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ABSTRACT

Flathead catfish, Pylodictus olivaris (Rafinesque), were studied in approximately 83.7 km of unchannelized and 67.6 km miles of channelized Missouri River. Growth rates were slower in the unchannelized section than they were in the channelized section. The oldest fish in the unchannelized section was 25 years old, while in the channelized study area the oldest was 10 years. In the pectoral spines of progressively older fish from both sections, enlargement of the lumen obliterated early annuli. Much of the annual increment of growth was accomplished during June, July and August. Males became sexually mature at 3 to 4 years of age and 350 to 425 mm, while females matured between 3 and 5 years and 350 to 500 mm with most mature females measuring at least 450 mm. Approximately 1,500 eggs per pound of body weight were produced.

Three orders of insects (Ephemeroptera, Trichoptera and Diptera) dominated the food habits of young-of-the-year flathead catfish in both study areas; however, there were some generic differences. Yearlings and adults consumed primarily fish and crayfish, with crayfish being more intensively utilized in the unchannelized study area.

Fish 200 mm and longer were marked in order to estimate movements and population sizes. Between the two study areas there was little difference in movement patterns. Based on fishermen's reports, 25 percent of the recaptured fish were within 1.6 km from the point of tagging. Mean upstream and downstream distances moved were identical (40.2 km) but 57 percent of the fish were reported downstream of the point of release. Our recapturing of marked fish indicated less movement (86 percent were within 1.6 km) than did recapturing by fishermen because we did not attempt to collect marked fish outside of the two study areas. Marked fish avoided crossing the main channel. Population estimates for fish 200 mm and longer were 17 fish per linear km and 9 per linear km in unchannelized and channelized study areas respectively. Estimated standing crops were 130 grams per hectare in the unchannelized study area and 149 grams per hectare in the channelized study area.

INTRODUCTION

The Missouri River in eastern Nebraska is of two distinct environmental types--an upper unchannelized section and a lower channelized section. The limnology of both sections has been altered by six main stem impoundments located immediately upstream of the unchannelized section. Channelization has also influenced the limnology of that section through narrowing and deepening of the flow. The effect of the main stem impoundments and channelization upon Missouri River limnology has been described (Neel, Nicholson, and Hirsch, 1963; Morris, Langemeier, Russell, and Witt, 1968). In general, the impoundments have improved downstream water quality while channelization has been detrimental by causing homogeniety of environment and reduction of the benthic area.

Flathead catfish occur throughout both unchannelized and channelized sections. Typically they inhabit brush piles and associated pools in unchannelized rivers while in the channelized section they are most frequently found along rock-covered stabilization structures and the pools at their downstream ends. Barren areas of swiftly flowing water are largely devoid of flathead catfish of any size.

Our purpose in this investigation was to study the life history of flathead catfish in both unchannelized and channelized sections. In each section we examined age and rate of growth, food habits, movement and population density. By so doing it was possible to pinpoint some of the environmental factors which affected population structure within each of the two study areas. Further, by comparing these environmental factors we were able to determine some of the ways in which channelization affects the studied aspects of flathead catfish life history.

Plan of Study

The study extended from 1963 through 1967 but field investigations were limited to June through August of each year. There was no field work in 1964.

Flathead catfish were studied in most of the 83.7 km of unchannelized section and in 67.6 km of channelized river (Figure 1). Most of the 257.6 km of river separating the two study areas was channelized; however, channelization was only partially complete immediately downstream of the unchannelized river.

The unchannelized study area was characterized by a meandering main channel bordered with sandy flats and brush islands which were separated by interconnected chutes. Fallen trees drifted together thus forming brush piles in both the swiftly flowing main channel and in the quieter chutes. Once formed these brush piles collected debris and sometimes exceeded 15 m in diameter. Frequently the moving water formed "holes" beneath the brush piles. Duration of individual brush piles varied but some were present throughout the investigation.

In the channelized study area, rock-lined pile dikes and revetments constricted the flow thereby eliminating most chutes and brush piles. However, barren pools were created at the lower ends of both types of stabilization structures. Larger pools were associated with the pile dikes because they extended at a downstream angle for a short distance into the main stem. Revetments, paralleling the flow of the river, did not cause the water turbulence necessary for forming large, deep pools.

Flathead catfish were collected by means of hand-cranked and motorized telephone generators (Morris and Novak, 1968) and by application of rotenone to selected slack-water areas. All fish used in mark and recapture experiments were collected with telephone shockers. During the five-year study, 471 flathead catfish were captured in the unchannelized study area while 900 were collected in the channelized study area.

Age and rate of growth as well as food preferences were based upon 299 fish from the unchannelized river and 350 from the channelized study area. These were collected in 1963. Supplementary information regarding seasonal growth of tagged fish was gained through the mark and recapture experiments.

Aging was by examination of pectoral spine cross sections (Snead, 1951). Spines less than 15 mm long were glued between pieces of balsa wood to prevent shattering during sectioning. Because annuli in the posterior field were frequently indistinct, all measurements were made along the antero-lateral radius.

After examining cross sections of spines from fish of increasing lengths, it became apparent that enlargement of the lumen in progressively older fish obliterated early annuli. Jenkins (1952) and Minckley and Deacon (1959) previously reported deterioration of the central lumen in flathead catfish but did not mention loss of annuli. In order to confirm loss of annuli, we sectioned spines through the articulating process where there was no lumen.

Stomachs were preserved in 10 percent formalin and the contents recorded as percentage of stomachs in which each kind of food occurred (frequency of occurrence) and as percentage of the total weight of all foods represented by each kind of food (percentage of total weight). Calculations were based only on those stomachs which contained food. At the unchannelized study area 73 percent contained food while at the channelized study area 61 percent had food items. Within each study area there were no measurable differences in stomach contents during the three months so the data was combined.

Tagging was begun in 1965 in order to estimate movement and population numbers through subsequent recovery of the marked fish. Each fish was tagged by rolling a numbered plastic bandette around the dentary bone after making an incision in the floor of the mouth. One of three sizes of bandettes was used depending upon the total length of the fish; however, only those fish 200 mm and longer were marked. In 1965 a total of 407 flathead catfish were tagged throughout the 33.8-km channelized study area. None were tagged in the unchannelized section. During 1966, an additional 179 flathead catfish were marked in a 33.8-km portion of the unchannelized study area while 148 were tagged in the channelized river. Marking was discontinued in 1967; however, several fish that had been previously tagged were recaptured.

In order to determine movement by the marked fish, distances between points of marking and recapture were estimated in the following manner. Individual flathead catfish habitats in each study area (i.e. brush piles and pile dikes) were numbered with fluorescent paint for future identification. The location of these places was then noted on maps and aerial photographs. Subsequently, the number from each marked fish was recorded on the maps and photographs at the places of marking and recapture. Distances were then estimated by measuring the shortest water route between the points. Movements were recorded to the nearest 0.16 km so that "0" distance in all discussions indicates a recapture at the marking site or within approximately 160 m either upstream or downstream.

Population estimates in both study areas were by the modified Schnabel method as marking extended from June through August each year.

Initial attempts to collect flathead catfish from the barren shorelines between brush piles in unchannelized river and between stabilization structures of the channelized study area were unsuccessful. Thereafter we limited collecting efforts to the brush piles and stabilization structures. For this reason it is probable that we did not shock all places where flathead catfish may have occurred and this likelihood could have caused bias in the movement data and in the modified Schnabel population estimates.

In order to encourage sport and commercial fishermen (commercial fishing occurs in the lower 77.3 km of unchannelized river and throughout the channelized river) to return tags from marked flathead catfish, we offered a reward of either $1 or $5, depending upon the tag number. To qualify for the reward, a fisherman returned the tag along with the date and place of capture and length of fish. We believe that commercial fishermen were suspicious of our objectives in tagging flathead catfish and did not return all tags.

It was not possible to determine whether commercial fishing pressure was greater in the unchannelized or in the channelized study area as permit holders in Nebraska were not required to report their fishing locations. However, during 1963, 25 percent lived in or within 40.2 km of the unchannelized study area. Almost one-half (45 percent) of the 297 commercial licensees lived in or within 40.2 km of the channelized study area. Together the 297 fishermen voluntarily reported harvesting 17,950 pounds of flathead catfish in 1963.

Additional commercial fishing pressure was exerted by residents of South Dakota, Iowa, and Missouri. The estimated number of these commercial fishermen totaled less than 70 in each study area during the investigation period (personal correspondence).

RESULTS

Age and Growth. -- Pectoral spine sections used for aging were removed just beyond the distal end of the basal recess. In older fish, enlargement of the basal recess causes the point of sectioning to move distally and the distances between early annuli and the lumen decrease due to the cone shapes of the growth areas. Because of the enlargement of the central lumen, a part of an annulus and even complete annuli were frequently lost in the pectoral spines. As mentioned previously, loss of annuli was confirmed by making a section through the articulating process. Although this section without a lumen permitted accurate aging, it was not used for back-calculating growth as a constant reference point such as the center of the lumen was not established.

As a result of enlargement of the lumen in age group I fish, a portion of the annulus was frequently lost, but in no case was the annulus missing along the radius used for back-calculations. In older age groups, however, portions or complete annuli were lost with increasing frequency (Table 1). Forty-nine percent of age group II, 91 percent of age group III and 100 percent of age group IV fish showed loss of the first annulus along the axis used for measurement. All succeeding age groups had 100 percent loss of the first annulus. The first four annuli were missing in those fish 15 years and older. It is apparent that serious errors in aging and back-calculating would have resulted if loss of annuli were not taken into account.

Body-spine relationships were determined for 200 fish (85-1,107 mm) from the unchannelized study area and for 190 fish (102-860 mm) from the channelized study area. The curvilinear relationship for fish from unchannelized river was:

$$BL = 22.3795 + 2.4629S + 0.00152$$

For the channelized study area it was:

$$BL = 6.6076 + 2.7751S + 0.0009S^2$$

where BL = total length of fish in mm

S = spine radius x 100

The differing intercepts were probably related to size ranges of fish in the two study areas. For fish from the unchannelized study area the range was considerably larger.

In each study area the data were analyzed for differential growth between the sexes. During the first five years of life there were no appreciable differences. Thereafter, the sample size was considered too small for valid comparisons, although in both study areas, growth rates of males exceeded that of females.

Sixteen year-classes were found at the unchannelized area ranging from age groups 0 through XXV, while in the channelized study area only 11 year-classes were found. These ranged from age groups 0 through X. Summaries of the growth patterns for age group I and older fish are presented for unchannelized and channelized study areas in Tables 2, 3 and 4 respectively. The abundance of older age groups in unchannelized river and the lack of them in channelized river remains unexplained.

The three flathead catfish in age groups XXII and XXV collected from the unchannelized study area appear to be the oldest on record; however, they are not the largest. McCoy (1953) reported a 15-year-old flathead catfish which weighed 95 pounds and measured 55.5 inches in length. The 25-year-old fish collected from the unchannelized study area weighed 44.1 pounds (20 kg) and was 42.4 (1,077 mm) inches long. The fast growth rate reported by McCoy may be due to the warmer waters and longer growing season in Oklahoma than in Nebraska.

Young-of-the-year flathead catfish were first collected on August 9 in the unchannelized study area and July 15 in channelized river. Those from the channelized study area were consistently larger as 149 which were collected between August 1-31 averaged 50.9 mm in total length while 99 collected in unchannelized river from August 9-22 averaged 41.5 mm. On August 30, 31 young-of-the-year collected in the channelized study area ranged in total length from 49-76 mm and averaged 62.8 mm. Forty-six were collected in unchannelized river on August 22. Those ranged in total length from 32-64 mm and averaged 48.1 mm.

Growth rates of flathead catfish in the Missouri River are rather slow and relatively even during the first five years of life (Tables 2, 3 and 4) when compared with other studies (Upper Missouri River Conservation Committee, 1946; Cross and Hastings, 1956; Purkett, 1958; and Minckley and Deacon, 1959). Growth in unchannelized river appeared to be somewhat faster during the second year of life than at the channelized study area during the same period. However, as just discussed, growth of young-of-the-year flathead catfish was greater in the channelized study area than in unchannelized river as was growth of older flathead catfish.

The only plausible explanation for this incongruity lies in the difference in intercept values used for back-calculations. In unchannelized river the value was 22.4 while in the channelized study area it was only 6.6. With the greater intercept value in unchannelized river than at the channelized study area, the fish would appear to be larger during their first years of life than they actually were. This hypothesis is substantiated by the data in Tables 2 and 4. Age group I fish in the unchannelized study area had an average total length at capture of 128 mm while those in channelized river were 151 mm long. Age group II fish were also larger in the channelized study area.

Another method used to show that the growth curve was inconsistent for the early years of life involved plotting the growth of fish in age groups I and II during the summer. Throughout the summer these age groups were smaller in the unchannelized study area than in the channelized study area, usually by 20 to 25 mm. Thus, it is apparent that the growth of flathead catfish in all age groups was consistently greater in the channelized study area which was 57.6 km downstream of the unchannelized study area. These results support Purkett's (1958) conclusion that stream fishes normally grow faster in downstream sections.

Information regarding summertime growth of flathead catfish was gained through the mark and recapture operations of 1965 and 1966. In considering these data it must be remembered that the jaw tags used in marking may have affected feeding and this in turn could have slowed growth.

The summertime growth of recaptured flathead catfish is summarized in Table 5. Fish in the unchannelized study area were at large from 2 to 70 days with a mean of 22 days. Time at large for those from the channelized study area ranged from 7 to 70 days and averaged 28 days. When these data are compared with annual increments of growth in Tables 2, 3 and 4, it is apparent that flathead catfish accomplish much of each year's growth during the summer months. In each size group the mean growth rate for fish in the unchannelized study area was slower than the corresponding rate for those fish in channelized river.

The length-weight relationships for flathead catfish in the two study areas are expressed by the following logarithmic equations:

Unchannelized study area --

young-of-the-year (22-64 mm) $\log W = 4.9359 + 3.0558 \log L$

others (85-1,107 mm) $\log W = 5.4098 + 3.1759 \log L$

Channelized study area --

young-of-the-year (19-80 mm) $\log W = 4.2611 + 2.6374 \log L$

others (102-860 mm) $\log W = 5.4382 + 3.1809 \log L$

where W equals weight in grams and L equals total length in millimeters. Average standard length and total length conversion factors for 537 fish from both study areas are as follows: SL = 0.8631 TL; TL = 1.1591 SL.

Sexual Maturity

Male flathead catfish attained sexual maturity at a length of 356 to 432 mm (3 or 4 years old). A few sexually mature males were less than 356 mm but these were three years old. Sexual maturity in the females was attained at a length of 356 to 508 mm (3 to 5 years old) with the majority of mature females measuring 457 mm or more in total length.

Minckley and Deacon (1959) stated that "loss of the light-colored patch at the tip of the upper lobe of the caudal fin may indicate sexual maturity." Our observations on the flathead catfish in the Missouri River do not verify this statement as both mature and immature individuals possessed this light-colored spot.

Dates for spawning by flathead catfish are June and July (Beckman, 1953, and Minckley and Deacon, 1959). In the Missouri River (1963) spawning occurred primarily during July with some spawning in late June. Food consumption during the breeding period may have been curtailed as all of the ripe females and nearly all of the ripe males which were collected had empty stomachs.

Ovarian egg counts were made on 11 mature females which ranged from 1.3 to 12.2 kg. As determined gravimetrically (Lagler, 1956) the mean number of eggs per kg of body weight was approximately 3,300.

Food Habits

Immature aquatic insects were the most abundant food items of young-of-the-year flathead catfish and comprised 99 percent and 97 percent of the total weight of food consumed and they occurred in 98 percent and 95 percent of the stomachs at the unchannelized and channelized stations, respectively.

The principal families and genera of the three most important orders of insects found in the stomachs of young-of-the-year flathead catfish at the unchannelized station were: Trichoptera-Hydropsychidae (*Hydropsyche*); Ephemeroptera-Baetidae (*Isonychia*); and Diptera-Tendipedidae. The remainder of the food items in stomachs of young-of-the-year at the unchannelized station included: Crustacea-Amphiopoda; Coleoptera and plant material. These items comprised only 1.3 percent of the total weight of food consumed.

At the channelized station the principal families and genera of the three most important orders of insects were: Trichoptera-Hydropsychidae (*Hydropsyche*); Ephemeroptera-Heptageniidae (*Stenonema*); and Diptera-Tendipedidae. Other food items of minor importance included Crustacea-Amphiopoda and Isopoda, Odonata-Coenagrionidae, Hemiptera and plant material. Plant material found in the stomachs at both stations did not include actively growing vegetation, such as algae, but rather was composed of woody fragments believed to have been taken fortuitously.

These food habits of young-of-the-year flathead catfish in the Missouri River were nearly identical to those of young-of-the-year in the Neosho and Big Blue rivers, Kansas (Minckley and Deacon, 1959).

Fish and crayfish were the two most important food items of yearling flathead catfish and those up to 360 mm in total length. Together these two items made up 93 percent of the total weight of stomach contents of flathead catfish at the unchannelized station and 90 percent of the total weight at the channelized station. Although the frequency of occurrence of insects in the diet was relatively high, 73 percent at the unchannelized station and 37 percent at the channelized station, insects comprised but a small percentage of the total weight, 5 percent and 3 percent respectively.

In the channelized river, fishes made up 79 percent of the weight of food items but only 63 percent at the unchannelized station. This decrease of fish in the diet at the unchannelized station was replaced by crayfish.

Principal fishes found in the stomachs of the flathead catfish at the two stations included: Ictalurida-Pylodictus olivaris, Ictalurus punctatus, and Ictalurus melas; Cyprinidae-Notropis spp. and Percidae.

It seems that the dissimilarity in consumption of fish is a result of the difference in abundance of forage fish and a difference in the degree of aggregation of these fish between the two stations. Samples by rotenone and seines indicated a greater abundance of forage fish, primarily cyprinidae, at the channelized station than at the unchannelized station. However, even if this is not a valid assumption, Ivlev (1961) has shown that patchiness in the distribution of food increases the amount of food consumed by comparison to an even distribution when the average concentration is the same in both cases. Consequently, an increase in the degree of aggregation, which was brought about by numerous stabilization structures in the channelized study area, is equivalent to a rise in the concentration of forage fish and results in increased competition.

The food habits of fish larger than 360 mm do not differ markedly from those of the size group just discussed. Insects were insignificant in the diet both in percentage of total weight and frequency of occurrence. Fish and crayfish were again the two most important food items at the unchannelized station making up 81 percent and 17 percent of the weight consumed respectively. Crayfish, however, entered the diet only once at the channelized station and made up an insignificant 0.6 percent of the total weight of food consumed. Fish comprised 98.5 percent of the diet and ocurred in 82.4 percent of the stomachs of flathead catfish at the channelized station. Ictaluridae - Ictalurus punctatus and Pylodictus olivaris and Cyprinidae - Cyprinus carpio were the principle families and fishes consumed. Others included Clupeidae - Dorosoma cepedianum, Cyprinidae - Hybognathus nuchalis, Hybopsis storeriana, Notropis sp., Sciaenidae - Aplodinotus grunniens and Percidae.

Movement

During the three years of mark and recapture (1965-1967) tagged fish were recovered with the telephone shocker 38 times in unchannelized river and 138 times in the channelized study area. Although there were wide variations in individual movements, to facilitate discussion, the recaptured fish were placed into three size groups based upon total length at tagging. Smaller groupings based on size at tagging, produced in similar patterns of movement. The selected size groups are as follows: small, 200-299 mm; medium, 300-499 mm; and large, 500 mm and larger.

The time at large between marking and recapture varied from 2 to 756 days with the mean number of days for small, medium and large fish being 98, 89 and 72 respectively. Twenty-five of the marked fish were recaptured twice while six were recovered three times after marking.

Sport and commercial fishermen together returned 41 tags or 6 percent of those that were placed upon flathead catfish. These fish were at large from 11 to 697 days and averaged 225, 178 and 128 days for small, medium and large-sized fish.

The patterns of movement as shown by our recapture of marked fish varied considerably with that as determined through sport and commercial fishermen's reports. Because of the comparatively small number of reports by fishermen and because the exact places of capture were difficult to pinpoint, the two patterns are best discussed separately.

As determined with the telephone shocker, movement patterns within the two study areas were similar. Most recaptured fish were sedentary since 58 percent in unchannelized river and 51 percent of the recaptures in the channelized study area were at the point of tagging. Ninety-two percent and 85 percent respectively were within one mile. In both study areas mean upstream movements were shorter than those downstream. Because of these similarities the data from both areas was combined (Table 6) for further discussion.

Little can be said concerning fish in the large-size group because of the few recaptures. Two were collected at the marking sites while the other five had not moved long distances.

Fish in the small and medium size groups showed little movement as 87 percent and 90 percent of the recaptures respectively were within 1.61 km upstream or downstream of the point of tagging. In both size groups, most were recaptured at the marking site. Considering those that moved, there was little difference in upstream versus downstream movements as approximately equal percentages of recaptured fish in the small and medium-size groups were collected each way from the marking sites. Mean distances moved by small fish, however, were somewhat greater than those of medium-sized fish.

It is interesting to note that on only seven occasions (4 percent of the 176 recaptures) were tagged fish found on the opposite side of the river. Apparently marked flathead catfish avoided crossing the barren main channel.

The 25 fish which were recaptured more than once showed little or no movement from one time to the next. Maximum movement was by a fish recaptured 41 days and 61 days after tagging. When first recaptured, this fish was 0.16 km downstream and at the second recapture it was 32.4 km downstream of the point of marking. Six fish were recaptured three times after tagging. Three of these were always at the site of release. The recapture record of the fish at large for the longest period was: 13 days, no movement; 322 days, 5.3 km downstream; and 370 days, same point as at 322 days.

Sport and commercial fishermen together returned 41 tags or 6 percent of those that were placed on flathead catfish. Although the information accompanying these tags was frequently incomplete and may not have been entirely accurate, some generalizations may be made. Mean movements as reported by fishermen (Table 7) were many times longer than those as determined through recaptures with the telephone shocker (Table 6). Only three of the reported fish (8 percent of the total) were said to be caught where they had been tagged. Twenty-three were captured downstream from the place of tagging while 14 were reported upstream. It was not possible to determine if any of these fish had moved across the river.

The movement information gained through the fishermen's reports was particularly valuable as it indicated greater ranging than we had observed while recapturing fish with the telephone shocker. In fact, 51 percent of the tagged fish which the fishermen caught had emigrated from the study areas and therefore were unavailable to us. It was important that the movement records of these fish be included in the final judgements concerning mobility of the species, however, as the wide-ranging fish were a part of the population.

When compared to each other, the fishermen's reports and our recapture information support the conclusion by Funk (1955) that flathead catfish populations in streams are composed of sedentary and mobile segments. Although the unchannelized study area was 21 miles long and the channelized study area 40 miles long, we would not have detected the wide-ranging habits of many fish in the mobile segment except for the fishermen's reports. Funk studied 43 such reports from streams in Missouri and found that about one-half of those flathead catfish belonged to each segment. He defined the sedentary segment as being composed of those fish that remained within one mile (1.61 km) of the point of release. Of the 40 fishermen's reports from which we could determine distances moved, 10 (25 percent were within one mile, 1.61 km, of the point of release and 30 (75 percent were in excess of one mile, 1.61 km).

Population Estimations

In the 33.8 km unchannelized study area population numbers for fish 200 mm and longer were estimated during 1966 on 10 dates from June 30 through August 8. These modified Schnabel estimates ranged from 978 to 534 and gradually decreased throughout the summer. Population estimates in a portion of the channelized study area 67.6 km long were made in 1965 on 30 dates from June 28 through August 25. For flathead catfish 200 mm and longer the modified Schnabel estimates ranged from 689 to 1,006 and gradually increased throughout the summer.

Because the estimates from both study areas changed during the experimental periods, it was decided to use the method of Ricker (1958, p. 105) to obtain a linear relationship between the reciprocals of successive Schnable estimates in each area. By back-producing this straight-line relationship to zero time (the dates of the first recaptured fish) it was possible to obtain a population estimate for each study area that was unaffected by natural mortality and/or recruitment.

For the unchannelized study area the population estimate back-produced to zero time (June 30, 1966) was 590 flathead catfish. The 95 percent confidence range was 321-3,599. Similarly for the channelized study area, the population estimate back-produced to zero time (June 28, 1965) was 627 fish. Confidence limits at the 95 percent range were 544-741. The wide limits around the estimate in the unchannelized study area resulted from the small number of daily estimates.

From the calculated population estimates it was possible to determine the number of flathead catfish 200 mm and longer per linear km in each study area. For the unchannelized study area, the standing crop was 5 percent fish divided by 33.8 km or 17 flathead catfish per linear km while for the channelized study area it was 627 fish divided by 67.6 km or 9 flathead catfish per linear km. Further, because all fish were measured at the time of marking, it was possible to determine an average length for the studied size group in each area. These lengths were 412.75 mm and 33 mm in unchannelized and channelized areas respectively. By using these average lengths and the length-weight relationships (see age and growth section) we determined an average weight for fish in the studied size groups in each section. These average weights (721 g in unchannelized river and 386 g in channelized river) when multiplied by the estimated number per linear kilometer yielded the following standing crops: 12,257 g per linear km in unchannelized river and 3,474 g per linear km in channelized river.

These figures are not directly comparable, however, because Morris et al. (1968) found that the average widths of unchannelized and channelized sections were not the same. Comparable standing crops were obtained by multiplying their previously determined average widths of 2,363 feet (720.7 m) in the unchannelized section and 789 feet, (240.6 m) in channelized river by the number of meters in a kilometer and reducing the product to hectares in a linear kilometer. For flathead catfish 200 mm and longer, the resulting standing crops are as follows:

Unchannelized river -
9,466 g in a linear km ÷ 74 hectares in a linear km =
130 g per hectare

Channelized river -
3,615 g in a linear km ÷ 24 hectares in a linear km =
149 g per hectare

As were the standing crops of benthos in unchannelized and channelized Missouri River (Morris et al, 1968) these standing crops for flathead catfish are almost identical. Similarily too, the greater standing crop was in the downstream, channelized study area.

Either one or both of the calculated standing crops for unchannelized and channelized river may be too small. This can be seen by multiplying the calculated standing crops in kg of flathead catfish per km for each study area by the number of kilometers. For unchannelized river there are 83.72 km and 425.04 km in the channelized portion. Using these values there would be 787.4 kg of flathead catfish in the unchannelized section and 1,526.8 kg in the channelized section for a total of 2,314.3 kg. In the four-year period (1963-1967) the voluntarily reported commercial harvest of flathead catfish 330.2 mm and longer averaged 6,050.6 kg per year.

Population Estimates

In the 67.6 km channelized study area, population numbers for fish 200 mm and longer were estimated during 1965 on 30 dates from June 28 through August 25. These modified Schnabel estimates ranged from 689 to 1,006 and gradually increased throughout the summer. Population estimates in a portion of the unchannelized study area 33.8 km long were made in 1966 on 10 dates from June 30 through August 8. For flathead catfish 200 mm and longer the modified

Schnabel estimates ranged from 978 to 534 and gradually declined throughout the summer.

Because the estimates from both study areas changed during the experimental periods, it was decided to use the method of Ricker (1958, p. 105) to obtain a linear relationship between the reciprocals of successive Schnable estimates in each area. By back-producing this straight-line relationship to zero time (the dates of the first recaptured fish) it was possible to obtain a population estimate for each study area that was unaffected by natural mortality and/or recruitment.

For the channelized study area the population estimate back-produced to zero time (June 28) was 627 flathead catfish. The 95 percent confidence range was 544-741. Similarly for the unchannelized study area, the population estimate back-produced to zero time (June 30) was 590 fish. Confidence limits at the 95 percent range were 321-3,599. The wide limits around the estimate in the unchannelized study area resulted from the small number of daily estimates.

From the calculated population estimates it was possible to determine the number of flathead catfish 200 mm and longer per linear mile in each study area. For the channelized study area, the standing crop was 627 ÷ 67.6 = 9 flathead catfish per linear km while for the unchannelized study area it was 590 ÷ 33.8 = 17 flathead catfish per linear km. Further, because all fish were measured at the time of marking it was possible to determine an average length for the studied size group in each area. These lengths were 333.25 mm and 412.75 mm in channelized and unchannelized areas respectively. By using these average lengths and the length-weight relationships (see age and growth section) we determined an average weight for fish in the studied size groups in each section. These average weights (398.1 g in channelized river and 789.6 g in unchannelized river) when multiplied by the estimated number per linear mile yielded the following standing crops: 3,582.9 g per linear km in channelized river and 13,423.2 g per linear km in unchannelized river.

These figures are not directly comparable, however, because Morris *et al.* (1968) found that the average widths of unchannelized and channelized sections were not the same. Comparable standing crops were obtained by multiplying their previously determined average widths of 789 feet (240.64 m) in the channelized section and 2,363 feet (720.72 m) in unchannelized river by the number of meters in a kilometer and reducing the product to hectares in a linear kilometer. For flathead catfish 200 mm and longer the resulting standing crops are as follows:

Channelized river -
3,582.9 g in a linear km ÷ 24.06 hectares in a linear km = 148.92 g per hectare

Unchannelized river -
13,423.2 g in a linear km ÷ 72.07 hectares in a linear km = 186.25 g per hectare

As were the standing crops of benthos in unchannelized and channelized Missouri River (Morris *et al.*, 1968), these standing crops for flathead catfish are almost identical.

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Table 1. The percent of pectoral spine sections in which loss of annulus occurred along the radius used for measurements of flathead catfish. Data from unchannelized and channelized study areas combined.

Age Group	Number of fish	Percent of spines with annuli missing 1st annulus	2nd annulus	3rd annulus	4th annulus
I	84	--	--	--	--
II	76	49	--	--	--
III	138	91	--	--	--
IV	41	100	7	--	--
V	16	100	44	--	--
VI	11	100	55	--	--
VII	6	100	83	17	--
VIII	5	100	40	20	--
IX	3	100	100	33	--
X	2	100	100	50	--
XI	2	100	100	50	--
XII	1	100	100	100	--
XIII	0	--	--	--	--
XIV	0	--	--	--	--
XV	1	100	100	100	100
XVI	0	--	--	--	--
XVII	1	100	100	100	100
XVIII	0	--	--	--	--
IXX	0	--	--	--	--
XX	0	--	--	--	--
XXI	0	--	--	--	--
XXII	2	100	100	100	100
XXIII	0	--	--	--	--
XXIV	0	--	--	--	--
XXV	1	100	100	100	100

Table 2. Back-calculated lengths, in millimeters, of 200 flathead catfish collected from the unchannelized study area, Missouri River, Nebraska, 1963.

Year	Age		TL at	Years of Life											
Class	Group	Frequency	Capture	1	2	3	4	5	6	7	8	9	10	11	12
1962	I	70	128	96											
1961	II	35	210	82	188										
1960	III	43	305	88	181	284									
1959	IV	16	383	-	179	257	358								
1958	V	9	477	-	185	263	354	468							
1957	VI	9	518	-	187	267	350	425	502						
1956	VII	5	595	-	201	222	327	439	507	595					
1955	VIII	2	623	-	193	298	352	440	510	587	616				
1954	IX	2	606	-	-	276	370	442	490	530	563	606			
1953	X	1	760	-	-	262	364	524	586	651	692	717	760		
1952	XI	2	822	-	-	375	432	504	626	681	708	743	784	822	
1951	XII	1	858	-	-	-	302	467	546	623	675	730	775	814	842
Grand average calculated length in mm				93	184	273	356	451	520	603	642	691	776	819	842
Grand average calculated length in inches				3.7	7.2	10.7	14.0	17.8	20.5	23.8	25.3	27.2	30.5	32.2	33.1
Average increment in mm				93	101	90	95	98	75	71	34	40	42	38	28
Average increment in inches				3.7	4.0	3.6	3.7	3.9	3.0	2.8	1.3	1.6	1.7	1.5	1.1

Table 3. Back-calculated lengths, in millimeters, of five flathead catfish collected from the unchannelized study area, Missouri River, Nebraska, 1963.

Year Class	Age Group	Frequency	Avg. TL at Capture	Years of Life 5	6	7	8	9	10	11	12	13	14	15
1948	XV	1	896	451	562	649	726	800	816	831	847	858	877	896
1946	XVII	1	1090	440	543	636	692	778	836	984	969	1016	1044	1063
1941	XXII	2	1019	374	482	588	650	729	771	794	815	845	858	880
1938	XXV	1	1077	430	584	650	675	687	729	760	784	802	828	858
Grand average calculated length in mm				414	530	622	679	744	785	832	846	873	893	915
Grand average calculated length in inches				16.3	20.9	24.5	26.7	29.3	30.9	32.8	33.3	34.4	35.2	36.0

Year Class	Years of Life 16	17	18	19	20	21	22	23	24	25
1948	-	-	-	-	-	-	-	-	-	-
1946	1077	1090								
1941	904	926	942	964	988	1003	1018			
1938	872	915	942	956	986	1016	1033	1047	1060	1077
Grand average calculated length in mm	939	964	942	961	988	1007	1023	1047	1060	1077
Grand average calculated length in inches	37.0	38.0	37.1	37.8	38.9	39.7	40.3	41.2	41.7	42.4

Table 4. Back-calculated lengths, in millimeters, of 195 flathead catfish collected from the channelized study area, Missouri River, Nebraska, 1963.

				Year of Life									
Year Class	Age Group	Frequency	TL at Capture	1	2	3	4	5	6	7	8	9	10
1962	I	14	151	99									
1961	II	41	238	87	195								
1960	III	95	341	80	172	306							
1959	IV	25	457	-	193	287	422						
1958	V	7	511	-	197	283	381	499					
1957	VI	2	622	-	-	280	404	515	622				
1956	VII	1	367	-	-	146	226	280	320	346			
1955	VIII	3	582	-	185	247	324	406	455	499	582		
1954	IX	1	764	-	-	-	357	488	596	653	722	764	
1953	X	1	806	-	-	-	355	483	598	670	719	761	816
Grand average calculated length in mm				90	181	298	399	466	515	528	637	762	816
Grand average calculated length in inches				3.5	7.1	11.7	15.7	18.4	20.3	21.3	25.1	30.0	33.0
Average increment in mm				90	93	123	121	107	78	48	74	42	55
Average increment in inches				3.5	3.7	4.8	4.8	4.2	3.1	1.9	2.9	1.7	2.2

Table 5. Summertime* growth of tagged flathead catfish in the Missouri River, Nebraska

Size Group at Tagging	Number	Mean Growth Per Day (mm)
Unchannelized Study Area (1966)		
200-299 mm	8	0.67
300-499 mm	20	0.33
500 mm and larger	6	0.48
Channelized Study Area (1965)		
200-299 mm	57	0.78
300-499 mm	48	0.66
500 mm and larger	--	---

*Includes June-August each year.

Table 6. Movement of marked flathead catfish in the Missouri River, Nebraska. Combined data from unchannelized and channelized study areas expressed as percentage of fish moving indicated distances.

	Distance (km)	Size at Tagging: Small* (86 recaptured)	Medium* (83 recaptured)	Large* (7 recaptured)	Totals (176 recaptured)
Upstream	8.21 and over	2%	2%	0%	2%
Upstream	1.77 - 8.05	2	4	14	3
Upstream	0.16 - 1.61	17	22	14	19
	0	59	47	29	52
Downstream	0.16 - 1.61	11	21	14	15
Downstream	1.77 - 8.05	5	4	14	6
Downstream	8.21 and over	4	1	14	3
	Range in km moved	0 - 33.8	0 - 27.37	0 - 9.66	0 - 33.8
	Mean number of km moved				
	Upstream	2.42	2.25	1.61	2.25
	Downstream	5.80	1.93	4.99	3.70

*Small includes fish 200-299 mm total length at tagging; medium those 300-499 mm; and large those 500 mm and longer.

Table 7. Movement of marked flathead catfish in the Missouri River, Nebraska, as determined through fishermen's reports. Combined data from unchannelized and channelized river expressed as percentages.

Movement	Size at Tagging			
	Small* (12 fish)	Medium* (25 fish)	Large* (3 fish)	Totals (40 fish)
Upstream	50%	28%	33%	35%
0	8	8	0	8
Downstream	42	64	67	57
Range in km moved	0 - 165.83	0 - 149.73	33.81 - 91.77	0 - 165.83
Mean number of km moved				
Upstream	17.71	53.13	80.50	40.25
Downstream	57.96	32.20	57.96	40.25

* Small includes fish 200-299 mm total length at tagging, medium those 300-499 mm, and large those 500 mm and longer.

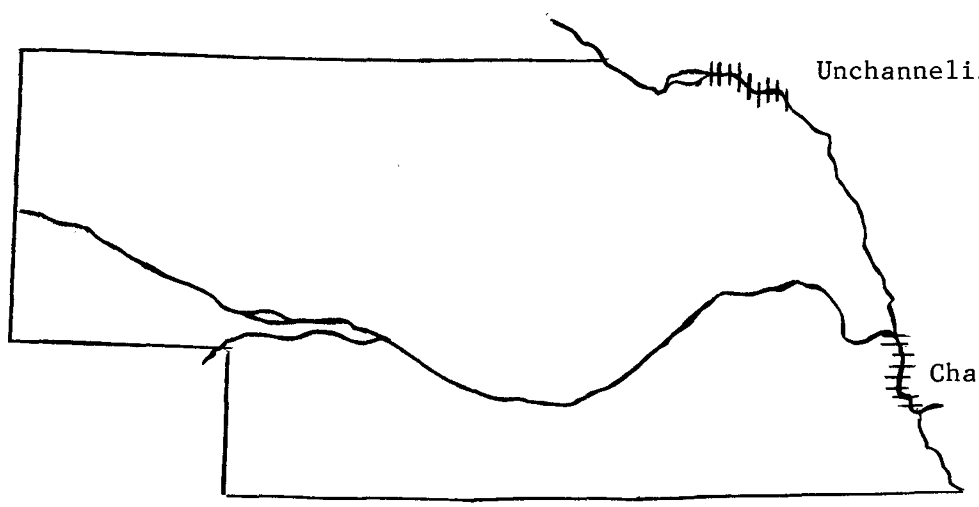

Figure 1. Location of the unchannelized and channelized study areas, Missouri River, Nebraska