

EARLY LIFE HISTORY OF CHANNEL CATFISH (Ictalurus punctatus)
IN NAVIGATION POOL 7 OF THE UPPER MISSISSIPPI RIVER

A Thesis

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ABSTRACT

Young-of-the-year (YOY) channel catfish (Ictalurus punctatus) were collected from Navigation Pool 7 of the upper Mississippi River near La Crosse, Wisconsin, USA. The objectives of this study were to describe distribution and abundance patterns, identify variations in growth, and determine food habits of YOY over the entire pool. Otolith aging technique was validated in the laboratory and used to evaluate growth of wild fish. YOY were captured by otter trawl at night in the navigable main channel during summer 1984 and 1985. A total of 296 YOY (15-83 mm SL) were collected in 1984 and 183 YOY (15-68 mm SL) in 1985. No significant differences in catch were detected throughout the pool. YOY appeared in the drift in mid-July, reached peak abundance in August, then declined sharply. In general, length did not differ significantly throughout the pool, although stations associated with a large backwater tributary produced significantly smaller fish early in both collecting seasons. No differences in growth between stations were detected. Smaller YOY appeared to feed in the water column on invertebrate drift, then switched to benthic invertebrates at about 50-mm SL. All reaches of the main channel appear to be of equal nursery value for channel catfish. A large backwater area in the pool may represent critical spawning habitat. Changes in feeding behavior dramatically affect catchability of YOY. Discharge is the major factor influencing adult spawning and YOY distribution patterns. Drifting YOY could be significantly impacted by hydropower development and commercial navigation. Otter trawling represents a means of evaluating channel catfish year-class strength. Current research gaps are presented.

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INTRODUCTION

Channel catfish (Ictalurus punctatus) is a major commercial species in the upper Mississippi River. However, concern exists over its status in many areas of the river primarily due to poor recruitment and/or over-exploitation (Holzer and Von Ruden 1984). Few data exist to evaluate recruitment of this species in the system. Consequently, the development of a long-term management plan for the fishery based on first year survival is not possible.

Young-of-the-year (YOY) channel catfish have been studied extensively in pond culture situations (e.g. Sandoz 1968, Simco and Cross 1966) and in small riverine systems (Armstrong and Brown 1983). However, little information is available on YOY channel catfish in large riverine systems. YOY channel catfish appear to use primarily the main channel and main channel border habitats of the river (LGL 1981, Holland and Sylvester 1983) making them more susceptible to potential navigation impacts (Rasmussen 1983) than young of most other exploited species. Commercial barge traffic in the system is projected to double by the year 2010 (UMRBC 1982), however impacts of increased navigation on recruitment of channel catfish are unknown.

This study was designed to identify main channel nursery habitats of channel catfish in Pool 7 of the upper Mississippi River and to describe the early life history of this species in a large riverine system. The specific objectives were to

(1) describe variations in the distribution of

YOY channel catfish in the main channel from

- upper to lower reaches of the pool,
- (2) identify variations in growth characteristics in different reaches of the pool, and
 - (3) determine general feeding patterns and spatial/temporal variations in those patterns.

Additional objectives of this study were to validate the otolith aging technique (see Beamish and McFarland 1983, Campana and Neilson 1985) for YOY channel catfish and to examine the effects of different feeding regimes on the deposition of daily growth increments.

STUDY SITE

The upper Mississippi River has been modified by a series of low-head dams designed to regulate flows and facilitate commercial barge navigation. The upper portion of each resultant navigation pool is generally characteristic of the river prior to impoundment (i.e. fast flowing, braided channel), while the lower portion is more lentic in nature. Navigation Pool 7 extends 19 km upstream from Lock and Dam 7 at Dresbach, Minnesota to Lock and Dam 6 at Trempealeau, Wisconsin and has a surface area of 6295 ha (Fig. 1). Seasonal discharge patterns are characteristic of those throughout the system; high spring flows related to snow runoff and low discharge during summer (Fig. 2). Pool elevation at the dam face normally is maintained at 194.6 ± 0.3 m above sea level, but fluctuations occur during flood periods.

Five areas of the main navigation channel were selected for study in 1984 and 1985, representing a gradation of habitat types from upper

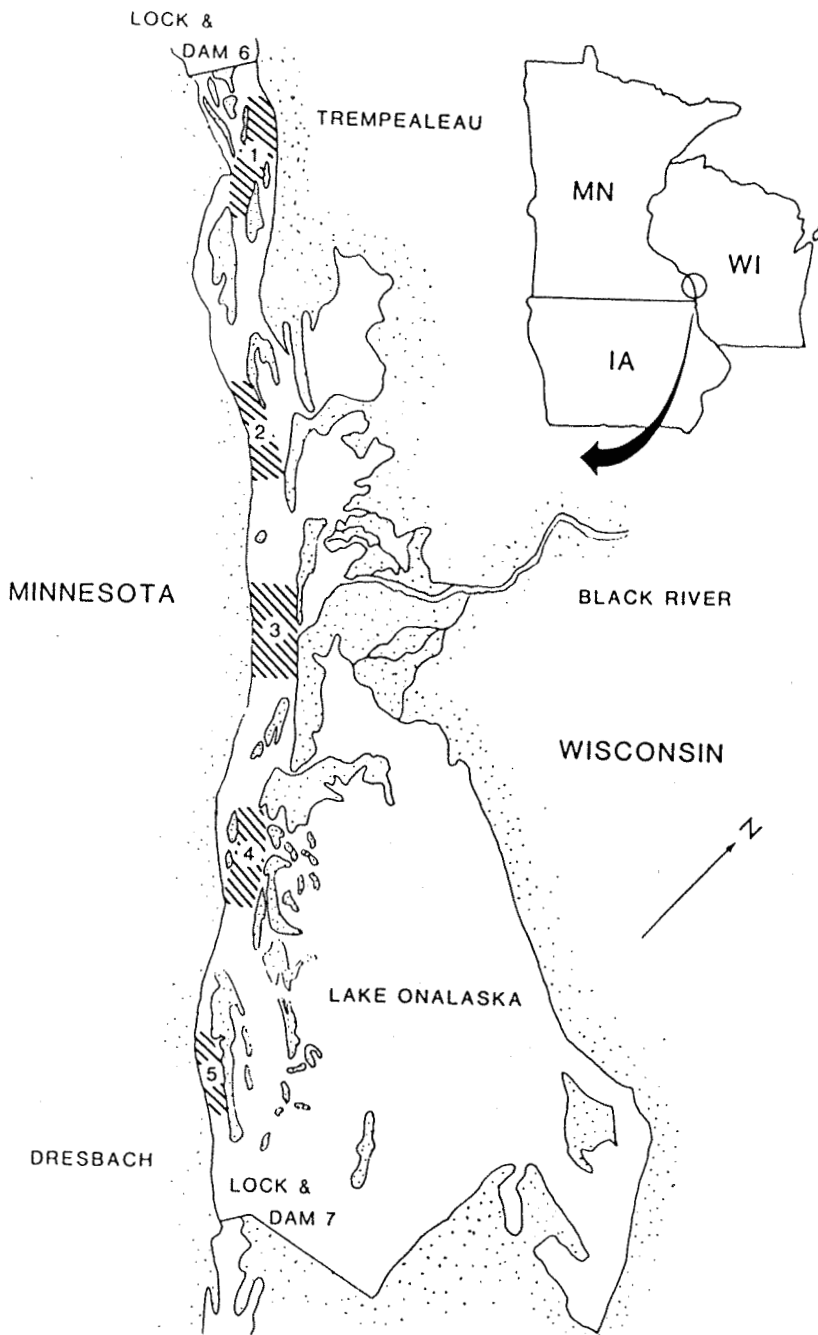


Figure 1. Location of YOY channel catfish sampling stations in the main channel of Navigation Pool 7, upper Mississippi River.

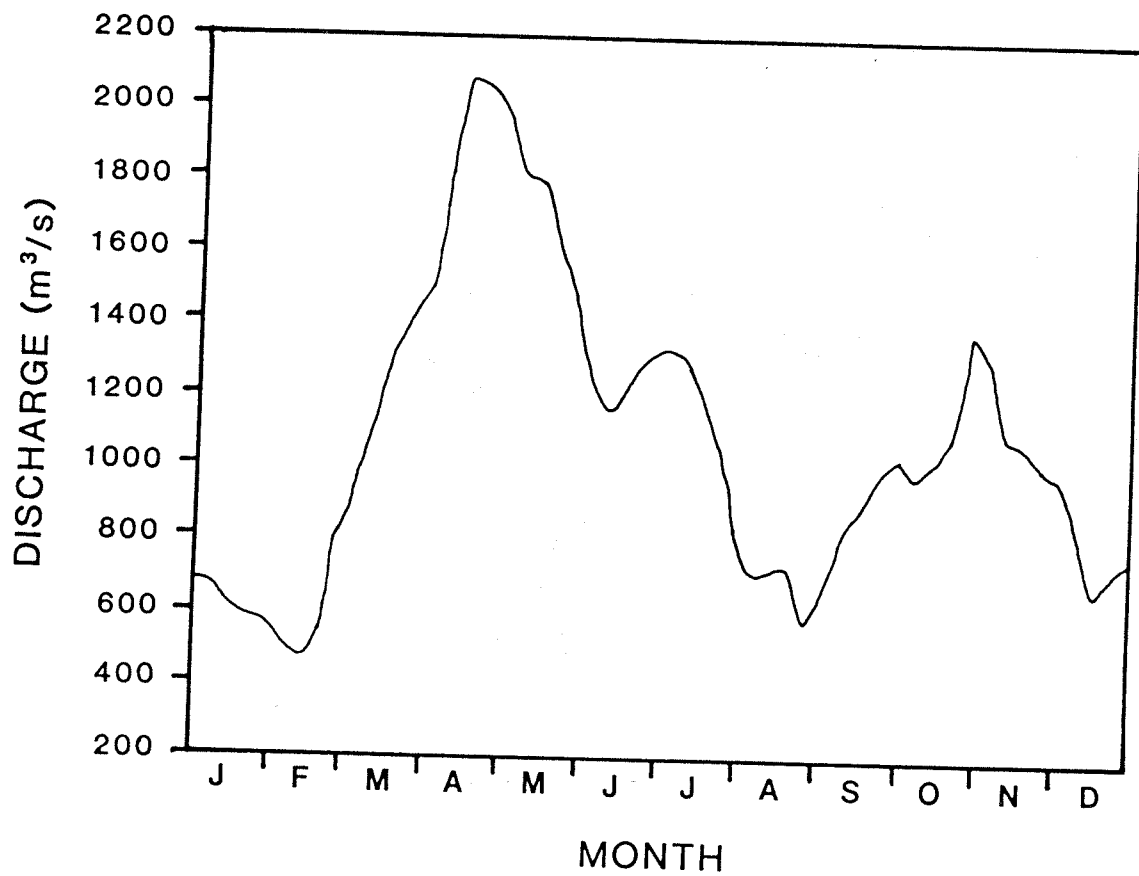


Figure 2. Mean weekly discharge 1980-85 at Lock and Dam 7, upper Mississippi River, Dresbach, Minnesota.

pool tailwater reaches to lower pool lentic habitats (Fig. 1). Station I was located at the upper end of the pool in the swift flowing tailwaters below Lock and Dam 6. Station II, 3.2 km downstream, was adjacent to a large backwater area. Station III was located about mid-pool at the mouth of the Black River, a major tributary to the pool. Station IV was located next to Sommers Chute, the primary source of water flowing into Lake Onalaska. In 1985 sampling, Station IV was moved upstream 1.6 km to a constriction of the main channel because of washing in of snags during spring. Station V was located on the west side of Dresbach Island 2.8 km upstream from Lock and Dam 7. Historically, the main channel flowed along the east side of the island. However, channel maintenance efforts have been focused on the west channel rendering the old east channel unnavigable due to accumulation of dead trees and sediment. Bottom contours for each station are highly irregular with dunes particularly abundant (Appendix I).

METHODS

Nursery Habitat Studies

Originally, a single year of sampling was intended; therefore YOY channel catfish were collected from 8 August to 5 October, 1984. Examination of 1984 catch data, however, suggested high water may have affected several aspects of YOY ecology. As a result, an additional sampling season was designed for 1985 to answer several questions that arose from 1984 data. Station IV was monitored to identify when YOY first appeared in the drift. All stations were sampled 7 August and 28 August to determine whether high variability in catch was typical of all years or unique to 1984. In addition, a study was initiated to determine whether gear avoidance could be minimized and therefore extend the sampling season further into the fall.

YOY were captured by otter trawl (4.8-m semiballoon trawl, 1.8-m vertical depth, 6.35-mm stretch mesh codend liner) during summer 1984 and 1985. Since Armstrong and Brown (1983) found that YOY channel catfish were most active between dusk and dawn and appear to feed strictly during these periods, fish were collected at night between 2030 and 0330 hours. Samples were collected in triplicate at each station in a downstream direction within the navigable main channel of the river. Effort was standardized per sample primarily by time (10-minute trawls) at a trawl speed of approximately 0.9 m/s. The catch/trawl for each replicate was recorded, and fish from all trawls were then combined by station and fixed in 10% formalin.

After return to the laboratory, formalin was decanted from samples, and fish were rinsed in distilled water and preserved in 70% ethanol.

Standard length in millimeters was recorded for each fish. Stomachs were removed and preserved in 70% ethanol. Food items were identified to the lowest practical taxon and enumerated. Volume of food items was determined for each taxon by water displacement, and percent volume was calculated. Sagittae (the largest of the three calcareous ear stones or otoliths) were dissected from each fish and greatest diameter was measured to the nearest 0.01 mm with a microscope fitted with an ocular micrometer. Otoliths were then mounted in epoxy resin and ground in sagittal section to expose the internal circuli for counting (Appendix IX). Otoliths were examined for growth increments and counted until three consistent readings were obtained; that number was assigned as the estimated age. Ten percent of all aged structures from both laboratory and field studies were randomly selected and reexamined. Quality check age estimates were compared to original age estimates (Appendix II).

A possible source of bias in the spatial distribution pattern of YOY channel catfish was evaluated in a series of collections on 30-31 July 1985. Armstrong and Brown (1983) found that drift of YOY channel catfish varied significantly in a diel pattern with a peak prior to midnight and another prior to dawn. During the present study, sampling to evaluate spatial variations in distribution in Pool 7 took about 7 hours to complete on each date. Station I was always collected first (2030 hours) followed sequentially by the other stations with Station V sampled at 0300 hours. Therefore, if the drift behavior observed by Armstrong and Brown (1983) held true in the study area, sampling bias would affect identification of nursery habitats in the pool. A sampling scheme was designed to determine if a time-related bias existed in the

catch data (Table 1). The actual design was slightly different due to interference from commercial barge traffic and equipment failure.

Age Validation Studies

Channel catfish were reared in the laboratory to validate the otolith daily ring aging technique. Channel catfish eggs were obtained from Frankfurt National Fish Hatchery (Frankfurt, Kentucky) and hatched in the laboratory. Fry were separated into three aquaria and held at 21.6°C for 60 d. A 14L:10D photoperiod was maintained throughout the rearing period. Food was provided only during the dark cycle of the photoperiod to simulate the natural feeding pattern (Armstrong and Brown 1983). Feed ratios for rearing channel catfish were modifications of those adapted by Ward (personal communication) from rainbow trout feed tables. Three levels of food availability were established (100%, 50%, and 10% of recommended rates) to determine if food availability in the field might affect the frequency of otolith ring deposition and, therefore, bias age estimates. Food amounts were determined as a percentage of body weight. The mean weight for all fish in an aquarium was determined at 10-d intervals to account for growth. Food supply was adjusted appropriately (Appendix III). A subsample of five fish was removed daily from each treatment for the first three weeks. Fish were fixed and preserved, and otoliths were removed as previously described. After the first three weeks, samples were collected every other week until the end of the study. All laboratory and field samples were processed similarly.

Data Analyses

Statistical analyses were conducted on all data. A significance level of $p < 0.05$ was selected a priori for all analyses. Differences

Table 1. Planned and modified designs for evaluation of station-time bias in YOY channel catfish data. All samples were collected at Station IV.

DESIGN	TIME SERIES							
	1	2	3	4	5	6	7	8
planned	1930	2100	2230	2400	0130	0300	0430	0600
modified	a	2100	2300	a	0100	0300 ^b	0500	0600

^a sample aborted due to interference from commercial barge traffic
^b only one trawl; net entangled on dead submerged tree

in standard length and catch at each station were statistically evaluated by one-way and two-way analyses of variance (ANOVA)(Sokal and Rohlf 1981). A Student-Newman-Keul's multiple range test was performed if treatment differences were significant to identify which station(s) or date(s) were different from the others. Standard length was regressed on otolith diameter and a least squares line was fitted to the data (SPSS Inc. 1983). Otolith increment counts were regressed on standard length. The resulting regression model was used to predict age of fish. Date of spawn was back-calculated from age predictions (predicted age + 8 days egg development time [Canfield 1947]). Sums of squares cluster analysis (Dixon and Brown 1979) were conducted on food habits data to determine if composition of diets differed between stations within a sampling date. One-way ANOVA was conducted on total volume of food items consumed to determine food consumption varied significantly between stations on any date. Effects of feeding regime on otolith increment counts of laboratory fish were analyzed by one-way ANOVA.

RESULTS

Daily growth increments were observed in otoliths from laboratory reared channel catfish. Growth increments appeared to be initiated at hatching and preceded outward from two central primordia (Fig. 3A). The field chosen for the enumeration of growth increments significantly affected the increment count (Fig. 3B). Subdaily rings were observed in the posterior and anterior fields but not in the proximal field. Therefore, the proximal field was selected as the primary counting field.

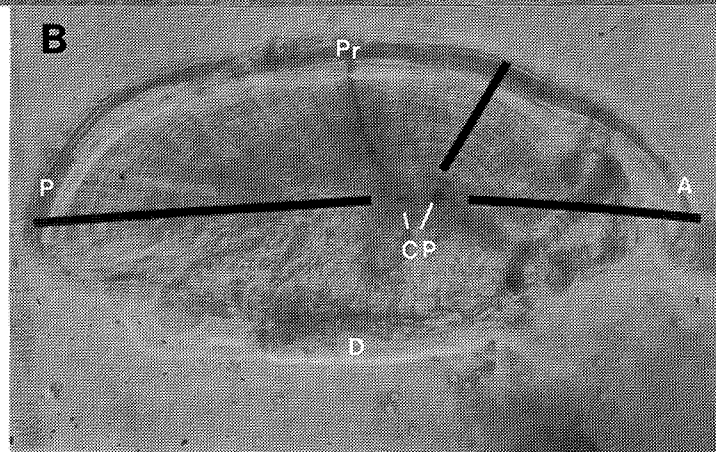
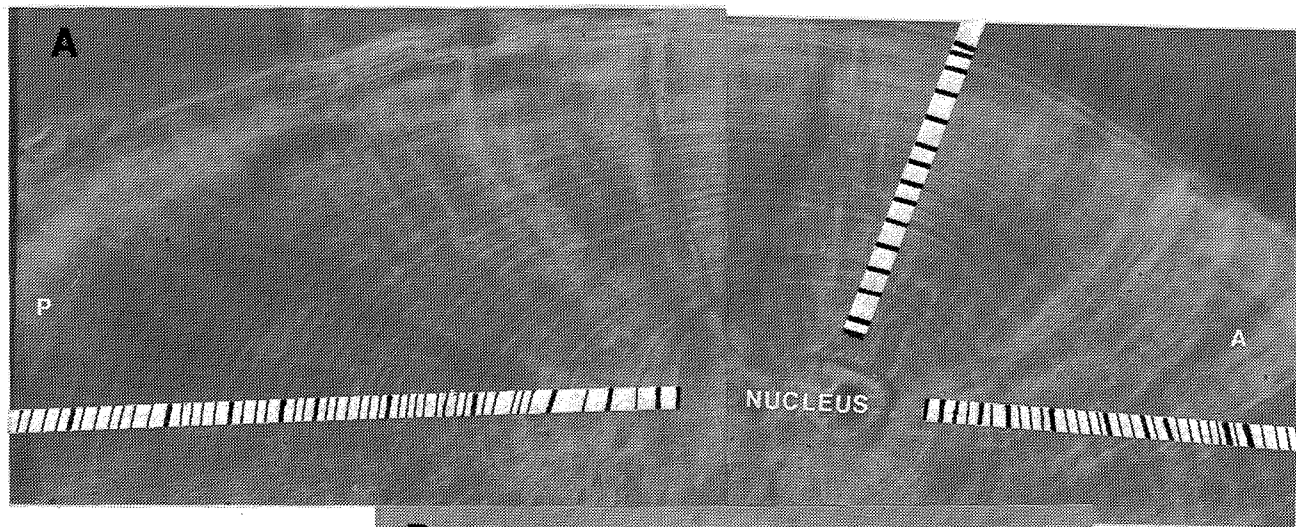
Food availability did not affect frequency of deposition of increments ($p > 0.05$). Ration did affect the width of discontinuous or opaque zones. Otolith increments for fish from all feeding regimes became less resolvable at the margin after 18-d post-hatch, which resulted in conservative age estimates (Fig. 4). This suggests that food was no longer a sufficient cue affecting increment deposition.

Increments were deposited about once per day (Fig. 4). Mean otolith increment counts were used for each sampling date because of variations in the dates of hatch within each treatment (∓ 2 d). The subdaily rings observed in the posterior and anterior fields were probably artifacts caused by inadvertent stress during laboratory tank maintenance; no subdaily rings were observed in wild fish otoliths.

No significant diel variations in catch were observed during the normal sampling period (2030-0330 hours). YOY appeared in the catch sometime after dusk, increased slightly during the night, and declined precipitously with the onset of dawn (Fig. 5). No data were available

- 3A. Photomicrograph of laboratory reared channel catfish sagitta displaying internal features. CP- central primordia; Pr- proximal field; D- distal field; A- anterior field; P- posterior field. Heavy lines correspond to increment counting fields in 3B. (400X)

- 3B. Photomicrograph of sectioned sagitta from 14 day-old channel catfish with increments marked in three fields. Bold lines represent true daily increments. Fine lines represent subdaily rings. (1000X)



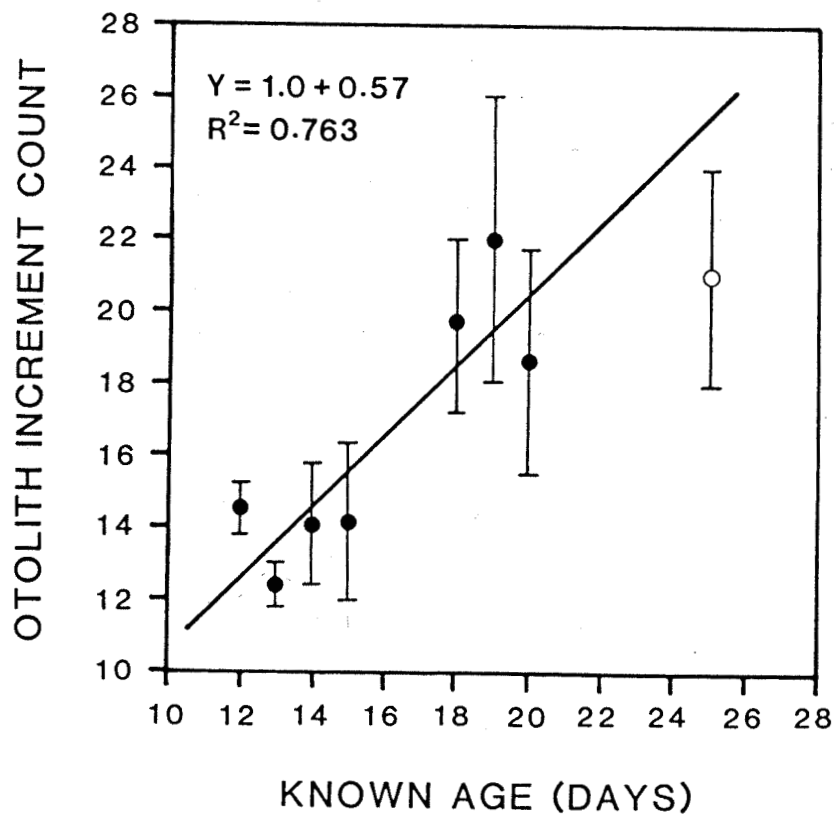


Figure 4. Regression relationship between known age of laboratory reared channel catfish and mean otolith increment counts. Open circle represents data not included in regression analysis because rings were not resolvable to margin.

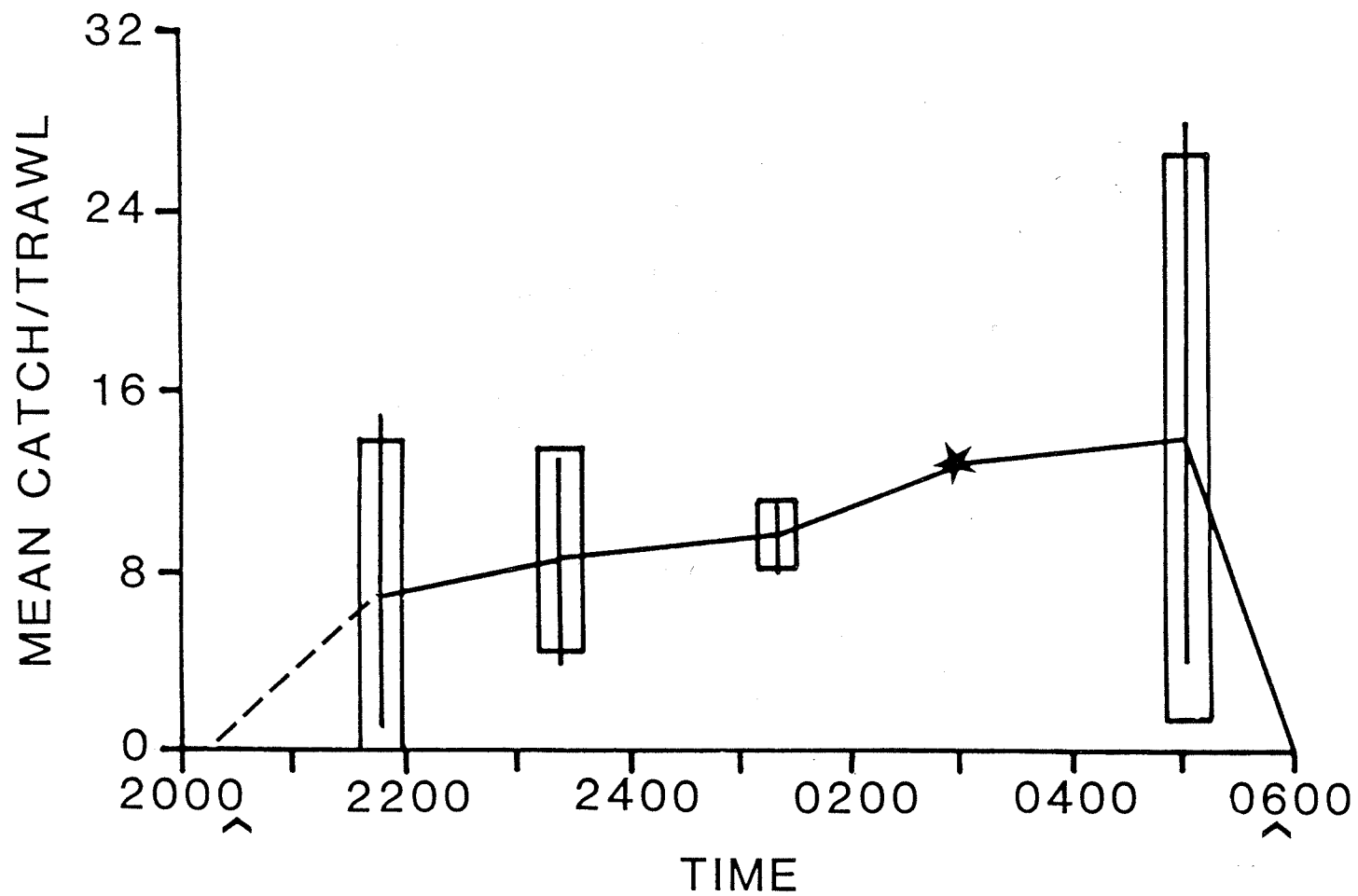


Figure 5. Diel catch of YOY channel catfish collected by otter trawl at Station IV, July 30-31, 1985. Dashed line represents estimated trend in catch. Vertical bar-standard deviation, vertical line- range, star- single trawl.

to evaluate catch prior to dusk. Gear avoidance data are inconclusive due to insufficient sample size.

A total of 296 YOY fish were collected from 75 trawls taken in 1984 and 183 fish from 30 trawls in 1985. Overall, catch did not vary significantly by station in either year. Significant station differences may not have been detected because coefficients of variation were high (13.3-175.8%, $\bar{x} = 69.3\%$ [Appendix IV]). Upper stations, however, produced significantly fewer fish ($p = 0.0049$) in mid-September 1984. Catch per effort at upper stations ranged from 0.67-1.33 fish/trawl as compared to 4.00-6.67 fish/trawl at lower pool stations (Table 2).

In general, catch peaked in August and then declined to a few individuals per trawl over time (Fig. 6). Catch in 1984 was low throughout the study period (8.5-1.1 fish/trawl) which extended into October. Peak catch occurred on 23 August (8.5 fish/trawl). In 1985, YOY first appeared in the drift in mid-July. Catch peaked on 7 August (9.7 fish/trawl) and declined sharply to insignificant catches by September. An exception to this seasonal catch pattern resulted in a significant date/station interaction ($p = 0.034$) in 1984. Station IV did not behave similar to other stations on 23 August. Whereas all other stations exhibited a peak in catch on that date, the catch at Station IV declined continuously throughout the season.

Overall, fish tended to be more abundant adjacent to and slightly downstream from a large backwater tributary, particularly early in the season. As the season progressed, YOY appeared to become randomly distributed throughout the pool.

Table 2. Mean catch of YOY channel catfish and (standard deviation) by station by date collected from Navigation Pool 7, upper Mississippi River, 1984 and 1985. Stations with similar letters are not significantly different at $p < 0.05$ based on Student-Newman-Keul's multiple range test.

STATION	DATE						
	8/8/84	8/23/84	9/11/84	9/23/84	10/5/84	8/7/85	8/28/85
1	5.33 (8.39)	12.67 (4.16)	0.67 (0.58)a	0.33 (0.58)	1.00 (0.00)	7.00 (4.36)	4.33 (0.58)
2	7.33 (3.51)	7.67 (5.13)	1.33 (0.58)ab	0.00 (0.00)	0.33 (0.58)	7.33 (4.16)	2.00 (2.65)
3	4.67 (1.53)	11.00 (2.65)	6.67 (1.15)c	2.33 (1.15)	1.33 (0.58)	14.00 (5.20)	3.00 (2.65)
4	7.00 (4.00)	5.33 (4.73)	4.00 (1.00)abc	1.67 (0.58)	1.33 (1.53)	17.67 (17.67)	1.00 (1.73)
5	1.00 (1.00)	6.00 (2.00)	4.67 (3.06)bc	3.33 (3.21)	1.67 (0.58)	2.67 (0.58)	2.33 (1.53)
\bar{X} (SD) =	5.07 (4.48)	8.53 (4.44)	3.47 (2.64)	1.47 (1.85)	1.13 (0.83)	9.73 (9.20)	2.53 (2.03)
p^a =	0.4783	0.1743	0.0049	0.1259	0.3882	0.2910	0.3807

p^a = probability that catch differed by station based on oneway ANOVA

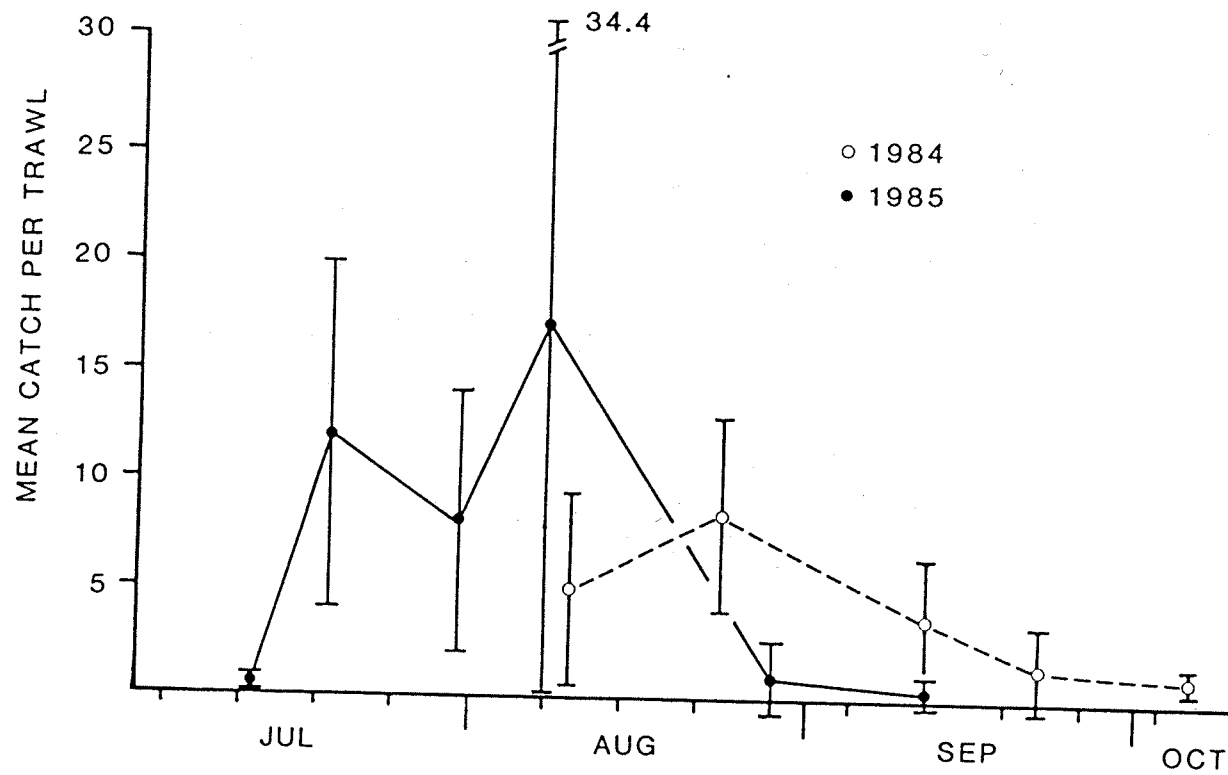


Figure 6. Catch of YOY channel catfish from Navigation Pool 7, 1984 and 1985. The 1984 catch is represented by all stations combined. The 1985 catch is represented by Station IV only.

The size of fish captured throughout the study area generally did not vary significantly (Table 3). Standard lengths ranged from 15-83 mm in 1984 and 15-68 mm in 1985. Early in 1984 and 1985, stations adjacent to or slightly downstream from a backwater tributary produced significantly smaller fish ($\bar{x} = 27.30$ and $\bar{x} = 29.94$ mm, respectively).

The 1984 length frequency distributions were distinctly bimodal (Fig. 7). The modes were about 25-30-mm apart. Both could be identified on each sampling date up to 11 September, whereafter catch was too low to resolve peaks. In contrast, the 1985 length frequencies were unimodal (Fig. 8). Again, the mode became less distinct over time as catch decreased.

Two-way ANOVA indicated that station and date interacted significantly ($p = 0.016$) in 1984. Generally, mean length decreased at all stations on 23 August and 5 October. Mean length increased at Station IV throughout the study. Significant interactions ($p = 0.051$) were observed between data and station again in 1985. Mean length increased from 7 August to 28 August at all stations except Station IV which decreased.

Growth of YOY was uniform throughout the study area. Fish grew at approximately 1.0 mm/d ($Y = 2.0 + 0.96 \bar{x}$, $R^2 = 0.879$, Fig. 9). Variability in growth increased as fish aged, particularly after 50-d post-hatch. Predicted age frequencies from the age-length model closely followed the observed length frequency distributions for both years (Appendix V).

Back-calculated spawning activity suggested that 1984 spawning was interrupted (Fig. 10). Spawning was initiated 5 June at a water

Table 3. Mean standard length and (standard deviation) of YOY channel catfish by station collected from Navigation Pool 7, upper Mississippi River, 1984 and 1985. Stations having similar letters are not significantly different at $p < 0.05$ based on Student-Newman-Keul's multiple range test.

STATION	DATE						
	8/8/84	8/23/84	9/11/84	9/21/84	10/5/84	8/7/85	8/28/85
1	34.50 (8.36)	33.68 (12.89)ab	52.50 (23.33)	79.00 (a)	55.00 (13.53)	35.14 (6.80)a	46.08 (7.95)
2	33.00 (13.18)	27.30 (10.43)a	41.75 (15.94)	----- (-----)	83.00 (a)	35.14 (7.33)a	39.33 (10.69)
3	41.43 (8.00)	36.09 (13.55)b	56.85 (16.02)	59.29 (16.37)	50.75 (10.87)	36.31 (4.30)a	46.33 (12.14)
4	33.71 (8.39)	38.44 (12.92)b	44.08 (12.24)	48.80 (13.55)	54.00 (17.91)	29.94 (7.13)b	29.33 (7.09)
5	28.33 (10.97)	42.28 (14.61)b	48.00 (12.47)	56.00 (15.24)	46.20 (16.16)	34.50 (7.76)ab	36.00 (10.15)
\bar{x} (SD) =	34.88 (10.33)	34.96 (13.50)	50.19 (15.05)	56.43 (15.51)	52.82 (15.60)	33.54 (6.95)	41.89 (10.89)
p^d =	0.0931	0.0051	0.1063	0.3269	0.3302	0.0001	0.0338

(a) = sample represented by only one fish

p^d = probability that length differed by station based on oneway ANOVA

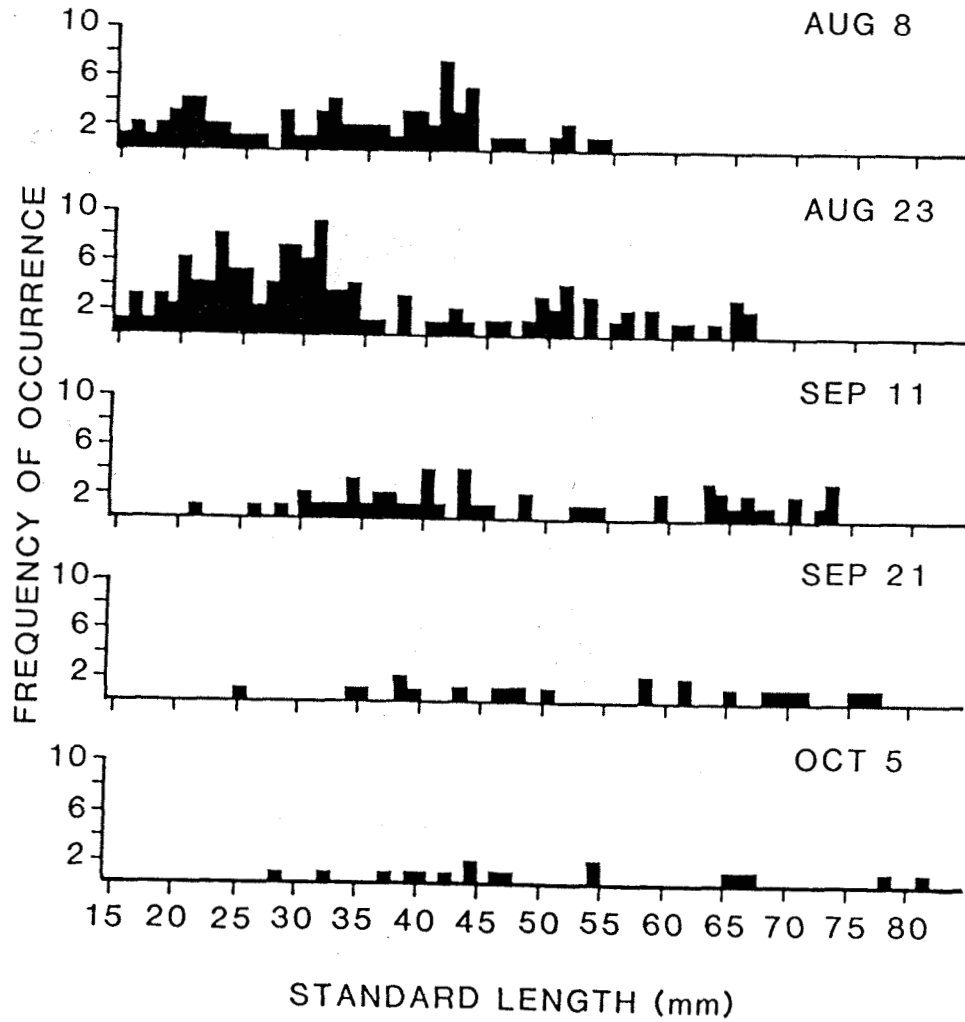


Figure 7. Length frequency distributions of YOY channel catfish by date of collection from Navigation Pool 7, upper Mississippi River in 1984.

1985 FIELD DATA

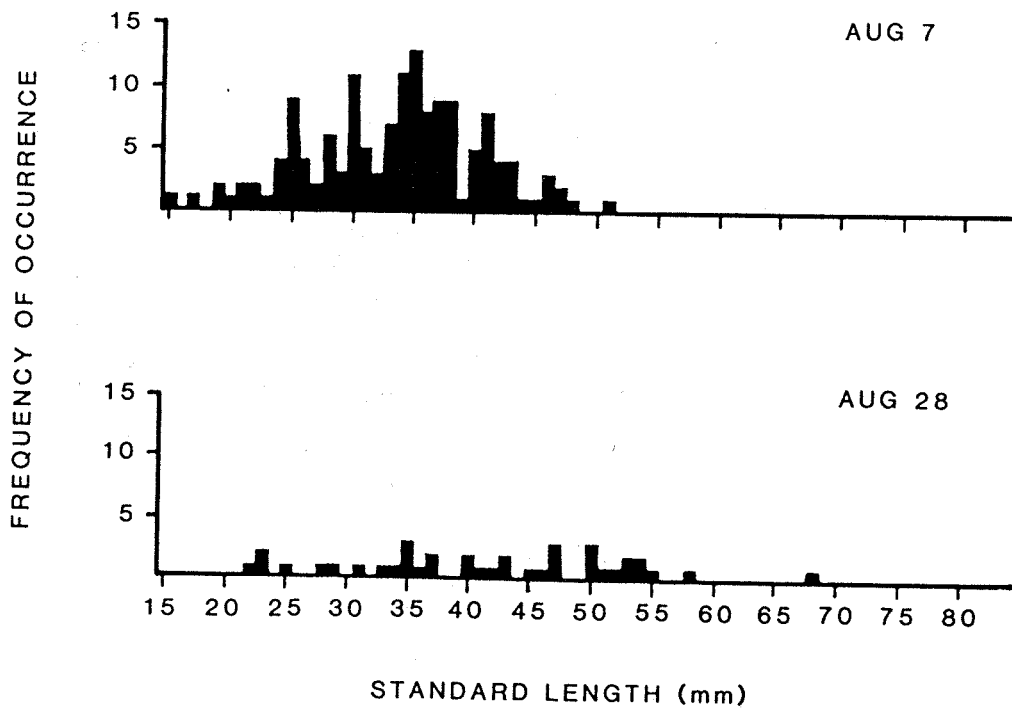


Figure 8. Length frequency distributions of YOY channel catfish by date of collection from Navigation Pool 7, upper Mississippi River in 1985.

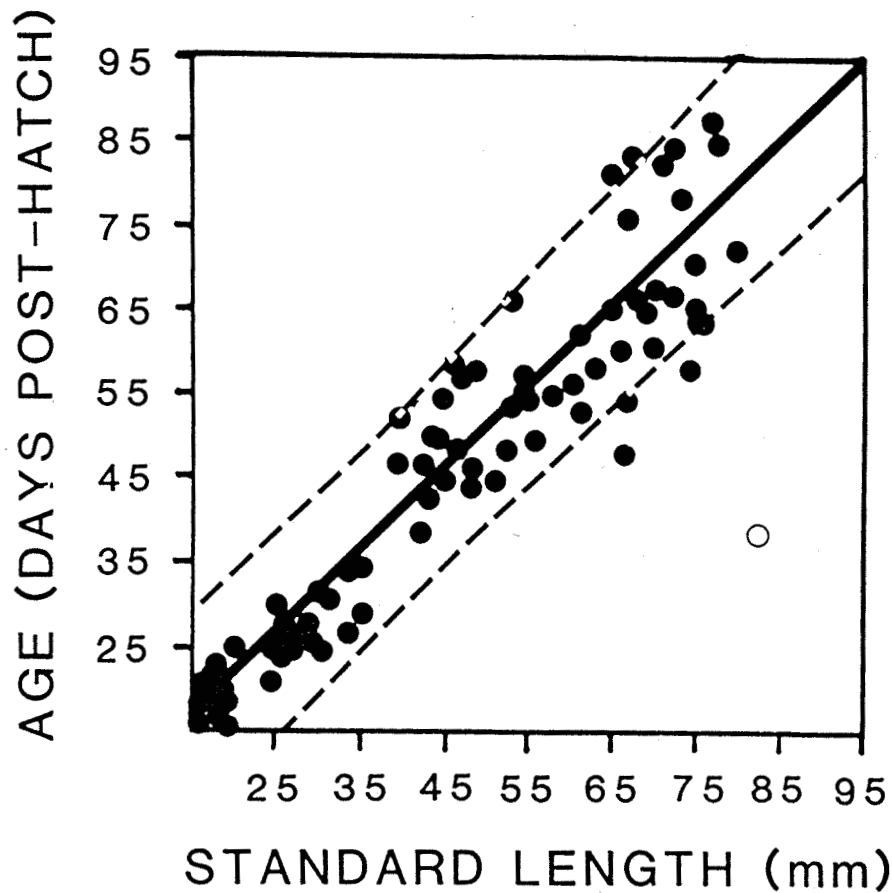


Figure 9. Regression relationship between estimated age and standard length of YOY channel catfish collected from Navigation Pool 7, upper Mississippi River. Open circle not included in analysis because otolith was not readable to the margin. Dashed line is 95% prediction limit.

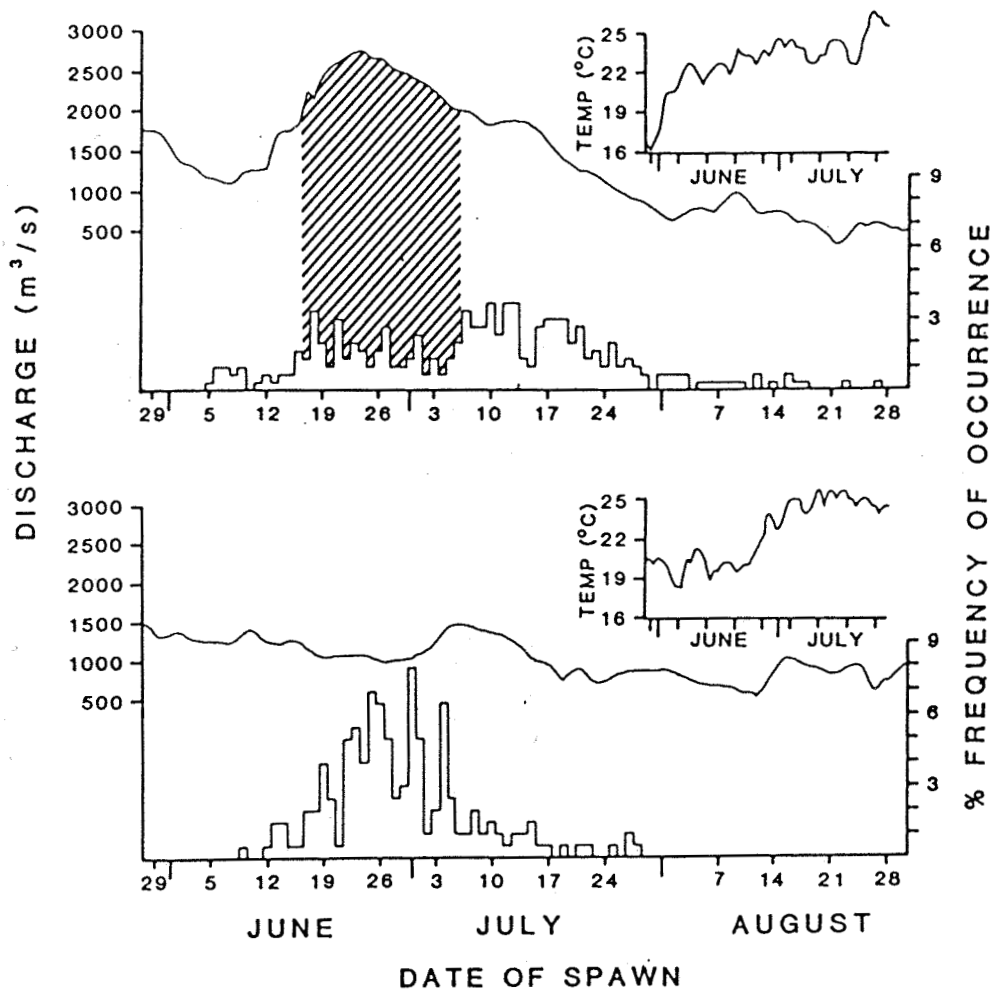


Figure 10. Channel catfish spawning activity back-calculated from YOY channel catfish collected from Navigation Pool 7 in 1984 (upper) and 1985 (lower). Mean daily discharge from Lock and Dam 7 is overlaid. Mean daily water temperature is presented in upper right.

temperature of about 21°C and continued into late August. On 17 June, spawning activity began to decrease as discharge exceeded 2000 m³/s. When discharge returned to levels below 2000 m³/s on 9 July, spawning activity increased again, peaking around mid-July.

The 1985 discharge was more typical of summer flows in Pool 7. Spawning activity was strongly unimodal beginning 9 June at a water temperature of about 19°C. Spawning peaked in early July and ended by 27 July.

Water temperature did not appear to be an important factor affecting channel catfish spawning. Water temperatures increased sharply in early June 1984 and leveled at about 23°C. In 1985, water temperatures were low (20°C) until late June, whereupon they increased rapidly to about 24°C. The effects of temperature on spawning activity were not detectable, however, low temperatures may have delayed spawning in 1985 by about a week.

The relationship between otolith diameter and standard length produced a significant linear regression fit (Fig. 11), therefore, back-calculations to length-at-age were possible. However, due to variability in the plane exposed by grinding, maximum otolith diameter was not always intersected. The resultant back-calculated lengths would thus have been underestimated of true lengths at specific ages. Therefore, no attempt was made to arrive at back-calculated length.

YOY channel catfish appeared to be very successful in obtaining food. Of the 101 stomachs examined, 96% contained identifiable organisms (Appendix VI). Most food items were typical of fast-flowing environments (Merritt and Cummins 1978) with occasional organisms common

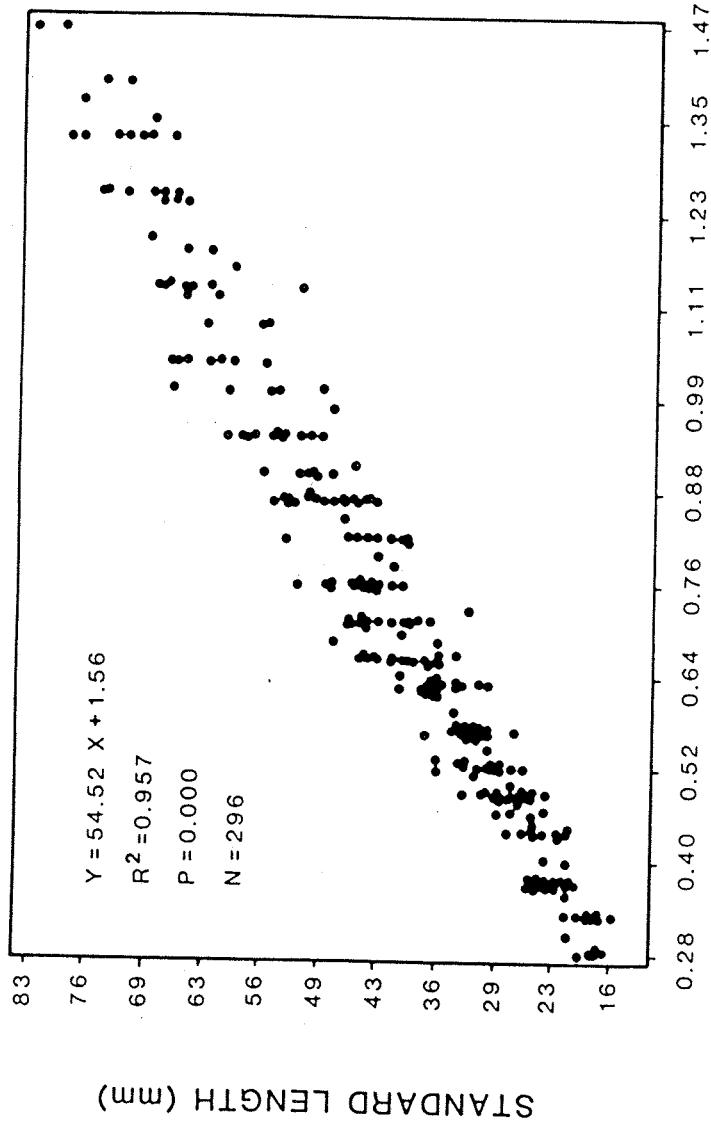


Figure 11. Regression relationship between standard length and otolith diameter of YOY channel catfish collected from Navigation Pool 7, upper Mississippi River in 1984.

to backwater (e.g. Hexagenia sp.) and shoreline (e.g. Carabidae) habitats. Based on qualitative observations from plankton tows, YOY appeared to be feeding on items common in the drift.

Four taxa represented over 90% of food items consumed on any date (Appendix VII). Trichoptera, largely comprised of Hydropsyche sp., represented greater than 83% of total food volumes throughout the study (Fig. 12). Cladocerans were important dietary items early in the season but decreased with time yielding to dipterans. Ephemeropterans, represented largely by Caenis sp. but also Hexagenia sp., were relatively consistent but not very important food items (<1.5% of total food item volumes on any date). No identifiable differences in composition of diets by station were detected (Fig. 13).

Furthermore, volumes of food consumed did not differ significantly by station on any date (Appendix VIII). There was, however, a noticeable change in feeding behavior as YOY grew. Pelagic food items (i.e. cladocerans) were common in diets of fish in mid-summer but became less frequent by late summer (Fig. 14). Conversely, frequency of occurrence of sand grains (presumably incidentally ingested during benthic feeding) increased throughout the study. This changeover occurred when YOY were about 50-55 mm in length.

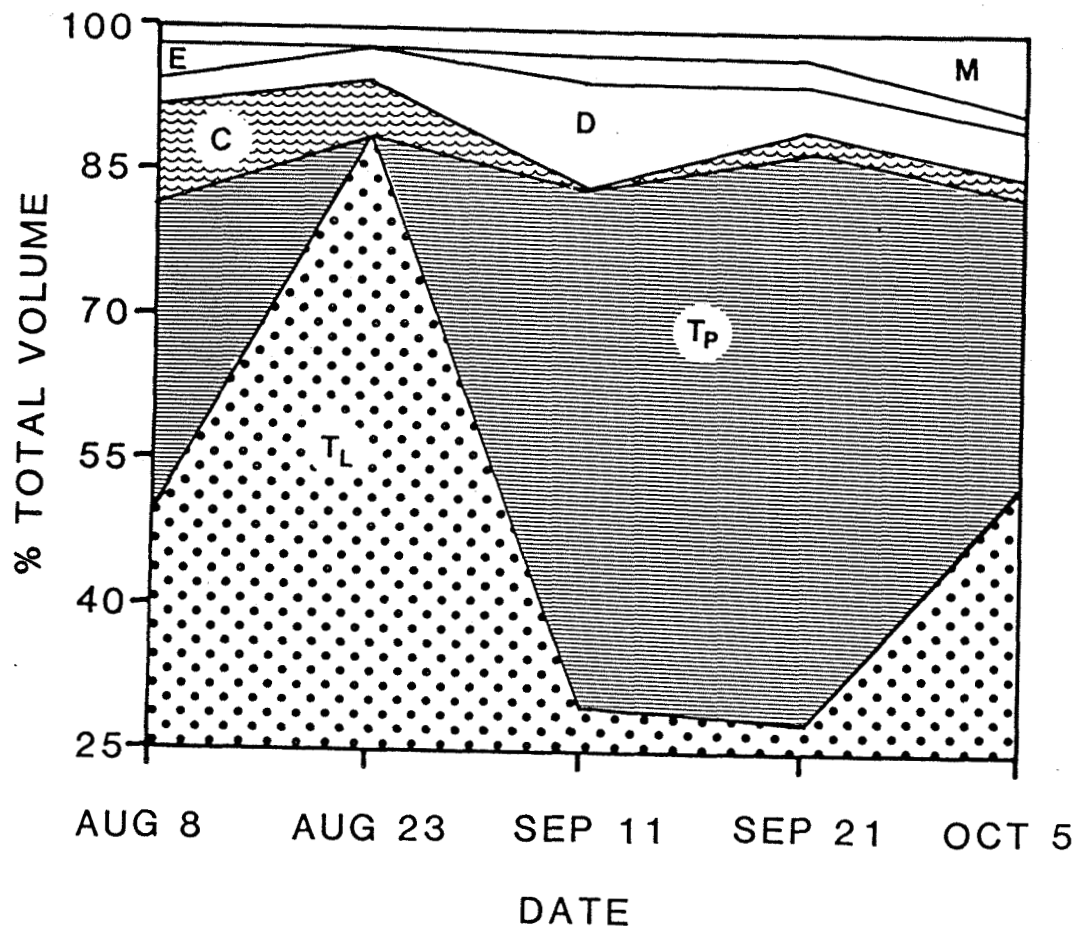


Figure 12. Seasonal changes in the composition of diets for YOY channel catfish collected from Navigation Pool 7, upper Mississippi River, 1984. T_L - Trichoptera larvae; T_P - Trichoptera pupae; C - Cladocera; D - Diptera; E - Ephemeroptera; M - miscellaneous.

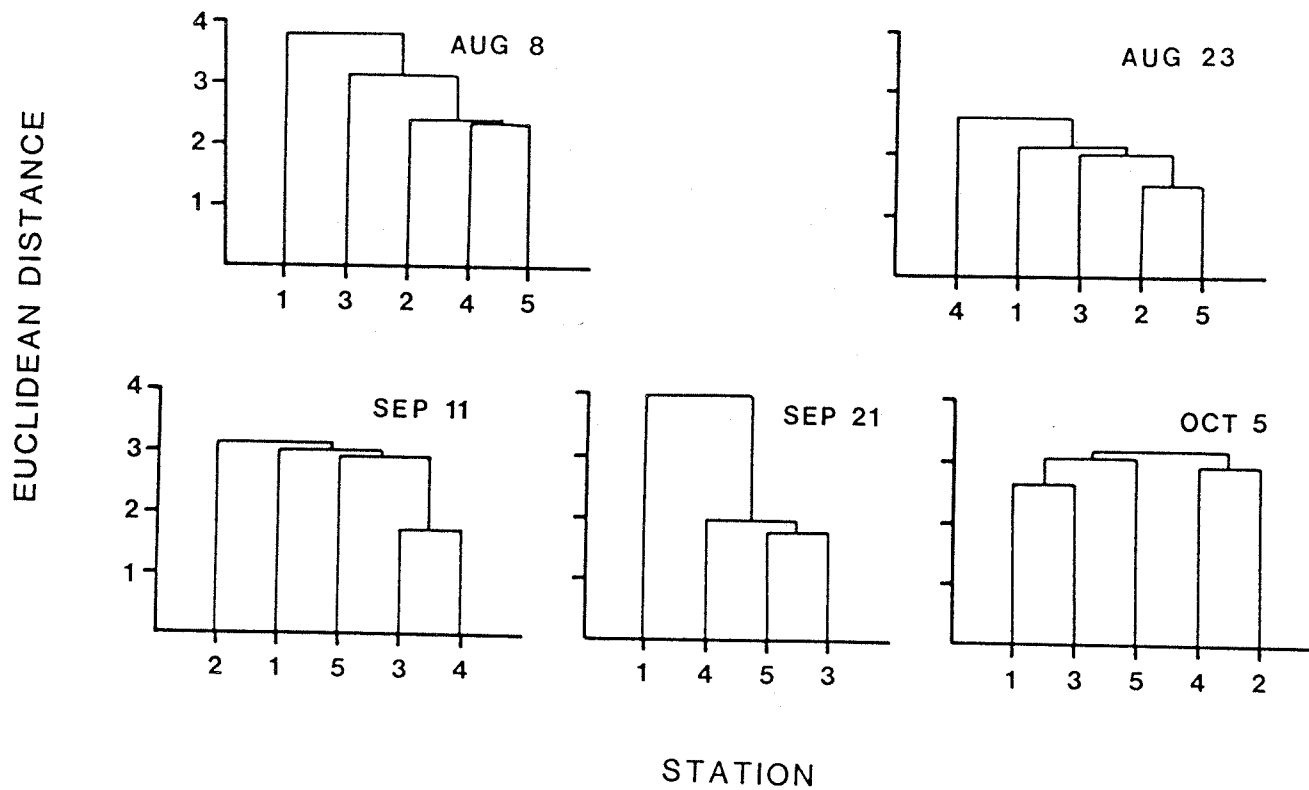


Figure 13. Sum of squares cluster analysis of food items by station for YOY channel catfish collected from Navigation Pool 7, 1984. No fish were collected from Station IV on 21 September.

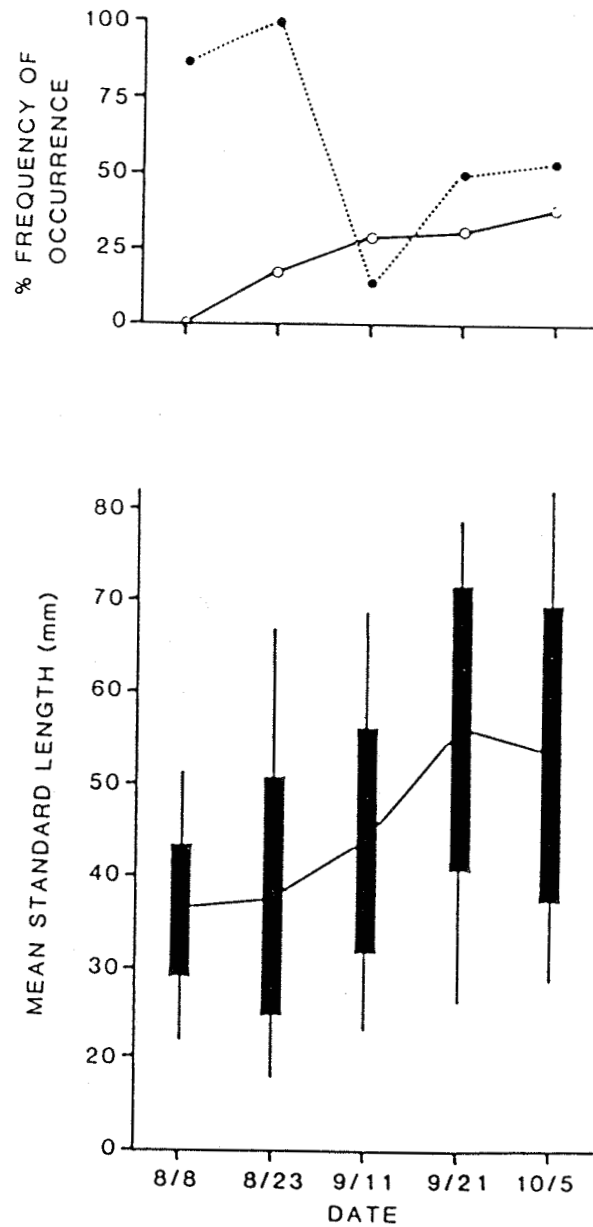


Figure 14. Seasonal change in food preference of YOY channel catfish collected from Navigation Pool 7, 1984. A. Percent frequency of occurrence of cladocerans (●) and sand grains (○) in stomachs. B. Mean standard length of YOY channel catfish examined for food habits. Vertical bar- standard deviation; vertical line- range.

DISCUSSION

The large backwater associated with the Black River delta may be an important spawning area for channel catfish in Navigation Pool 7. In both 1984 and 1985, stations adjacent to or slightly downstream from this backwater area have produced statistically smaller fish early in August. Perhaps this corresponds to a mass exodus of YOY from nest sites within the backwater to the main channel.

High variability in catch is largely due to the clumped distribution of YOY drifting in the water column. YOY move out of dune troughs to feed on drifting invertebrates. As food preference changes to benthic organisms, however, YOY become less susceptible to the gear.

Becker (1983) stated that YOY channel catfish will feed over sand bars in slow flowing areas of the river. The river is slow and wide with extensive sand bars prior to constricting at Station IV. This station, particularly in 1985, exhibited a high variability in catch. This variability could have been a result of intermittent outwash of YOY from slow flowing shoal areas into the main channel. Such variability may require increased effort by managers in order to reduce catch standard deviations.

Discharge appears to be a major factor influencing adult channel catfish spawning and YOY distributional patterns. Discharge has been identified as the primary variable affecting the temporary disruption of the 1984 spawn. It is unclear how extending a spawn into late summer will affect winter survival of YOY. Current year-class estimates are based on data from age 1+ and older individuals (Holzer, personal

communication); therefore, estimates of the success of the 1984 year-class may not be available for at least two years.

YOY channel catfish distributional patterns are clearly affected by discharge. Catch was relatively low and extended late into the season because high discharge interrupted spawning in 1984. In contrast, catch in 1985, a typical discharge year, peaked rapidly and declined precipitously. Although apparently comparable numbers of YOY were produced in each year, year-class estimates based on a single sampling each year would be grossly different. Perhaps single samplings during peak drift would produce reasonable estimates of year-class strength in years of comparable discharge. It is apparent, however, that YOY should be monitored periodically throughout the drift period to arrive at an accurate year-class estimate.

All areas of the main channel appear to be of equal nursery value for channel catfish. Significant differences in growth were not detectable among stations. In addition, food habits were not different throughout the pool. Thus, for mitigation purposes, the entire pool must be considered when evaluating impacts on recruitment of YOY channel catfish.

Hydropower impacts on drifting YOY could be significant. The majority of drift occurs in a relatively confined window of 3-4 weeks which coincides with the principal operational period of proposed hydropower installations (Western Wisc. Municipal Power Group 1984). During this time, YOY are actively feeding in the water column and are passively carried through dams, when exceeding 50-mm SL, YOY become sedentary (or at least drift minimally) and feed on benthic organisms.

It is unclear whether non-drifting YOY would be susceptible to turbine impacts.

Commercial barge traffic can significantly impact channel catfish populations, as well, because all life stages occupy main channel and main channel border habitats. Wave action can wash alevin from nesting structures (Harber et al. 1978). The effects of premature dispersal are unknown.

Once in the main channel, YOY are susceptible to shear forces in the propeller wash, wash-out from main channel structures (logs, wood and shell debris, interstices), and physical abrasion. For example, catch declined measurably following barge passage, requiring 10-15-min redistribution time before sampling could resume.

No measure of navigation related mortality is available for present traffic levels. Projected increases in commercial barge traffic could, however, have system-wide consequences on the channel catfish fishery. Therefore, it is essential that navigation related mortality of YOY be measured to mitigate future impacts on the fishery.

Otter trawling represents a means of estimating year-class strength of channel catfish, but the gear has certain limitations. In the UMR, trawling is restricted to the main channel where the probability of entangling the net on submerged wing dams or snags is minimized. As a result, potentially productive habitats such as the east side of Dresbach Island remain unevaluated. In addition, the otter trawl does not effectively sample uneven bottoms; therefore, fish are able to escape capture by descending into dune troughs. The gear will not follow the contours of duned bottoms common in the UMR.

If effort is standardized between years and samples are collected during periods of peak YOY drift (early August for Pool 7), otter trawling could produce reasonable year-class estimates. Perhaps areas adjacent to or slightly downstream from large backwaters should be identified as standard sampling sites.

Although this study provides insight into the ecology of early life stages of channel catfish, several areas of needed research have become apparent. In particular, I would recommend the following areas of research:

- telemetry studies of adult channel catfish to identify spawning areas,
- mortality estimates of YOY for mitigation purposes,
- dispersal patterns of YOY to identify winter habitats and to estimate the proportion of fish drifting through dams,
- improved otolith sectioning techniques to arrive at more detailed length-at-age growth information, and
- laboratory studies to identify cues affecting increment deposition and when in the diel cycle increments are deposited.

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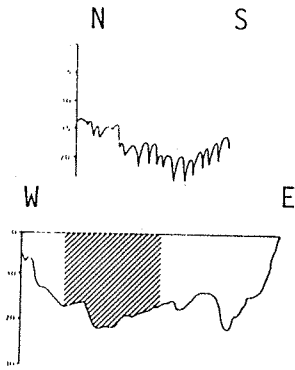
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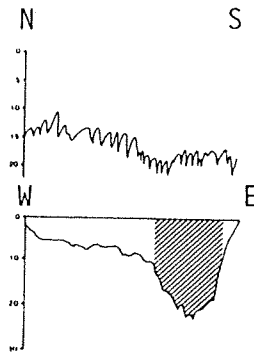
APPENDIX

Appendix I. Longitudinal (upper) and transverse (lower) bottom profiles from YOY channel catfish sampling stations, Navigation Pool 7, upper Mississippi River. A- Station I; B- Station II; C- Station III; D- Station IV; E- Station V.

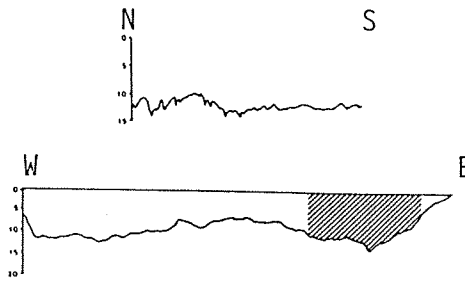
A



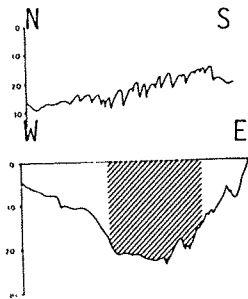
B



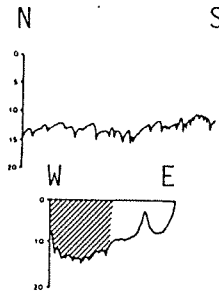
C



D



E



Appendix II. Quality assurance data from YOY channel catfish otolith increment counts.

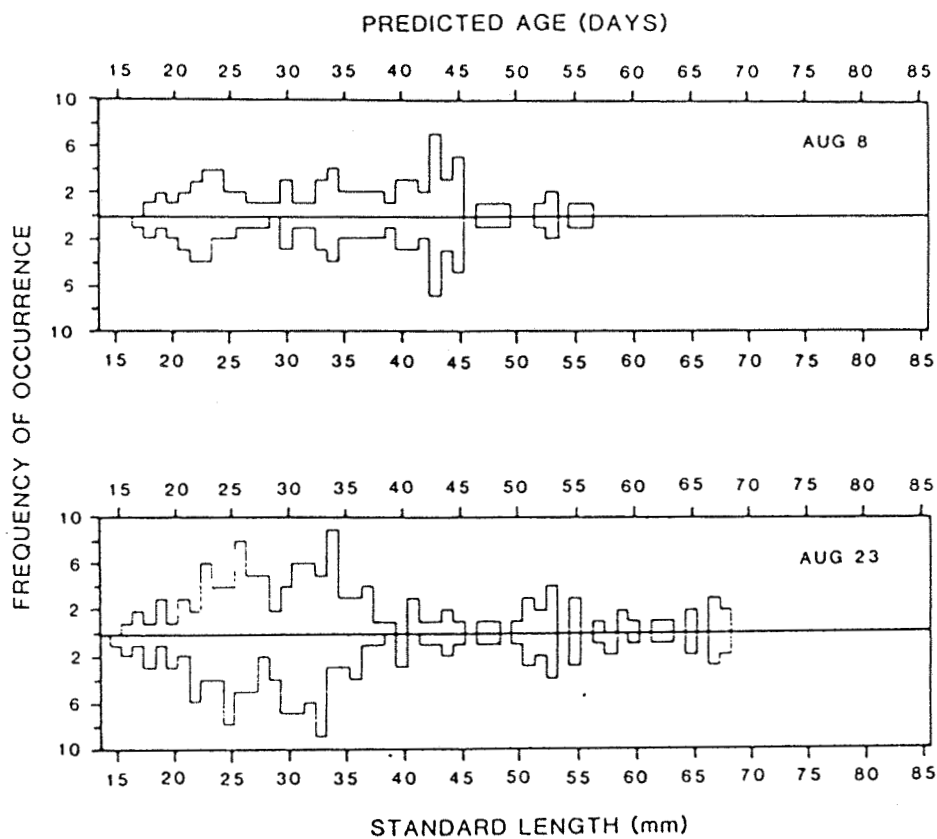
Fish	Estimated age	Quality check	Difference	$\frac{\text{Difference}}{\text{estimated age}} \times 100$
Field samples				
F191	54	54	0	0.0
F210	81	65	16	19.8
F235	62	60	2	3.2
F176	49	46	3	6.1
F128	24	34	10	41.7
F131	21	24	3	14.3
F261	61	56	5	8.2
F36	19	18	1	5.3
Laboratory samples				
1M7	18	19	1	5.6
2R14	21	20	1	4.8
1M4	16	15	1	6.2
1A3	11	11	0	0.0
3R3	13	12	1	7.7
2M4	15	11	4	26.7
3A1	12	10	<u>2</u>	<u>16.7</u>
			$\bar{x} =$	3.33
				11.09

Appendix III. Feed ratios by date for laboratory reared channel catfish raised under three feeding regimes. Regime A = 100%; B = 50%; and C = 10% of recommended feeding rates.

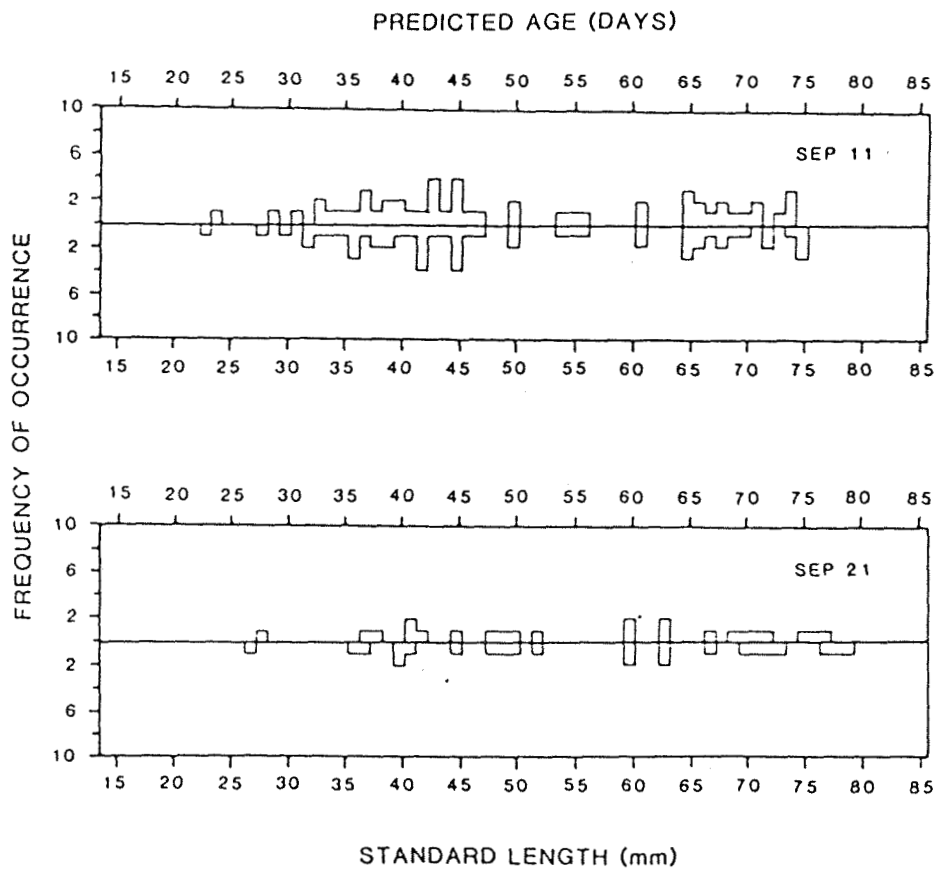
DATE	FEEDING REGIME								
	A			B			C		
	g fish	g feed	% body wt.	g fish	g feed	% body wt.	g fish	g feed	% body wt.
7/16	225.9	19.2	8.50	225.9	9.6	4.25	225.9	1.9	0.85
7/28	275.8	22.3	8.10	267.2	10.8	4.05	123.4	1.2	0.81
8/8	351.4	28.5	8.10	384.9	15.6	4.05	69.4	0.6	0.81
8/22	1164.0	78.0	6.70	956.0	32.0	3.35	70.0	0.5	0.67
9/3	2170.0	145.4	6.70	1568.0	52.5	3.35	76.0	0.5	0.67
9/16	2400.0	160.8	6.70	2000.0	67.0	3.35	50.0	0.3	0.67

Appendix IV. Coefficients of variation (Sokal and Rohlf 1981) by station for YOY channel catfish collected from Navigation Pool 7, upper Mississippi River, 1984 and 1985.

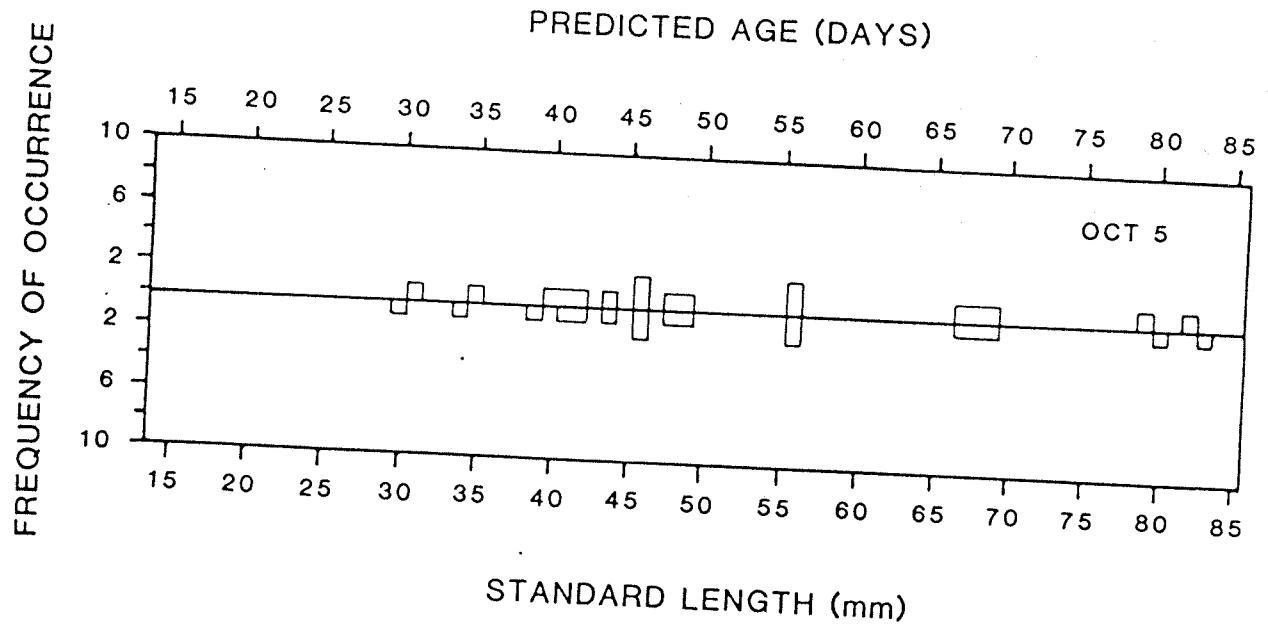
STATION	DATE						
	8/8/84	8/23/84	9/11/84	9/21/84	10/5/84	8/7/85	8/28/85
1	157.41	32.83	86.57	175.76	0.00	62.29	13.39
2	47.88	66.88	43.61	----	175.76	56.75	132.50
3	32.76	24.09	17.24	49.36	43.61	37.14	88.33
4	57.14	88.74	25.00	34.73	115.04	100.00	173.00
5	100.00	33.33	65.52	96.40	34.73	21.72	65.66
\bar{X} =	89.52	52.46	77.54	131.32	77.77	95.20	82.35



Appendix V. Predicted age frequency and length frequency of YOY channel catfish by date of collection from Navigation Pool 7, 1984.



Appendix V (continued).



Appendix V (continued).

Appendix VI. Taxonomic list of food items isolated from stomachs of YOY channel catfish collected from Navigation Pool 7, upper Mississippi River, 1984.

TAXONOMIC LIST OF FOOD ITEMS

Kingdom: Animalia
 Phylum: Arthropoda
 Subphylum: Chelicerata
 Class: Arachnida
 Order: Araneae
 Subphylum: Crustacea
 Class: Branchiopoda
 Class: Ostracoda
 Class: Copepoda
 Class: Malacostraca
 Subclass: Eumalacostraca
 Superorder: Peracarida
 Order: Amphipoda
 Class: Insecta
 Subclass: Pterygota
 Order: Ephemeroptera
 Family: Ephemeridae
 Genus: Hexagenia
 Family: Caenidae
 Genus: Caenis
 Family: Baetiscidae
 Genus: Baetisca
 Order: Odonata
 Suborder: Zygoptera
 Order: Hemiptera
 Family: Corixidae
 Order: Coleoptera
 Family: Carabidae
 Order: Trichoptera
 Family: Hydropsychidae
 Genus: Hydropsyche
 Order: Diptera
 Family: Chironomidae
 Family: Ceratopogonidae
 Phylum: Bryozoa

Appendix VII. Percent total food item volume and (% frequency of occurrence) of dietary items from stomachs of YOY channel catfish by date of collection from Navigation Pool 7, upper Mississippi River, 1984.

ITEM	DATE				
	8/8	8/23	9/11	9/21	10/5
Trichoptera larvae ^a	50.3 (82.6)	89.4 (78.3)	30.3 (81.0)	28.3 (93.8)	52.6 (69.2)
pupae	32.1 (26.1)	0.0 (0.0)	53.7 (23.8)	58.9 (50.0)	30.7 (15.4)
Cladocera	11.5 (87.0)	7.9 (100.0)	0.1 (14.3)	0.5 (50.0)	1.0 (53.8)
Diptera pupae	1.7 (21.7)	1.0 (21.7)	7.4 (47.6)	2.9 (43.8)	2.2 (15.4)
Chironomidae	1.6 (65.2)	1.2 (65.2)	4.8 (71.4)	4.1 (75.0)	3.4 (92.3)
Ephemeroptera ^b	1.2 (26.1)	0.2 (4.3)	0.9 (14.3)	1.3 (25.0)	1.4 (23.1)
miscellaneous	1.5 (21.7)	0.3 (13.0)	2.7 (28.6)	4.0 (31.2)	8.7 (38.5)
sand grains	----- (0.0)	----- (17.4)	----- (28.8)	----- (31.2)	----- (38.5)

^a largely represented by Hydropsyche sp.

^b largely represented by Caenis sp.

Appendix VIII. Mean total food item volume and (standard deviation) by station from stomachs of YOY channel catfish collected from Navigation Pool 7, upper Mississippi River, 1984.

STATION	DATE				
	8/8	8/23	9/11	9/21	10/5
1	0.038 (0.033)	0.016 (0.023)	0.017 (0.019)	0.007 (a)	0.002 (0.004)
2	0.026 (0.017)	0.007 (0.005)	0.005 (0.001)	--- (---)	0.085 (a)
3	0.020 (0.014)	0.014 (0.007)	0.037 (0.043)	0.026 (0.018)	0.001 (0.002)
4	0.030 (0.027)	0.173 (0.350)	0.011 (0.014)	0.034 (0.029)	0.022 (0.031)
5	0.035 (0.048)	0.010 (0.005)	0.019 (0.016)	0.037 (0.028)	0.002 (0.002)
\bar{X} (SD) =	0.030 (0.028)	0.044 (0.158)	0.019 (0.025)	0.031 (0.024)	0.011 (0.025)
p^a =	0.9246	0.5654	0.2073	0.7236	0.0828

(a) = sample represented by only one fish

p^a = probability that volumes differed by station based on Kruskal-Wallis ANOVA

Appendix IX. Otolith grinding procedure for preparing sections of channel catfish sagittae.

Materials

0.3 μm alumina polishing compound (Fisher Scientific Co., Fairlawn, NJ)
felt polishing cloth (Fisher Scientific Co.)
grinding discs (assorted grits) and cutting wheel (E. C. Moore Co., Dearborn, MI)
Dremel™ variable speed drill with drill press and accessories (Dremel, Racine, WI)
reostat
thermoplastic resin (Buehler Ltd., Lake Bluff, IL)
epoxy resin (Buehler Ltd.)
EM tissue molds (Ernest F. Fullam, Inc., Latham, NY)
glass microscope slides
hot plate (0-300°C range)
paraffin oven
dissecting microscope
compound light microscope
hand-held counting instrument
dissecting forceps (fine tipped)
dissecting needle
watch glass
100% ethyl alcohol
immersion oil
glass etching pen
scale envelopes
safety glasses

Methods

Otoliths were dissected from fish by removing gill arches from underneath and exposing the sacculus chamber. Bony tissues were removed leaving sagittae exposed and easily accessible. Once sagittae were removed, tissue and debris were carefully teased from the otolith with dissecting needle and forceps. Too much pressure from forceps typically shattered the otoliths. Otoliths were transferred to a watch glass filled with 100% ethyl alcohol to remove grease and other materials that which might hamper curing of epoxy around the structure.

Following wash in alcohol, otoliths were allowed to dry and placed in precast EM tissue molds filled half-full with epoxy resin and hardened in paraffin oven at 60°C. The dorsal surface of the otolith was oriented with the squared edge of the mold under a dissecting microscope. Otoliths were covered with fresh epoxy resin and returned to the paraffin oven to eliminate air bubbles from resin. Once cleared, molds were removed from the oven and last minute adjustments of otolith orientation were made. The resin was allowed to cure at least 10 hours. Cured epoxy blocks were removed from molds, placed in labeled scale envelopes, and stored until ready for processing.

Thermoplastic resin was melted onto slides warmed on a hot plate at 270°C. Epoxy blocks were fixed onto slides with square edge down (i.e. dorsal surface of otolith down) and slides were allowed to cool for a few minutes. Slides were labeled with a glass etching pen to identify samples. Safety glasses were worn to prevent glass chips from entering eyes.

Excess epoxy above the otolith was removed by cutting across the block with a Dremel™ variable speed drill placed in the drill press accessory. The drill was fitted with a cutting wheel attachment. Cuts were made as close to the otolith as possible without cutting into the structure. Samples were typically processed in batches of 12-15 because of the number of tool attachment changes necessary to obtain a completed section.

Once excess epoxy was cut away, the Dremel™ drill was fitted with sanding disc attachments. The upper surface of the epoxy blocks was ground with a coarse grit sanding disc. Progress was checked every few seconds of grinding under a magnification of 1000X until the otolith was reached. A fine sand grit was then used to grind toward the otolith nucleus, again, checking frequently under the microscope to evaluate progress.

Once the nucleus was about to come into plane, the surface was polished on a water soaked polishing cloth with a few drops of 0.3- μm alumina polishing compound added. Progress was checked periodically until the nucleus was intersected and rings were resolvable to the margin. The entire grinding and polishing process was eventually reduced to 5-10 min per sample.

All samples were viewed at 1000X oil immersion. Rings were tallied with a hand-held counting instrument. Each sample was counted repeatedly until three consistent counts were obtained. That number was assigned the estimated age.