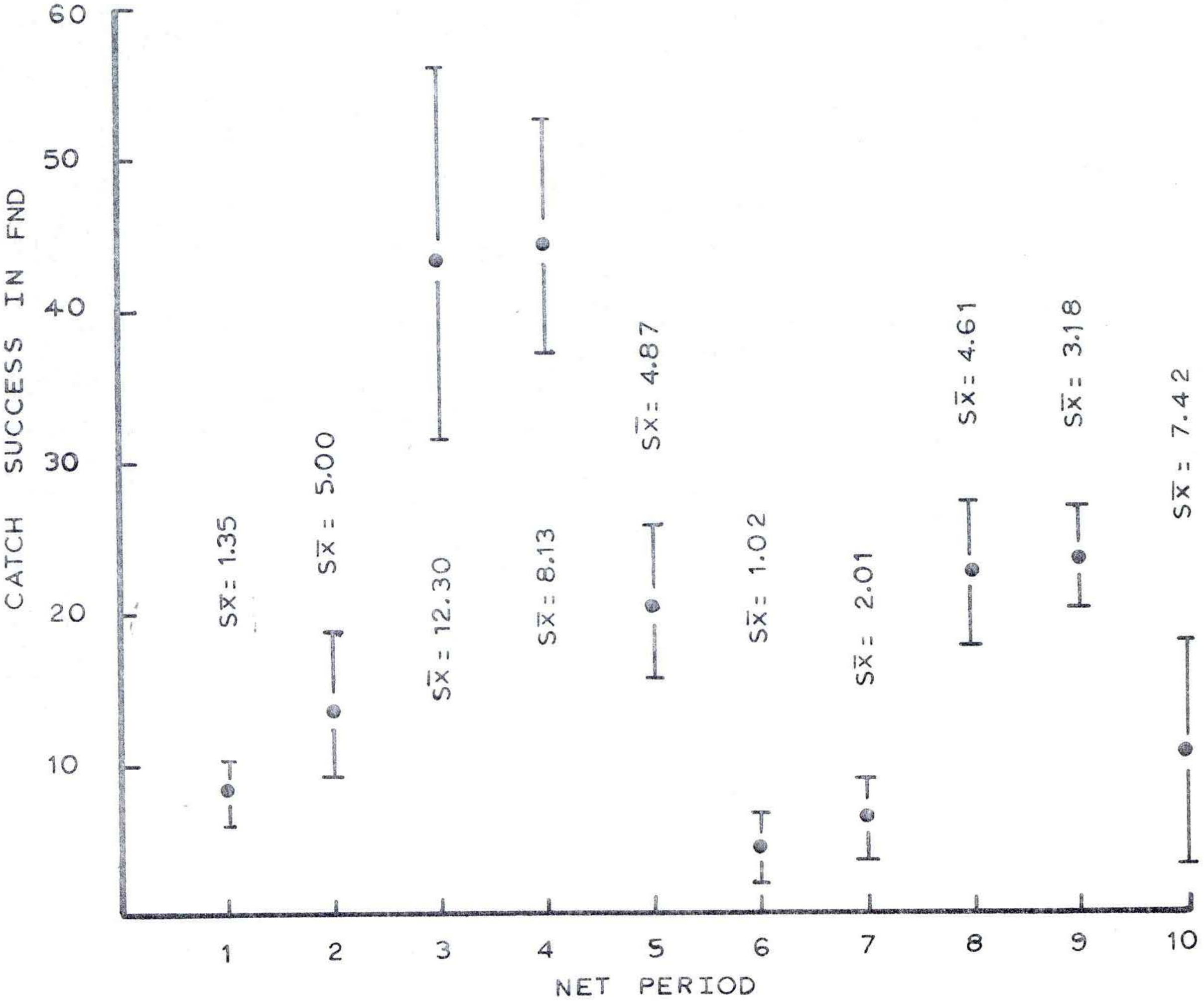

Figure 6. Catch success of channel catfish in baited hoop nets and slat traps during 1967.

Table 13. Catch success and exploitation rate of channel catfish during 1967

Interval	Catch success	% Exploitation at P	Temp	River stage	Turbidity	Effort
1	8.7 ± 1.35	0.93	62.7	7.73	3.78	19.0
2	13.7 ± 5.00	1.61	63.2	14.17	4.58	23.6
3	43.5 ± 12.30	3.70	74.7	11.27	5.43	15.5
4	44.4 ± 8.13	4.66	81.2	9.79	6.11	12.3
5	20.4 ± 4.87	2.48	80.6	8.77	6.25	12.4
6	4.8 ± 1.02	0.72	76.1	8.24	8.78	18.4
7	6.4 ± 2.01	0.71	72.7	8.14	12.04	18.8
8	22.8 ± 4.61	2.32	66.3	8.13	9.83	14.7
9	23.5 ± 3.18	1.69	52.7	7.64	10.50	11.7
10	10.4 ± 7.42	0.64	49.0	7.60	12.67	11.7

Previous evaluation of the effects of exploitation on catch success was somewhat complicated by the fact environmental and biological factors also influenced catch success. This type of fishing gear relies on movement for self entrapment of fish and any factor which accelerates movement also increases catch success, masking the true effects of the fishery. Most important factors were river flow, temperature, and turbidity. Fishing effort is also an integral part of computing catch success, being the ratio of total catch and effort, and because of its computational procedure might also effect catch success.

To test the effects of the net fishery on catch success of channel catfish a multiple linear regression analysis was completed where environmental influence and effort were held constant in the model

$$Y_{ij} = \mu + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + \varepsilon_{ij}$$

where

Y_{ij} = j^{th} catch success in the i^{th} net lift
X_1 = cumulative exploitation rate in %
X_2 = water temperature in ^{o}F
X_3 = river stage in ft
X_4 = turbidity in Secchi inches
X_5 = effort in net days.

Simple product moment intraclass correlation between independent variables (Table 14) showed significant values at the .05 level for temperature and flow rate. Correlation coefficients between turbidity values, lowering temperature and increased river stage were highly significant ($P < .01$). The correlation between exploitation rate and effort was highly significant because the total number of fish captured is used in the computation of both values.

Table 14. Simple product-moment intraclass correlation between variables effecting catch success of channel catfish

Variable	Exploitation rate	Temperature	River stage	Turbidity	Effort
Temperature	+.17				
Flow	+.24	+.25*			
Turbidity	-.23	-.40**	+.43**		
Effort	+.13	+.05	+.15	-.07	
Catch success	+.88**	+.20	+.15	-.21	-.20

*About ±.25 required for significance at .05 level.

**About ±.33 required for significance at .01 level.

The b_1 value in the model can be considered as a unit measure of changes in catch success with each unit change in exploitation rate. Partial regression coefficients to satisfy the normal equations and their standard deviations are listed in Table 15.

Table 15. Partial regression coefficients with catch success as the dependent variable

Variable	b value	S.D. of b
Exploitation rate	-.12	± .76
Temperature	+.26	± .24
River stage	+.83	±1.36
Turbidity	-.62	±1.36
Effort	-.56	± .30

This analysis revealed catch success declined slightly with cumulative exploitation, but the rather large standard deviation of the b_1 value indicated there might also be a slight increase. Analysis of variance for individual components (Table 16) showed non-linearity $(H_0:b_1=0)$ between catch success and exploitation rate. Extension of the analysis of variance revealed none of the independent variables strongly influenced catch success. Only about 3% of the

Table 16. Analysis of variance for regression model with catch success as the dependent variable

Source of variation	df	SS	MS
Regression on X_1	1	10	10
Regression on X_2	1	495	495
Regression on X_3	1	150	150
Regression on X_4	1	150	150
Regression on X_5	1	82	82
Residual	64	25,287	397
Total (corrected)	69	26,274	

deviation mean squares could be attributed directly to variability of independent variables. Apparently other unmeasured variables were effecting catch success and were not being included in the analysis.

Close inspection of the catch statistics indicated a random effects model might be less effective than a model where the variability of netting periods was fixed. Since catch success and exploitation rate are correlated, changing one would proportionately effect the other in a mixed model.

High catch success rates in Period 3 and 4 were attributed mainly to accelerated movement associated with spawning activity, particularly in the male segment of the catfish population. The secondary mode of Periods 8 and 9 was attributed to increased movement of smaller sized fish from shallow riffle areas, where nets were not set, to deeper pools when water temperature declined rapidly with the approach of late autumn. Channel catfish, which were previously not available for capture, suddenly moved into close proximity to baited nets. Low catch success in Periods 6 and 7 was attributed to sedentary habits during paternal nest care and guarding following deposition of eggs and care of young fish. Numerical values cannot be placed on biological activities, but by measuring periodicity components most of the influence of these factors was also measured. They must, however, be considered in combination because their individual influence was inseparable.

Adding the period effect, the model became

$$Y_{ij} = \mu + \rho_i + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + \varepsilon_{ij}$$

where Y_{ij} is the j^{th} catch success in the i^{th} period and ρ_i is the unique effect of the i^{th} period. All other variables are the same as before.

The value of b_1 increased about six units with each unit increase in exploitation (Table 17). Periodicity in catch success has a marked influence upon exploitation rate increasing in a linear fashion with accelerated catch rates. Again, this was not surprising because both catch success and exploitation rate are related by their association with total catch.

Table 17. Partial regression coefficients including effects of netting period with catch success the dependent variable

Variable	b value	S.D. of b
Exploitation rate	+5.93	±2.62
Temperature	- .22	± .68
River stage	-2.00	±1.91
Turbidity	+ .54	±1.40
Effort	- .19	± .25

Extension of the analysis of variance to include all independent variables indicated their unique contributions to the deviations mean squares after the effects of ρ_i were added to the model remained below the level of significance (Table 18). About 52% of the variability in catch success was attributable to variation of independent variables, of which 45% was due to variability between netting periods.

Table 18. Analysis of variance in catch success including the effects of netting period

Source of variation	df	SS	MS
Among periods	9	12,130	1,370*
Regression on X_1	1	1,212	1,212*
Regression on X_2	1	26	26
Regression on X_3	1	259	259
Regression on X_4	1	36	36
Regression on X_5	1	128	128
Residual	55	13,057	237
Total (corrected)	69	27,048	

*Significant at .05 level.

Accelerated movement as the result of spawning activity proved to be the single most important factor, although catch success also increased when movement increased in other periods. Separation of period effect into unique categories related to movement patterns was impossible. River stage was the most important environmental factor, but remained slightly below the 95% level of significance.

After the fish kill in project year 1967, when mortality was estimated at nearly 55%, catch success was drastically reduced during the following season. The catch success curve (Figure 7) showed the typical bimodal characteristics with inflections in the curve occurring at approximately the same periods. Catch success was reduced nearly 75% in early netting intervals and 50% in later periods. Loss in population density of this magnitude by any method would result in lowered catch success. Since the fish kill was an immediate reduction in population density its overall effects on catch success was probably more noticeable than sustained mortality, but continuous reduction in stock probably would be reflected in catch success regardless of the origin of mortality.

POTENTIAL EQUILIBRIUM YIELD

The original intent of this study was to gradually and systematically increase experimental exploitation of channel catfish in a mock commercial fishery while concurrent measurements of the biological reaction of remaining stock was evaluated. Exploitation by the net fishery would continue at increased levels until equilibrium yield was achieved. It soon became apparent without assignment of additional personnel to fishing crews it was impossible to exploit more than 20% of the catfish population during one calendar year. At this rate harvest barely exceeded recruitment of smaller fish into the fishery. By discontinuing collection of biological data from samples of exploited fish, the fishery might have been expanded slightly, but not to the extent where measurable changes in population characteristics could be expected. Then, without comparative data an appraisal of the fishery would be impossible. The best solution seemed to be construction of theoretical yield models where all forcing factors which increase biomass, such as growth and recruitment, were held in equilibrium with total mortality. A steady state model of this type would meet the original requirements of appraising the net fishery at different levels of fishing effort and still not jeopardize the quality of the sport fishery.

Potential equilibrium yield models are the principal tool for regulating many high seas fisheries, and truly sophisticated models were developed for optimizing harvest. They have been employed to a lesser extent for appraisal of small lake fisheries (Ricker, 1948; Patriarche, 1968; Zweiacker and Brown, 1971). Carlander (1958) discussed the application of mathematical models to actual fish populations and concluded models are generally useful to determine types of data needed for in-depth fishery appraisals and were most accurate when investigators had thorough knowledge of existing populations.

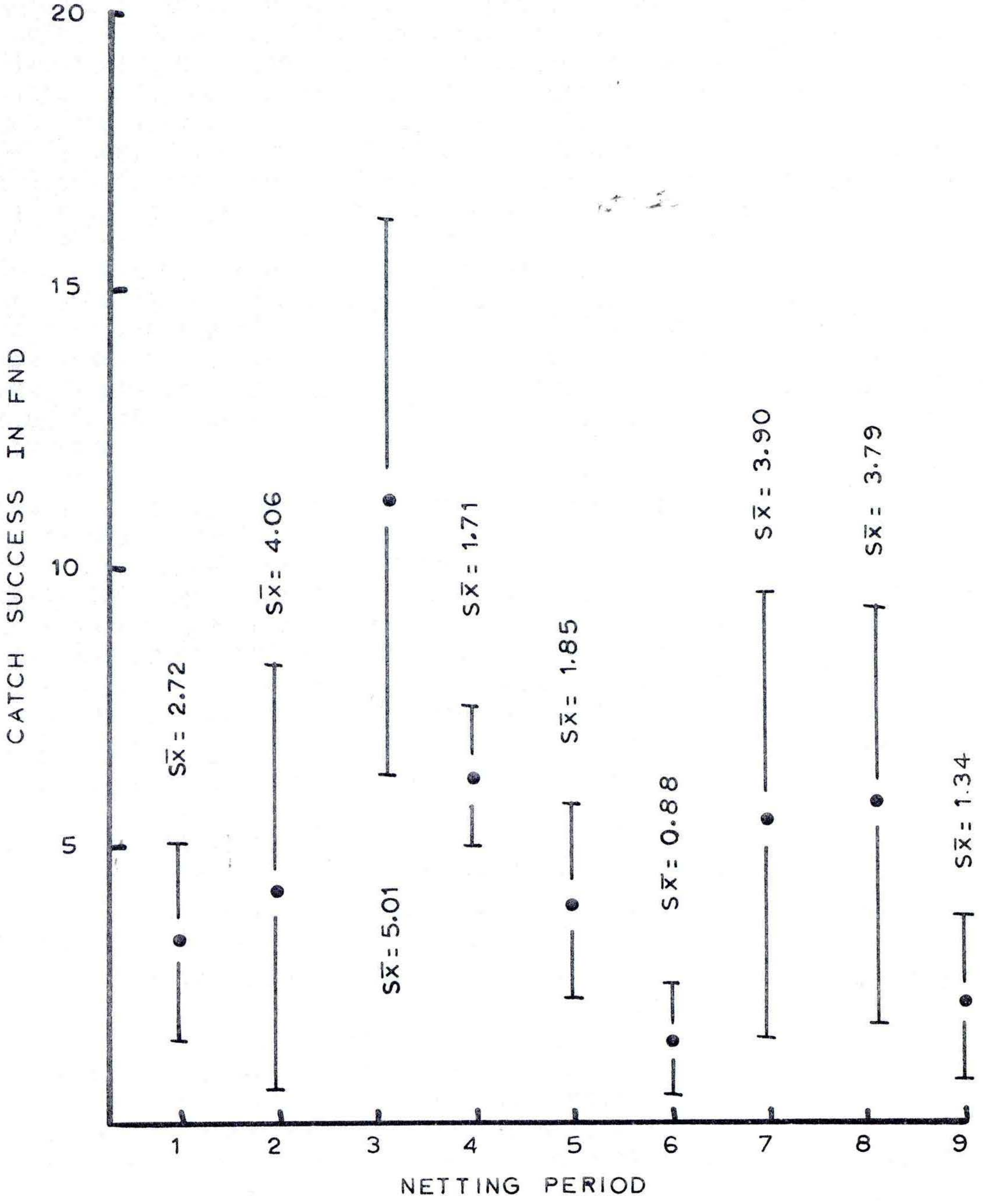

Figure 7. Catch success of channel catfish in baited hoop nets and slat traps during 1968.

The equilibrium yield models for channel catfish presented in this report followed the Beverton and Holt (1957) procedure after Ricker (1958). Potential equilibrium yield was computed at varied rates of fishing while growth and recruitment were held constant with total instantaneous mortality. Under these conditions stock would remain in a steady state and total instantaneous mortality rate equalled that established for the existing population before initiation of the net fishery. The portion of the fishery attributable to the sport fishery was included in the rate of fishing, but never comprised more than 10% of the harvest or .11 of the total instantaneous mortality rate.

Two potential yield models are presented for an initial stock of 4,000 catfish per mile. Although this value differed from the estimated mean annual numerical population of 3,605 fish it simplified computation of yield. Model A used the maximum observed weight of 6.12 lbs and Model B used the maximum attainable weight of 9.79 lbs from the Walford transformation. Minimum size of fish harvested in the models was 10-inches TL which entered the fishery at age 3.8 years or older.

Fishing rate (p) was the difference between total instantaneous mortality (i) and natural mortality (q) expressed algebraically by th equality $i = p + q$. With i at the maximum observed value of .70, p values varied from 0 with no fishing to .80 when all natural mortality was accoutned for by exploitation ($q=0$). Fishing rates were expressed in terms of annual mortality taken from a table of exponentail values, where total annual mortality (a) was the product of natural mortality (n) and fishing mortality (m) (symbols from Ricker, 1958). Since some of the fish caught in the net fishery would have died from natural causes and vice versa, total annual mortality can be expressed as $a = n + m - nm$. Total annual catch in terms of mortality was then $\frac{m}{n + m}\,a$.

Using the notations

T_Q = 3 years = age of recruitment into the fishery
T_R = 3.8 years = initial age of exploitation ($\geq$ 10-inches TL)
T_0 = 0 years = age at 0 length
T_λ = 8 years = maximum observed age of fish which was simplified by $t_\lambda = \infty$, where ∞ = 15 years
p = .10 to .80 = rate of fishing
q = 0 to .70 = rate of natural mortality
i = .70 = total instantaneous mortality
W = 6.12 and 9.79 lbs = asymptotic weight
K = .12 = $-\log_e k$, where k is the estimated slope of the Walford line.

The initial decrease in numbers of fish from T_Q to T_R by natural mortality was determined by

$$R = Q_e^{-q(t_R - t_Q)}.$$

At 3.8-years the loss of fish due to natural mortality from the age of initial recruitment at 3-years was

$$R = 4{,}000_e^{-.56 \times .8} = 4{,}000_e^{-.45} = 4{,}000(.64) = 2{,}550.$$

The number of catfish entering the fishery at other ages was as follows: 4-years, 2,284; 5-years, 1,305; 6-years, 745; 7-years, 426; and 8+-years, 243.

When growth is isometric so $b \approx 3.0$ in the growth curve

$$W_t = W_\infty(1 - e^{-K(t - t_0)})^3$$

then theoretical equilibrium yield by Jones' modification from Ricker (1958) can be expressed as

$$Y = pRW_\infty\left(\frac{1}{i} - \frac{3e^{-K(t_R-t_0)}}{i + K} + \frac{e^{-2K(t_R-t_0)}}{i + 2K} - \frac{e^{-3K(t_R-t_0)}}{i + 3K}\right)$$

In Model A with the age of fish entering the fishery set at 3.8-years and W_∞ at 6.12 lbs potential yield ranged from 296 lbs per mile at a fishing rate of .10 to 998 lbs with a .80 rate (Table 19). Yield isopleths in Figure 8 were highest near the point of entry, curving upwards to the right, nearly reaching maximum yield at the .50 exploitation rate. Continued effort would produce only small additional poundage, because most of the harvestable biomass was contained in fish 6-years old or younger. Potential yield at all rates of fishing and ages of entry into the fishery for Model A are listed in the table.

Table 19. Potential equilibrium yield of channel catfish in lbs per mile of stream using Model. Initial size of stock was 4,000 per mile, maximum observed weight was 6.12 lbs and total instantaneous mortality was .70

Age at entry into fishery	N entering fishery	Rate of fishing .1	.2	.3	.4	.5	.6	.7	.8
3	4,000								
3.8	2,550	296	530	702	811	858	936	983	998
4	2,284	265	474	628	726	768	838	880	894
5	1,305	151	271	358	415	438	479	502	511
6	745	85	154	204	236	250	273	286	291
7	426	48	88	116	135	143	156	164	166
8+	243	27	49	66	77	81	88	93	94

Yield of catfish in Model B was higher because of a greater maximum attainable weight. Using 3.8-years as the initial age of entry into the fishery, production ranged from 474 lbs per mile at a .10 rate of fishing to 1,597 lbs at the maximum rate (Table 20). Potential yield at other rates of fishing are listed in the table. As shown in Figure 9, yield contours showed nearly identical distribution as in Model A except for higher values at all levels of fishing.

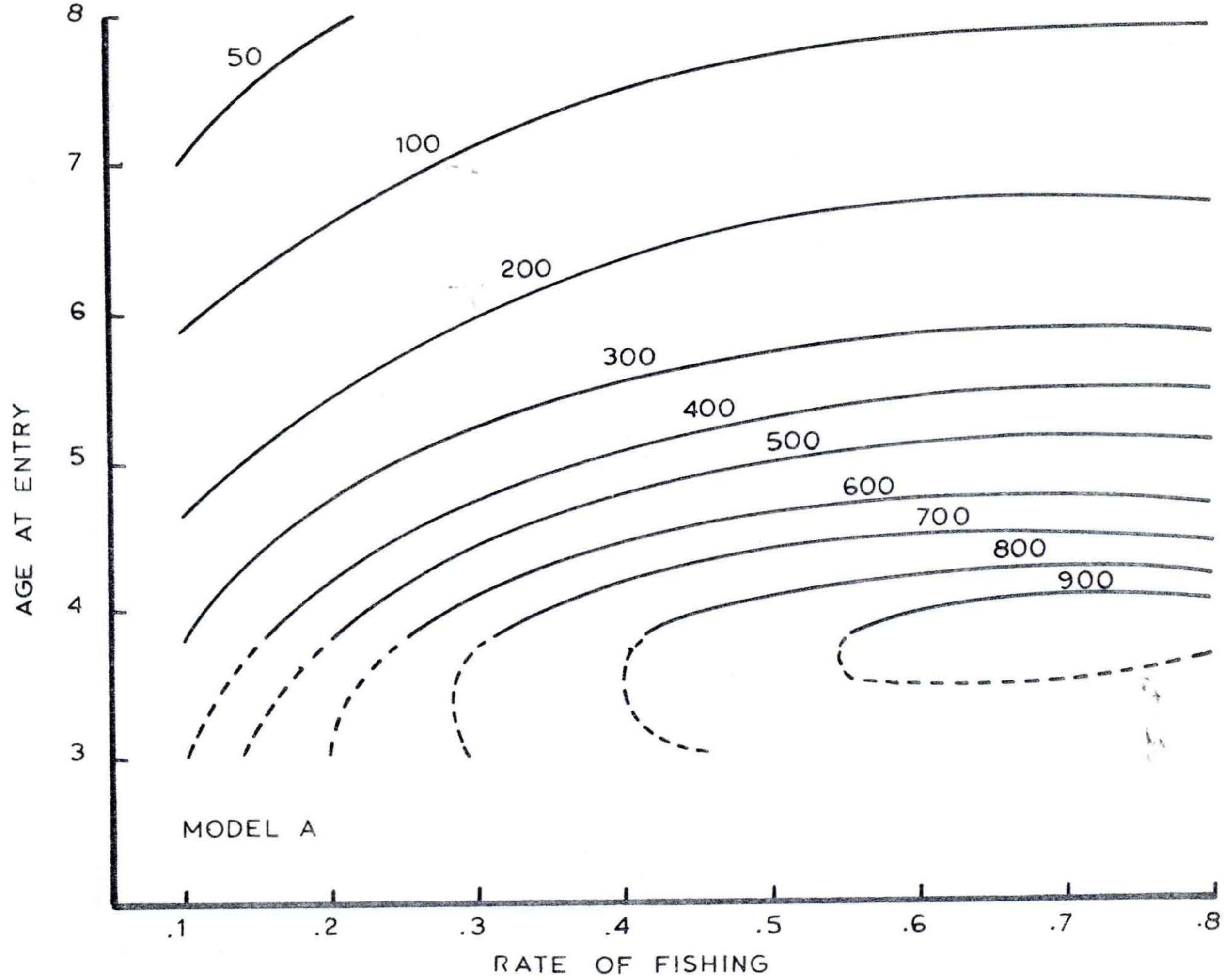

Figure 8. Isopleth contours of potential equilibrium yield of channel catfish. Total instantaneous rate is the same as Model A and $W_\infty = 6.12$ lbs. Dotted lines are values of fish < 3.8 years or 10 inches TL.

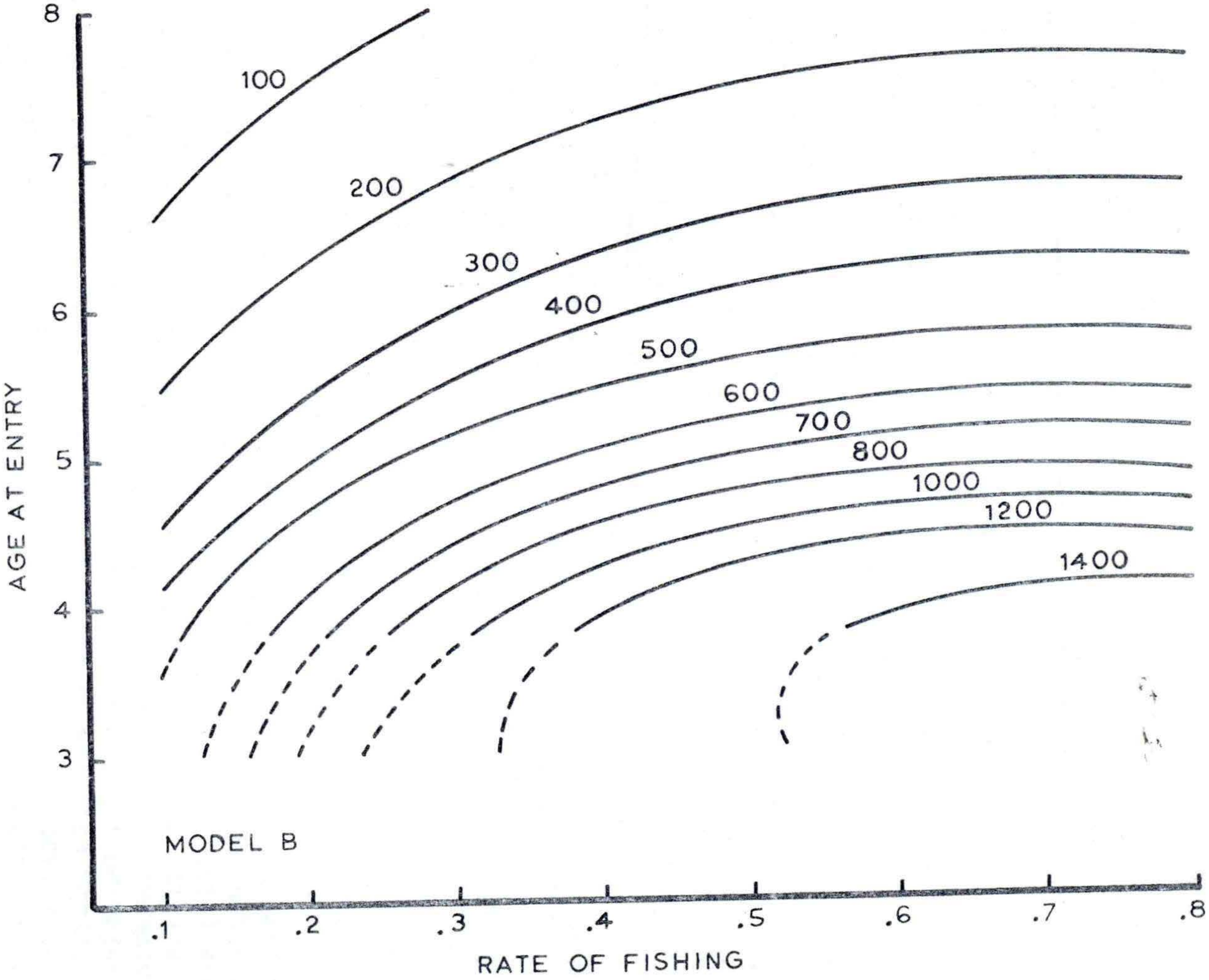

Figure 9. Isopleth contours of potential equilibrium yield of channel catfish. Model assumes a total instantaneous mortality (i) of .70, and W_∞ = 9.79 lbs. Dotted lines are values for fish < 10 inches TL.

Table 20. Potential equilibrium yield of channel catfish in lbs per mile of stream using Model B. Initial size of stock was 4,000 per mile, maximum attainable weight was 9.79 lbs and total instantaneous mortality was .70

Age at entry into fishery	N entering fishery	Rate of fishing .1	.2	.3	.4	.5	.6	.7	.8
3	4,000								
3.8	2,550	474	848	1,123	1,298	1,373	1,497	1,572	1,597
4	2,284	424	758	1,005	1,161	1,229	1,341	1,407	1,430
5	1,305	241	434	574	664	702	766	804	817
6	745	137	247	327	379	400	437	459	466
7	426	78	141	186	216	229	249	262	266
8+	243	44	79	105	123	130	141	149	151

Age at entry into the fishery can be changed in both models to accommodate different size restrictions. If the 10-inch size limit presented was too small and regulations were adopted so a minimum size of 13-inches TL comparable to the Mississippi River fishery was desirable only the age of entry must be increased to compute yield. Age of entry for a 13-inch TL regulation in this study would be about 4.7 years. Equilibrium yields for fishing rates ranging from .10 to .80 would be 184, 304, 391, 448, 471, 512, 535 and 544 lbs per mile for Model A and 295, 488, 628, 718, 756, 820, 858 and 871 lbs per mile for Model B. Any number of similar changes could be made in fishing rates or size regulation using the available information.

CONCLUSIONS AND RECOMMENDATIONS

Each mile of the lower Des Moines River study area contained a mean annual standing crop of 3,508 channel catfish having a TL of 10-inches or greater and a mean annual weight of 2,769 lbs. Of this population, total annual mortality from all causes was estimated at 1,765 fish. Mortality attributal to the sport fishery was 194 fish and the remaining 1,570 succumbed from natural causes. Total poundage of the portion of the population dying from natural cause was approximately 1,178 lbs. It is this segment of all fish mortality which could be exploited by a net fishery and not jeopardize the sport fishery nor change the present population biomass. The equilibrium yield models, where the available stock was adjusted for growth, recruitment and mortality, showed predicted surplus yields varying from 998 lbs to 1,597 lbs per mile depending upon use of maximum observed or attainable body weight in the computations. Potential yield for a fishery with a 13-inch TL minimum size restriction was nearly 875 lbs per mile.

Monetary value of a commercial fishery based on the reported average price for catfish in the round of 35¢ per lb at Mississippi River landing was estimated at $350-$559 per mile in the two models. It is fairly obvious the channel catfish population density was not sufficient to support profitable traditional commercial fishing ventures. Each commercial operator would have to fish more than 35 miles of the river to capitalize his investment and return a reasonable profit. Boat navigation of the river is generally undependable in late summer and early autumn because of low river flow, and access to many reaches of the stream would require motorized road transportation. Twice during the study certain reaches of the stream were isolated by such low flow over riffles boat passage was impossible. Workable fish landings to centralize commercial fishing operations are scarce along much of the lower Des Moines River basin and fishermen would soon become discouraged and abandon fishing.

The greatest potential for utilization of surplus stocks of catfish seems to be by extension of the sport fishery to include entrapment types of fishing gear. Through issuance of an additional license, fishermen would be permitted to set a limited number of slat traps or hoop nets. A similar license is currently issued for the Mississippi and Missouri Rivers for slat traps and trotlines with annual sales for about 2,000 pieces of gear. Territorial limitations, seasons, attendance regulations, minimum size limits and other restrictions could be set to accommodate enforcement problems. Initiation of a fishery of this type would undoubtedly cause criticism simply because it is a new procedure, but a thorough education and information program would minimize much of the adverse response.

Regulations for controlling seasons, size limits and number of traps allowed to individual fishermen would be necessary. Some sort of net ownership identification and catch report system would also be desirable. Seasonal limitations are important in regulating the harvest of large numbers of spawning catfish. Of most concern is the concentration of great numbers of fishermen into a reach of the stream where access is easy, resulting in heavy netting pressure when catch success of mature female catfish is high, thereby lowering production of young fish. Minimum size limits are easily controlled by either departmental regulation or by restricting mesh size. Traps with 1 1/4-inch openings would take few catfish < 13-inches TL.

Biological adjustment of catfish stock to increased exploitation by the experimental net fishery was unresolved for the most part, but several changes could be anticipated. First, by imposing a size limit there would be an immediate reduction in mean size of fish in the population due to protection of smaller fish. Second, as yield approached a steady state of balance between all the forcing factors there would be acceleration of both rate of growth and recruitment into the fishery. Growth of catfish in the present study was slow and the population could be classified as "stunted". Increased growth from optimizing surplus yield by the net fishery should produce a faster growing, better quality catfish for both the sport and net fisheries. Fastest growth and best body condition values for catfish reported in this state was from the Mississippi River where an intensive net fishery yields up to one-half million lbs of catfish yearly. In the long run a net fishery in the Des Moines River, would probably enhance the quality of the sport fishery, although liberalization of fishing methods as a sport fish management tool should not be the main reason for allowing the net fishery.

Two major problems exist which might hinder human utilization of catfish for food. First, catfish flesh in this stream contain high concentrations of residual Dieldrin, and second, there was a chronic taste and odor problem in fish taken below metropolitan Des Moines. Samples of fish flesh analyzed by the State Hygienic Laboratory during 1971 contained Dieldrin concentrations ranging from 520 to 560 ppb (Report No. 71-10, The State Hygienic Laboratory, Iowa City). Food and Drug Administration guidelines for maximum permissable concentrations are 300 ppb. Further studies of Dieldrin in fish flesh indicated lower basin and larger sized fish samples would probably contain greater concentrations. Legalization of a fishery which would permit increased utilization of this resource for human consumption has moral implications which must be resolved. A warning of high concentrations of Dieldrin should accompany any license issued for a fishery of this type.

Complaints of a tainted taste which resembles a petroleum material such as gasoline or kerosene have been received from fishermen in this region of the Des Moines River for many years. Cooperative investigations with the State Hygienic Laboratory were conducted in the study area during 1967. Sampling procedures and analytical results can be reviewed in the Semi-Annual Report, State Hygienic Laboratory (1967). These studies revealed as high as 70% of the sampled catfish were unpalatable to the tasting panel. No single cause could be isolated except for the fact the river in general was being polluted by untreated wastes containing oil materials from the sewage disposal plant bypass and the treated effluent. Since enlargement of the plant in 1968 there has been little improvement in the taste of fish flesh in the vicinity of the study area, and complaints have continued each summer. It would be of little benefit to expand the harvest of fish by libralizing methods of capture unless flesh of the fish was usable.

Anticipated fishing pressure with slat traps and hoop nets is difficult to determine, particularly when a net fishery was previously prohibited. The amount of effort required to harvest surplus stocks of catfish becomes important to prevent over exploitation. Catch success of catfish $\geq$ 10 inches TL ranged from 2.6 FND in 1968 to 9.1 FND in 1967 with an overall mean of 5.1 FND or about 4-lbs of catfish per net day. At the mean rate of catch success determined in this study between 244 and 372 net days per mile would be required to exploit the catfish population at an equilibrium rate. Actual highest effort exerted in the study area was 105 net days in 1968 following the fish kill when catch success was extraordinarily low. Least pressure occurred in 1967 when 55 net days per mile were expended. The number of suitable netting sites would restrict effort in many reaches of the stream. Fishing effort in excess of the higher values by a public fishery seems highly unlikely.

Overall appraisal of the catfish population revealed only a small portion is being utilized in the sport fishery. The bulk of the total annual mortality is simply lost from the population with an equal biomass replaced by younger fish. Potential equilibrium yield models indicated exploitation could be increased six to eleven-fold from its present level and not change the total population biomass. With increased harvest and anticipated acceleration of growth rate and recruitment the quality of the sport fishery should also improve. Without increased harvest there is little chance the biological characteristics of the population will improve, growth will remain stunted and the catfish in rather poor body condition. Mostly, the population will continue to be a vast and virtually untapped natural resource.

Based on findings of this study the following recommendations for increasing utilization of surplus stocks of channel catfish are presented.

1. The use of entrapment types of fishing gear should be legalized on an experimental basis in the lower Des Moines River while the biological impact of the fishery and its popularity among fishermen are evaluated. Suggested territorial boundaries opened to the fishery are located from County Road P bridge below Red Rock Dam and Reservoir in Marion County to the confluence of the Mississippi River in Lee County. These boundaries would effectively reduce the taste and odor problem below Des Moines and the reservoir would serve as a large collecting basin for lowering concentrations of residual insecticides in catfish flesh. The upper boundary was suggested to reduce interference with the heavy sport fishery in the tailwaters of the dam outlet. If harvest of surplus catfish stocks was orderly and without regulation enforcement problems of large magnitude there is no biological reason why the fishery could not be expanded to other large interior streams in Iowa. Possession of species of fish statutorally classified as rough fish should also be permitted.

2. Present licensing procedures for individual pieces of gear used in the Mississippi and Missouri Rivers should be followed for this fishery. The combined number of pieces of fishing gear permitted for each licensee should be restricted to three or fewer until some estimates of fishing pressure are completed. Legal gear should be restricted to hoop nets and slat traps with a minimum stretch opening of 1 1/4-inches to reduce handling of large numbers of smaller catfish. All gill nets, trammel nets, fyke nets and drag seines should be prohibited. Ownership identification tags for each piece of fishing gear should be compulsory.

3. Minimum size limit of catfish in possession of the net owner should be restricted to fish 13-inches or greater TL to protect the large population of immature fish and the younger mature fish. Further, not many fishermen regard a smaller catfish with much table value.

4. Seasonal regulations should be set to prohibit net fishing during catfish spawning activity from June 1 through July 30 each year. These dates would prevent over harvest of large female catfish during the time they are highly vulnerable to these types of gear. Daily catch limits of eight channel catfish should be removed from both the sport and proposed net fishery.

5. A compulsory report card should be filed monthly for total number and weight of fish caught with the Fisheries Section.

6. Comprehensive fisheries research should continue to evaluate the biological impact of the net fishery by a Commercial Fisheries Research and Development project. Findings of the research should be useful in maximizing optimum yields.

7. Regulatory rules governing the fishery should be flexible so harvest can be adjusted to the availability of the resource.

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