ILLINOIS NATURAL HISTORY SURVEY

AGE STRUCTURE AND ANALYSIS OF CARP POPULATIONS IN THE MISSISSIPPI AND ILLINOIS RIVERS

Aquatic Biology Section
Technical Report

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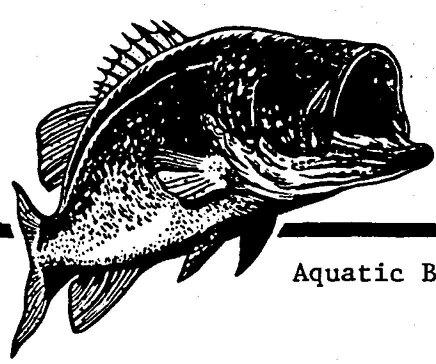

Progress Report, F3-383-R1

Aquatic Biology Technical Report 1984(9)

Illinois Natural History Survey
Aquatic Biology Technical Report 1984(9)

Progress Report

1 October 1983 - 30 June 1984

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August 1984

Project 3-383-R, Age Structure and Analysis of Carp Populations in the Mississippi and Illinois Rivers, was conducted under a memorandum of understanding between the Illinois Department of Conservation and the Board of Trustees, University of Illinois. The actual research was performed by the Illinois Natural History Survey, a division of the Department of Energy and Natural Resources. The project was supported by National Marine Fisheries funds and was performed in compliance with its provisions. The form, content, and data interpretations made in this report are the responsibility of the University of Illinois and the Illinois Natural History Survey, and not that of the Illinois Department of Conservation.

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SUMMARY OF RESEARCH PROGRESS

Carp Collections

We completed the initial phase of carp collections (i.e., from reaches of the Illinois River) in 1983. Total collections and individuals taken from the Peoria, La Grange, and Alton navigation pools were: 15, 184; 9, 260; and 30, 122, respectively. Although these numbers were below our initial goal of 300 fish per pool, they appear to be sufficient to satisfy our primary objective of describing the age structure of carp populations in the Illinois and Mississippi rivers.

Review and Testing of Aging Methods

A comparative study of aging methods using four carp bony structures from Illinois River carp was conducted to determine which structures would be most useful throughout the entire project. Results of this study were presented by Mr. Brian Hartsfield at the 1984 meeting of the Illinois Chapter of the American Fisheries Society (abstract attached as Appendix B). Recommendations from this study included using scales as primary aging structures, and opercles and dorsal spines to verify ages of selected specimens. The use of otoliths was discontinued, because of the time and relative degree of technical skill required to prepare a section for aging and because otoliths did not prove to be more precise than scales.

Construction of Computer/Digitizer Aging System

A digitizing pad and interface were purchased and connected to an Apple II+ microcomputer at the Pool 26-River Research Lab, Grafton, Illinois. "DISBCAL," a scale measurement program (Frie 1983), was obtained in early 1984. The system was put on line in March 1984 and has worked well since. Scales from carp from the Alton Pool, Illinois River, have been aged (by two readers) and measured using this system. Data files for individual carp collections have been stored on diskettes for future analyses.

Preliminary Aging Results and Conclusions

Carp collected from Pool 19, Mississippi River, in 1982 ranged from 1 to 11 years of age. They exhibited moderate growth rates in comparison to carp collected by other researchers upstream on the Mississippi, in Pool 6 of the Illinois River in the 1950's, and in the Missouri River. A relative lack of 3- and 4-year-old carp in 1982 indicated that Pool 19 carp populations may suffer from poor annual recruitment in some years. We suggest a long-term study of these populations until potential causes of limited recruitment are identified.

Carp from Pool 8, Illinois River, ranged from 0 to 5 years of age and showed slow growth rates after their third year. These population conditions have probably existed since the late 1950's and are related to a lack of benthic food resources. We have started experiments to demonstrate the minimum benthic densities necessary to support different carp growth rates.

ACKNOWLEDGEMENTS

Mr. Jim Cassens assisted with the collection of carp, was a principal reader of annuli, and operated the digitizing equipment used to measure bony structures. Mr. Jerry La Shelle and Mr. Don Johnson, commercial fishermen, helped us obtain measurements and aging structures of carp in Pool 13 and the open river reach of the Mississippi. Ms. Cynthia White and Ms. Teresa Simington typed the report, proofread sections of the manuscript, and measured carp.

AGE STRUCTURE AND ANALYSIS OF CARP POPULATIONS IN THE MISSISSIPPI AND ILLINOIS RIVERS

OBJECTIVES

The objective of this project is to describe the age structure of carp populations in selected reaches of the Mississippi and Illinois rivers. This information will be used to explain, in part, recent declines in commercial carp harvest and average carp sizes in these rivers. Since previous studies (Starrett and Fritz 1965, Mills et al. 1966, Jackson and Lubinski 1983) have shown that mean total length of Illinois River carp is typically less than that of carp from the Mississippi River, a specific question asked was, "Are Illinois River carp smaller because they have slower growth rates or because they have shorter life spans?"

MATERIALS AND METHODS

Carp Collections - 1983

In 1983, carp were collected in main channel border, side channel border, and backwater habitats of the lower three Illinois River navigation pools. Electroshocking collections (n = 39) (Appendix A, Table A-1) accounted for 566 fish. Hoopnet collections (n = 15) in Pool 8 (Alton), Illinois River, accounted for 23 individuals (Appendix A, Table A-1). Fish markets in the Grafton, Illinois, area contributed 30 carp to the study. Information related to the location and habitats of these carp was obtained from commercial fishermen.

A 230-v A.C. generator (3-phase, 180 cycles per second) was used for the electroshocking collections. Current was transmitted into the water via three cables that were mounted on the bow of a 4.8-m aluminum boat. The distal ends of the cables were 1.4 m apart and each was suspended to a depth of 1 m below the water surface. Stunned fish were dipped from the water using 0.6-cm mesh nets and placed in buckets until the end of the collection period (typically 15-30 minutes) when they were identified, measured, and released. Fish kept for otoliths or opercles, however, were either brought back to the lab or buried after the structures were removed.

Hoopnet collections were made in a backwater habitat and a main channel border habitat at Illinois River mile 3.0. The net used in the backwater had seven rings, 0.6-0.9 m in diameter, two throats, and bar mesh ranging from 2.5 to 3.8 cm from the back to the front (open) end of the net. The net used in the main channel border habitat had seven rings, 0.8-1.0 m in diameter, two throats, and bar mesh ranging from 5.0 to 6.4 cm from the back to the front of the net.

Aging Methods

Scales. Four scales were removed from the first row above the lateral line on the right side of each carp between the pectoral and pelvic fin insertions. Scales were placed in a small, labelled envelope and were allowed to air dry. To prepare the scales for reading, they were washed in tap water, air dried, and temporarily mounted between two glass microscope slides. Two minutes were required for cleaning and mounting. The mounted scales were viewed by projecting their images onto a white background using an Eberbach scale projector, producing an image approximately 30 cm in diameter.

There were several difficulties with this aging method. If the scale had been regenerated at any time during the life of the fish, all circuli prior to the time the scale was replaced were lost, making regenerated scales useless for age determination.

Many "false" annuli were observed. During spawning or other periods of abbreviated growth, some circuli, or portions of them, were reabsorbed leaving an incomplete record of growth. These zones at first appeared to be annuli, but often did not extend concentrically around the focus. These zones were not counted as annuli. In other instances, a certain annuli was read as "true", but due to a non-concentric growth of the scale, it did not form a complete distinct zone around the focus. This especially presented problems when measuring distances along a standard axis. When this occurred, the annuli was traced from its known position, around the focus, to where it would have crossed the axis along which the measurements were being taken.

A good deal of experience is required to confidently differentiate between "true" and "false" annuli. The amount of time to determine the age of the scales from one carp was high relative to the other bony structures we looked at, with an average of 4 minutes being required. We elected to have two readers age each carp using this method, and discrepancies between readers were resolved by repeated readings.

Dorsal Spines. The first two spines of the dorsal fin were clipped from each carp as close to the fin base as possible using a pair of sharp wire cutters. Care was taken not to crack or otherwise damage the lower edges of the spines. The stout, double-serrated second spine was used for age determinations, but the smaller, first spine was also clipped for use as a reference point while cross-sectioning the second spine. Less than 1 minute was required to collect these structures. The spines were then placed in a labelled envelope and were allowed to air dry.

To prepare the dorsal spines for cross-sectioning, they first were soaked for 3 minutes in 33% hydrochloric acid. This softened the integument, which was then removed with forceps and scouring pad. The spines were then held in place with a small C-clamp while cross-sections were cut using a small, high speed, rotary hobby tool with a fine-toothed, circular saw blade. The first cut was made near the base of the second spine to ensure an even starting point. Several cross-sections were then made at an approximate thickness of 0.5 mm. All of the sections were taken from the second spine below the level of the top of the first spine.

The cross-sections were mounted flat on labelled glass slides using thermoplastic cement. Using 600-grit sandpaper and water, the first side of the spine section was lightly sanded to eliminate the rough grooves left by the rotary saw blade.

The thermoplastic cement was then melted and the cross-section remounted on its other side. Sanding was done first with 220-grit sandpaper to a point where the annuli became visible. Then fine sanding was done with 600-grit sandpaper and water until the section had a uniform thickness and the annuli were distinct. Frequent visual checks for thickness and clarity of the annuli were made so that sanding was not continued past the optimum point. These checks were made using a stereoscopic dissecting microscope with reflected light at a magnification of 25x. It took an average of 10 minutes to prepare each dorsal spine cross-section.

Dorsal spine sections were read by viewing them through a stereoscopic microscope against reflected light at 25-30x magnification. Alternating light (translucent) and dark (opaque) zones were visible when the sections were viewed. The faster growth periods appeared as lighter zones while the slower growth periods showed as darker zones. The outer edge of each dark band was considered an annulus. Age determination was relatively easy and took an average of 2 minutes per mount, but the edges of growth zones in dorsal spines were less distinct than in scales, making measurements between annuli more variable.

"False" annuli were less apparent on dorsal spines, as well as the other bony structures observed, than they were on scales.

<u>Otoliths</u>. Of the three pairs of otoliths present, only the largest, the sagittae, was used. Otoliths were removed by first cutting laterally across the isthmus and longitudinally along the length of the ventral side of the head using a pair of tin snips. The molariform teeth were then removed exposing a cartilaginous, triangular, pharyngeal plate. The otoliths were enclosed in the otic capsule which lay above and slightly forward of the pharyngeal plate but below the brain. By cutting around the brain case, leaving a 2-cm area around the pharyngeal plate intact, the entire ventral portion of the brain case was removed, exposing and allowing easy access to the otic capsule. The otoliths were then removed from the

otic capsule with a pair of fine forceps, taking care not to crack the structures. This removal procedure took an average of 8 minutes per carp. The otoliths were stored in labelled envelopes and air dried until they were prepared for mounting.

The otoliths were cleaned by placing them in 95% ethanol for 5 seconds. They were then mounted on labelled glass slides using thermoplastic cement with the sulcus (proximal face) away from the slide. The otoliths were sanded using 220-grit sandpaper down to half of their original thickness, and then with 600-grit paper and water to remove scratch marks. The thermoplastic cement was then melted and the otolith mounted on its other side, with the sulcus facing down. Sanding was continued slowly and evenly to reach the thickness at which the annuli were most distinct. This was somewhat difficult because different sections of the otolith would sand down faster than others due to slight variations in the pressure of the sandpaper on the otolith. Also, the slightly thicker side of the section required a bit more sanding than the rest. Sanding was done alternately using 220-grit sandpaper and 600-grit sandpaper and water. Frequent checks of the clarity of the annuli were necessary so that optimum thickness (approximately 0.25 mm) was not passed. Placing the mounted otolith in 33% hydrochloric acid for 3-5 seconds and then rinsing with water helped to enhance the annuli. The average time required to prepare one otolith was 20 minutes.

Otoliths were viewed through a stereoscopic dissecting microscope using reflected light at 25-30x magnification. Viewed in this manner, light (translucent) and dark (opaque) bands were visible, representing periods of rapid and slow growth respectively. The outer edge of each dark zone was considered an annulus. Age determination was relatively easy and took an average of 2 minutes per otolith.

<u>Opercles</u>. The entire left opercle was clipped from each carp. It was then trimmed of excess tissue, allowed to air dry, and stored in a labelled envelope. Collections of each opercle took less than 1 minute. To prepare the opercle for reading, it was placed in boiling water for 3-5 minutes. The integument and other tissue were then removed with forceps and scouring

pad. The opercle was then air dried and ready for viewing. Preparation time for each opercle was 5-6 minutes. The annuli were visible when the opercle was held against a lighted background and were usually apparent without magnification. If magnification was required, a stereoscopic dissecting microscope was used (8-10x) with reflected light against a dark background. The annuli appeared as light and dark bands. With light shining through the opercle, the darker bands showed the zone of faster growth while lighter bands showed the zones of slower growth. When light was transmitted down onto the opercle, the opposite was true. In either method, the outer edge of the slower growth band was considered an annulus. The annuli could be seen on either side of the opercle but seemed to be clearer on the proximal (internal) side. An average of 2 minutes was required to determine the age of each opercle.

Method Comparison Criteria

Aging methods for all structures were compared using four criteria. Time required for processing was broken down into the categories of collection, mounting, and reading. Percent reading success was calculated by dividing the initial number available into the number of readable structures at the end of the processing; this criterion yielded a measure of loss or breakage during processing. The capacity of the structures to yield replicable ages when read by two technicians was calculated as percent agreement at three levels of precision--exact match, within 1 year, and within 2 years. Lastly, we considered whether collection of the structure required sacrificing the carp.

Construction of Computer/Digitizer Aging System

The computer/digitizer aging system constructed for use in this study was completed in March 1984. The system was a duplicate of the one described by Frie (1983) except for the scale projector. It includes a scale projector, a digitizing pad, a computer interface, and an Apple II+ microcomputer.

The software package that allows the measurement of scales (or any other semi-transparent structure), is called DISBCAL (Frie 1983). This package was obtained at no charge from Mr. Frie. The program allows for measurements, body-scale regressions, back-calculations of total lengths at previous annuli, and disk storage and retrieval of data files.

Since we suspect that carp within a given collection frequently exhibit scale (or other structure) measurements that are somewhat unique from carp taken in other collections, we are storing measurements from each collection in an individual disk file. Later we will combine data from collections by habitat type or navigation pool.

RESULTS

Comparison of Bony Structures

In terms of processing time required, scales and opercles were the most convenient structures to use (Table 1). Spines required about twice as much time and otoliths about 4 times as much to process.

Scales and opercles produced 100% reading success. It should be noted, however, that at least four scales were collected from each carp, reducing the chance of obtaining all unreadable replacement scales. Dorsal spines also yielded a high reading success percentage (96%). Losses were accrued when spines fractured and when spinal lumens were large enough (i.e., in older carp) to obscure early annuli. Otoliths yielded only 56% reading success due to the large numbers of structures that were lost during collection or that were broken or sanded too thin during processing. These losses were highest at the onset of the study and would have reached a mininum threshold at some point, but we were not able to determine when that point would be reached.

Percentages of reader agreement for large and small carp are presented in Table 2. All structures were relatively similar in terms of their capacity to be aged by one reader to within 1 or 2 years of the other. However, if an exact match between two readers was considered necessary, scales and

Table 1. Time required to process carp bony structures.

Structure	Time (in minutes) required to: Collect	Mount	Read	Total
Scales	1	2	4	7
Dorsal spines	1	10	2	13
Otoliths	8	20	2	30
Opercles	1	5	2	8

Table 2. Percentage of age agreement between two readers. Results for small (≤33 cm) and large carp are presented separately at three levels of agreement.

	Small Carp				Large Carp			
		Level of Agreement				Level of Agreement		
Structure	N	Exact Match	Within 1 yr	Within 2 yr	N	Exact Match	Within 1 yr	Within 2 yr
Scales	20	65	100	___	29	55	97	100
D. spines	20	65	95	100	28	50	93	100
Opercles	10	30	90	100	27	33	89	100
Otoliths	1	0	100	___	19	42	89	100

spines outranked opercles and otoliths for large carp, and they outranked opercles for small carp. Not enough otoliths were obtained from small carp for a valid comparison.

Mortality associated with collecting scales and dorsal spines from carp was unknown but believed to be minimal or non-existent. All carp that provided opercles and otoliths were sacrificed.

Scatter plots of age determinations by both readers are presented by structure in Figures 1-4. Ages determined using all structures by each reader are plotted against total lengths in Figures 5 and 6.

Preliminary Age Analyses

Ages of carp collected from Pool 8, Illinois River, in 1983 (as determined using scales; Appendix A, Table A-1), were combined with a length-frequency histogram and compared with a similar set of data generated from Pool 19, Mississippi River in 1982 (Figure 7). Both sets of data were obtained primarily from electrofishing collections, and although this gear selects against young-of-the-year carp, the bias was believed to be consistent and did not affect the comparison of older year classes. The Pool 19 carp population appeared to lack individuals of the third and fourth year classes. Illinois River carp were clearly smaller than Mississippi River carp of equal age. Furthermore, no Illinois River carp were captured that were beyond 5 years of age, in contrast to the Mississippi River population which included individuals in their 11th year.

Carp Growth Rates in the Mississippi and Illinois Rivers

A subset of the data included in Appendix A, Table A-1, was analyzed using the computer/digitizer system and software described earlier to compare carp growth rates in the Illinois River to those in the Mississippi and other midwestern rivers (Figure 8). Illinois and Mississippi River carp from Pool 19 grew at intermediate rates, between the low rates reported for impounded and unimpounded reaches of the Missouri River and the high rates

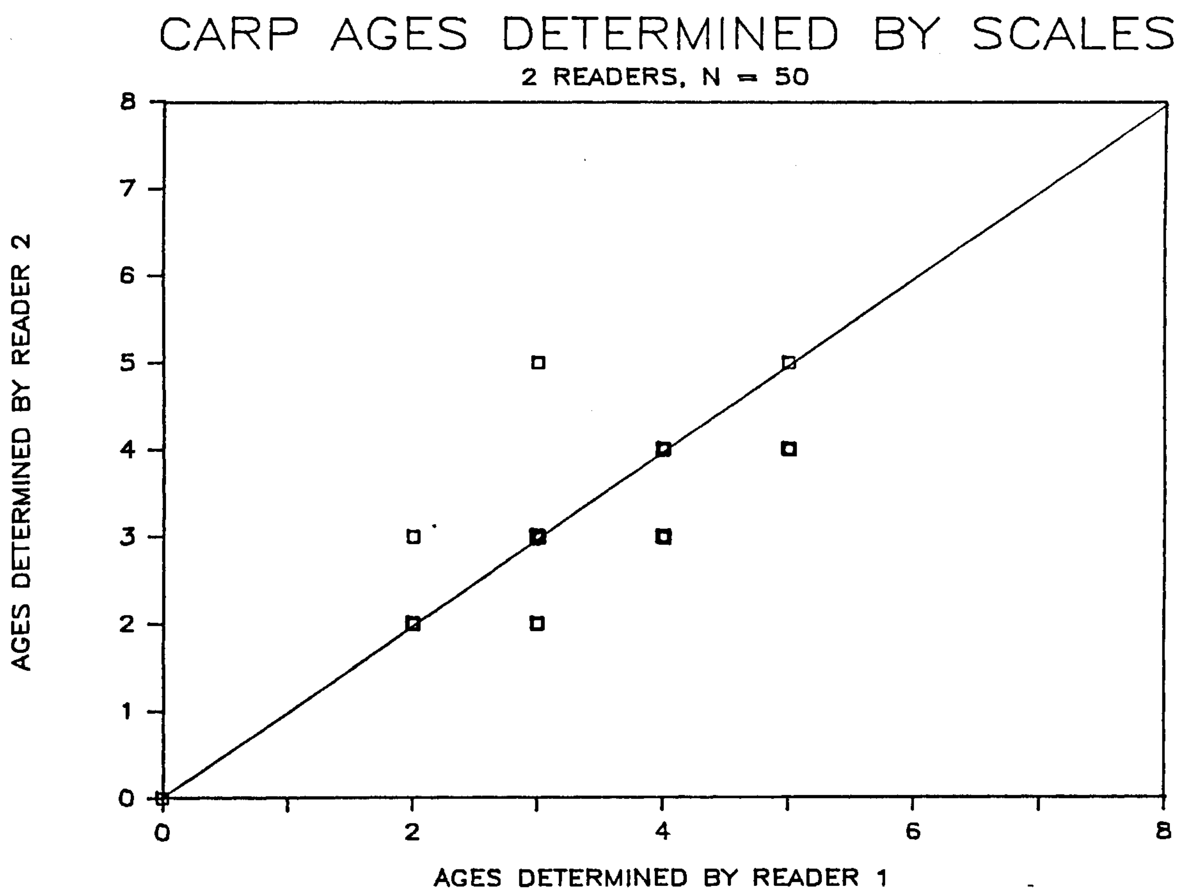


Figure 1. Illinois River, Pool 8, carp ages as determined using scales. Diagonal line indicates perfect agreement between readers.

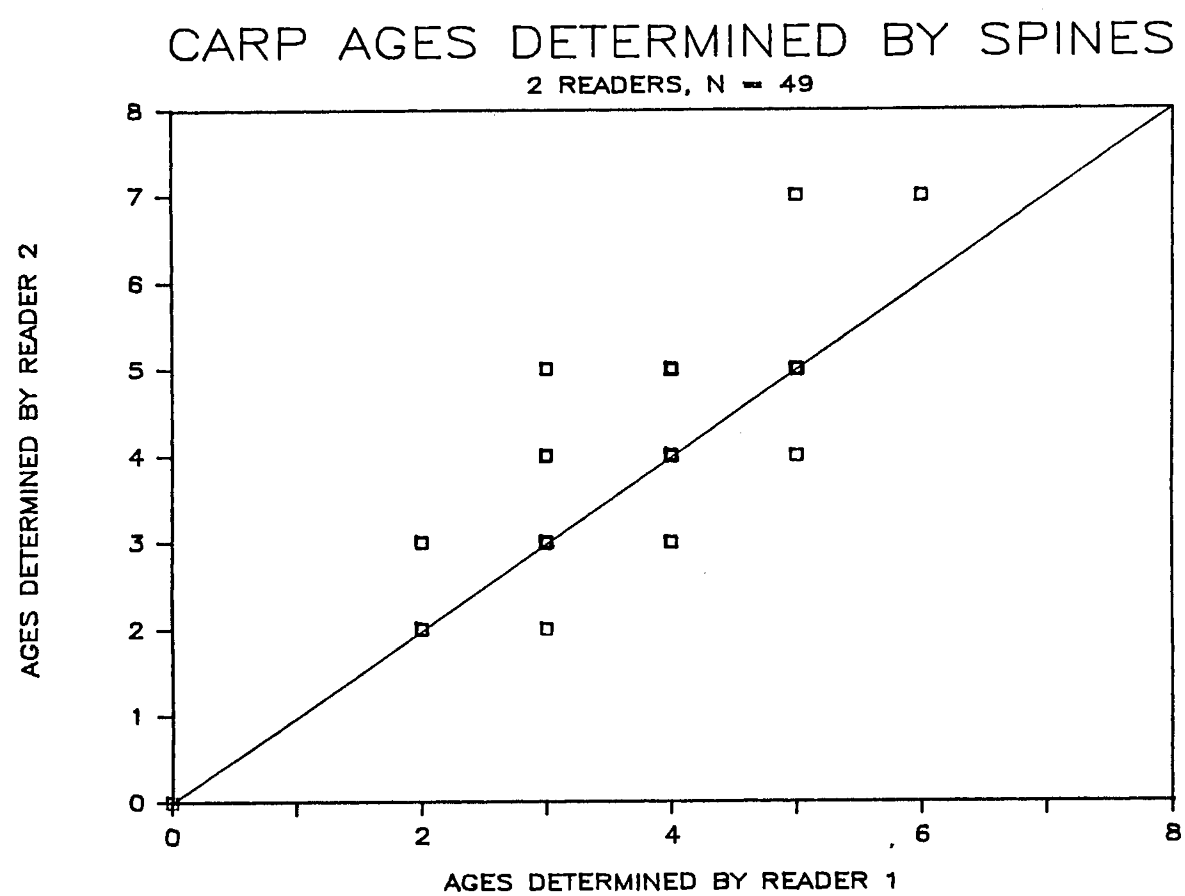


Figure 2. Illinois River, Pool 8, carp ages as determined using spines. Diagonal line indicates perfect agreement between readers.

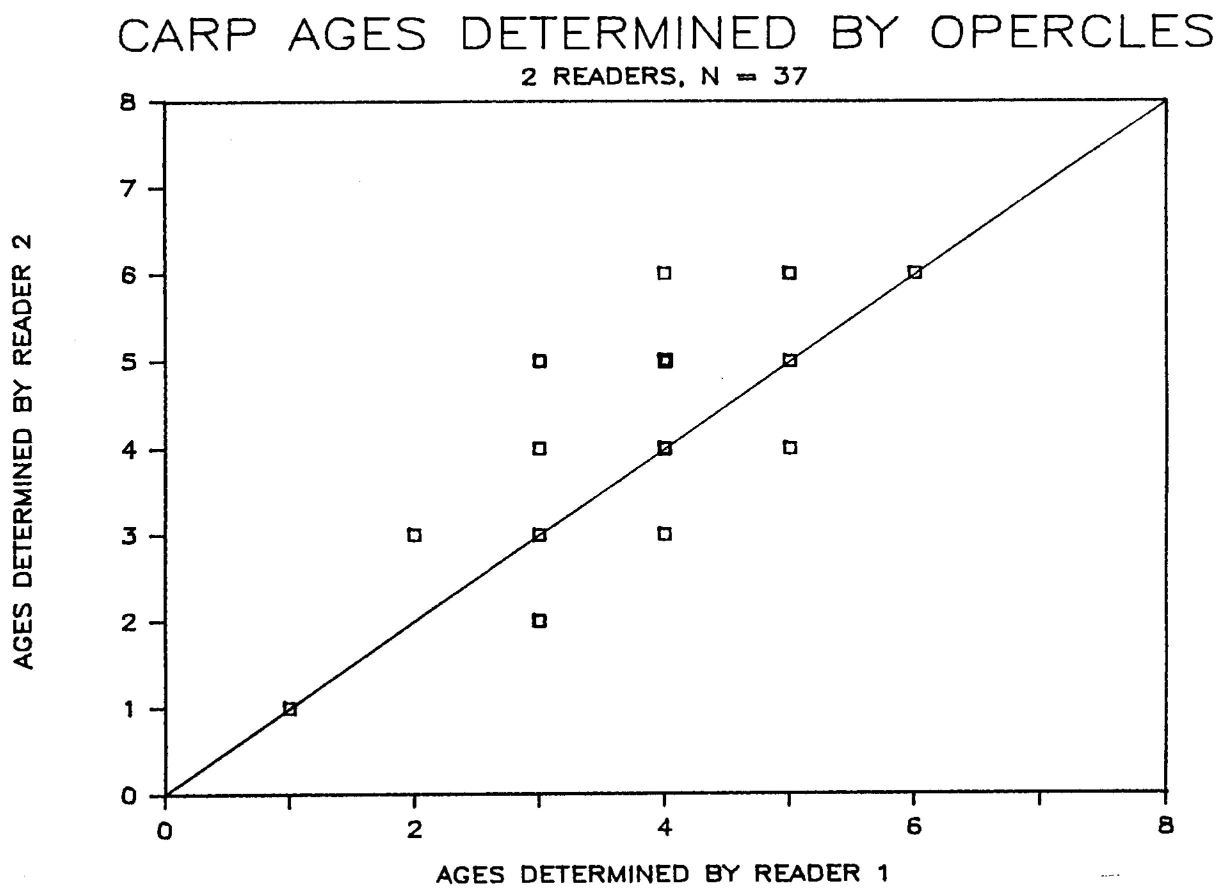


Figure 3. Illinois River, Pool 8, carp ages as determined using opercles. Diagonal line indicates perfect agreement between readers.

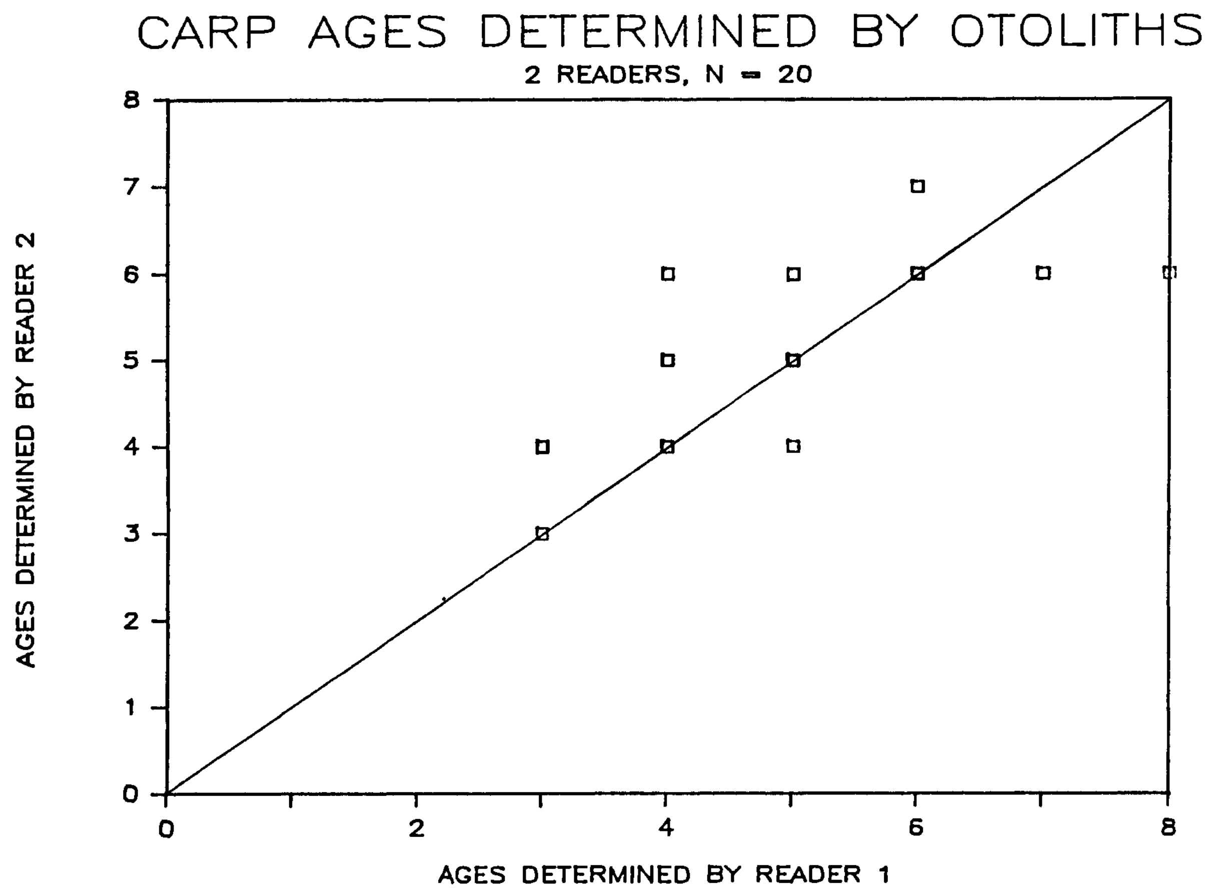


Figure 4. Illinois River, Pool 8, carp ages as determined using otoliths. Diagonal line indicates perfect agreement between readers.

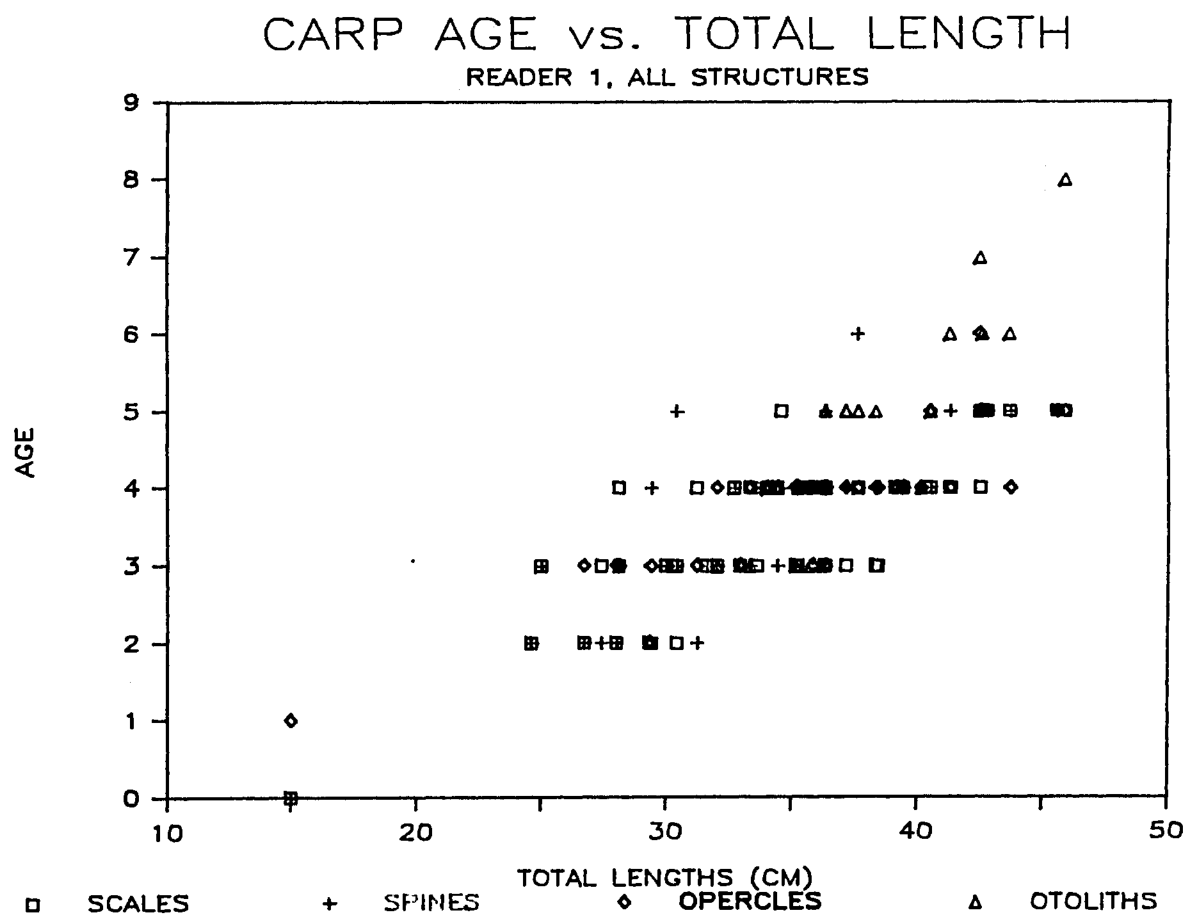


Figure 5. Illinois River, Pool 8, carp ages (all structures) vs. total lengths, Reader 1.

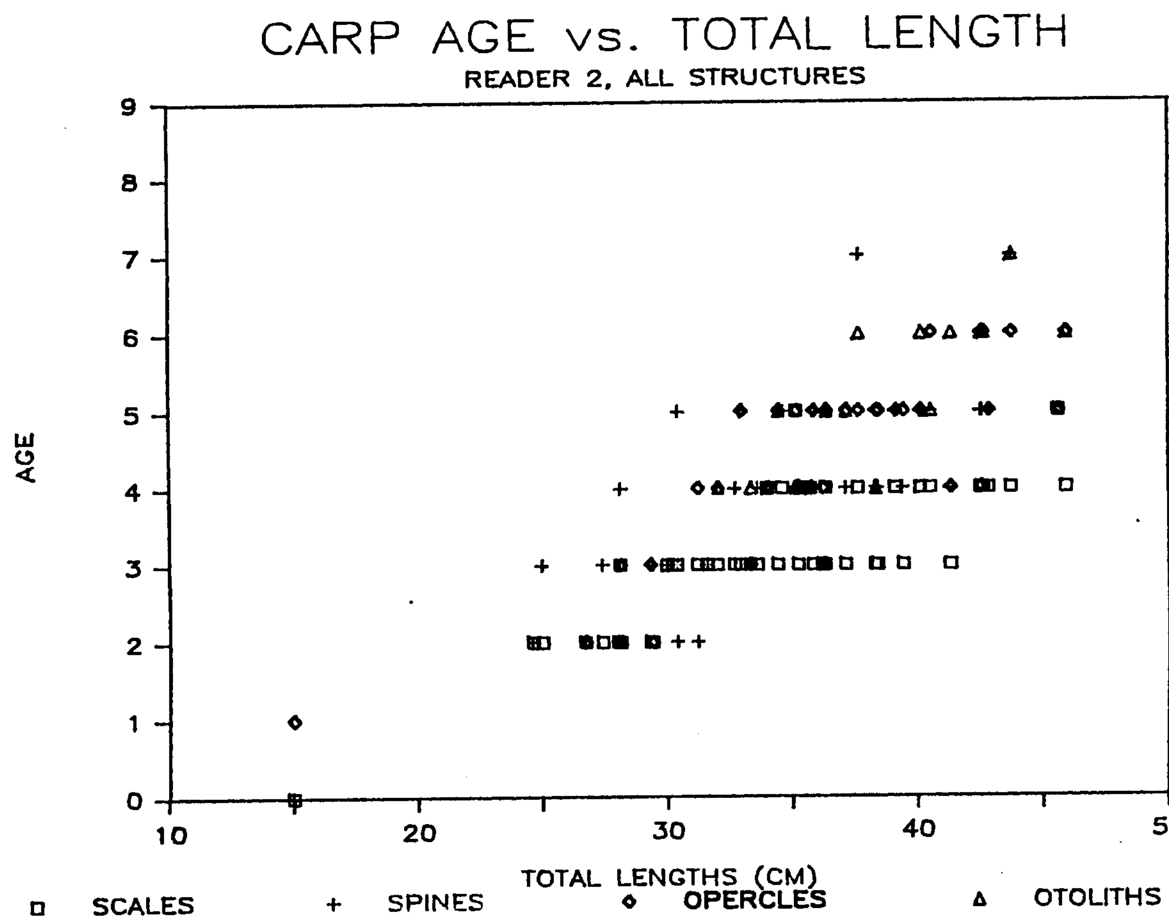
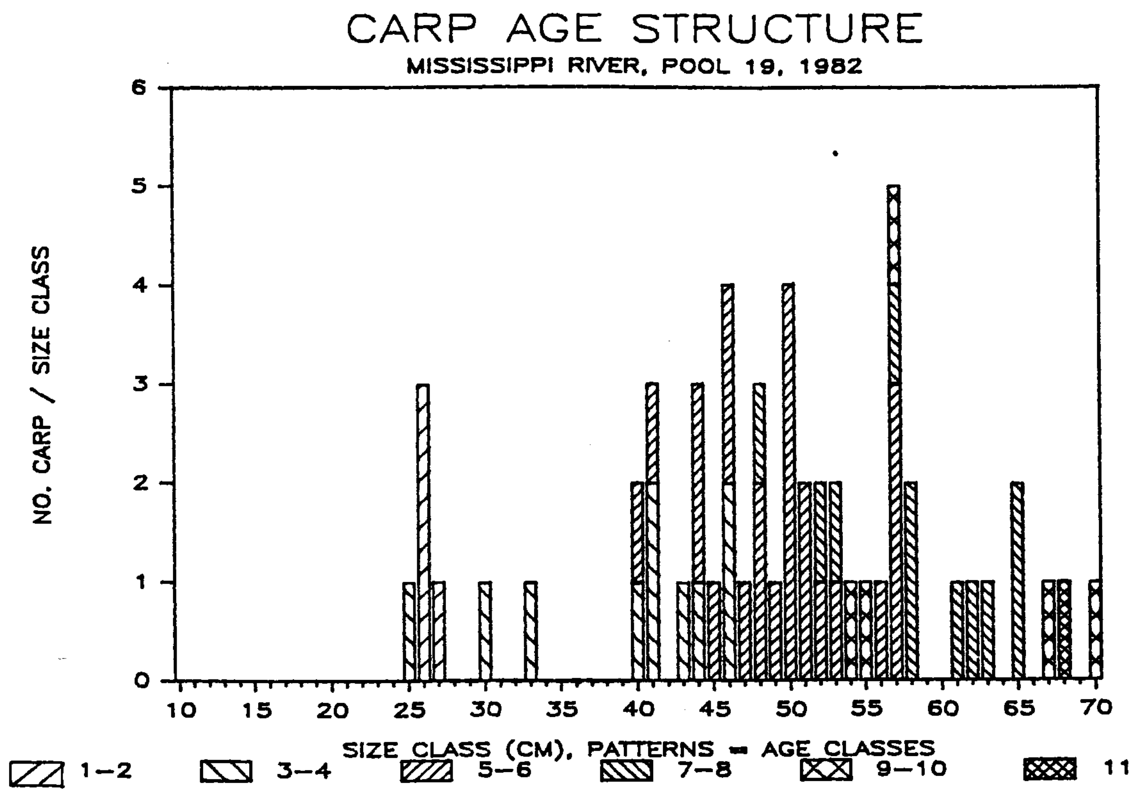


Figure 6. Illinois River, Pool 8, carp ages (all structures) vs. total lengths, Reader 2.



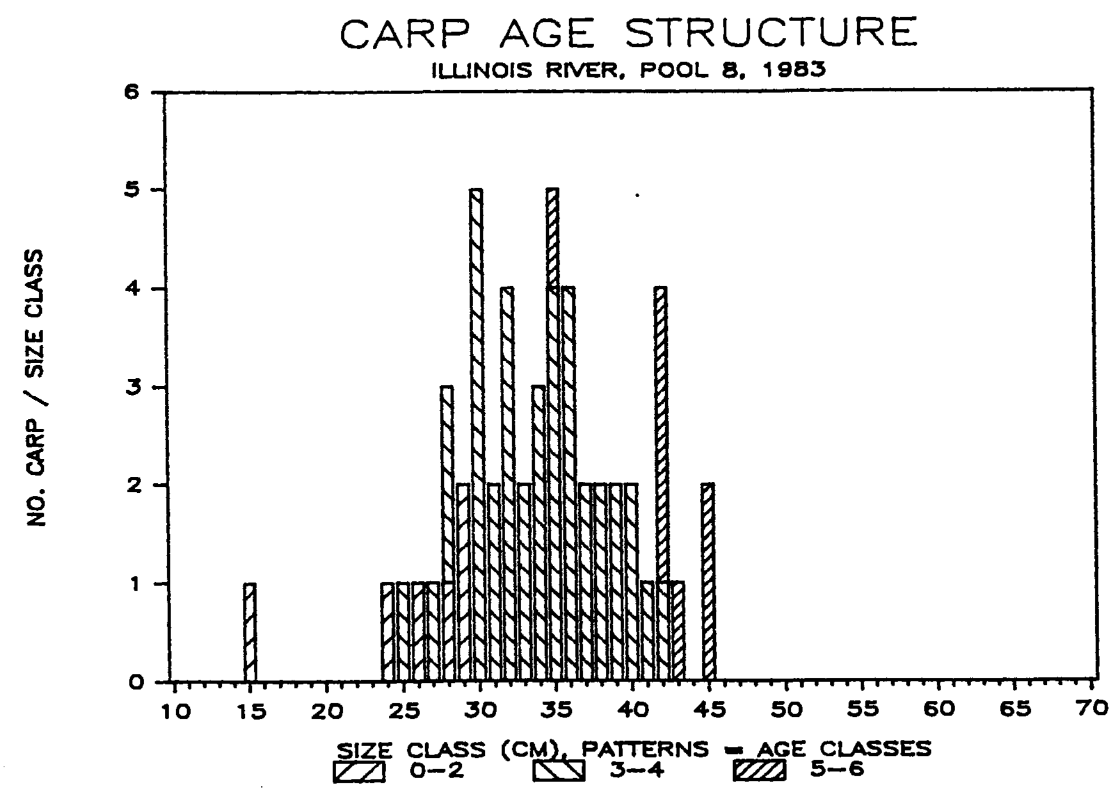
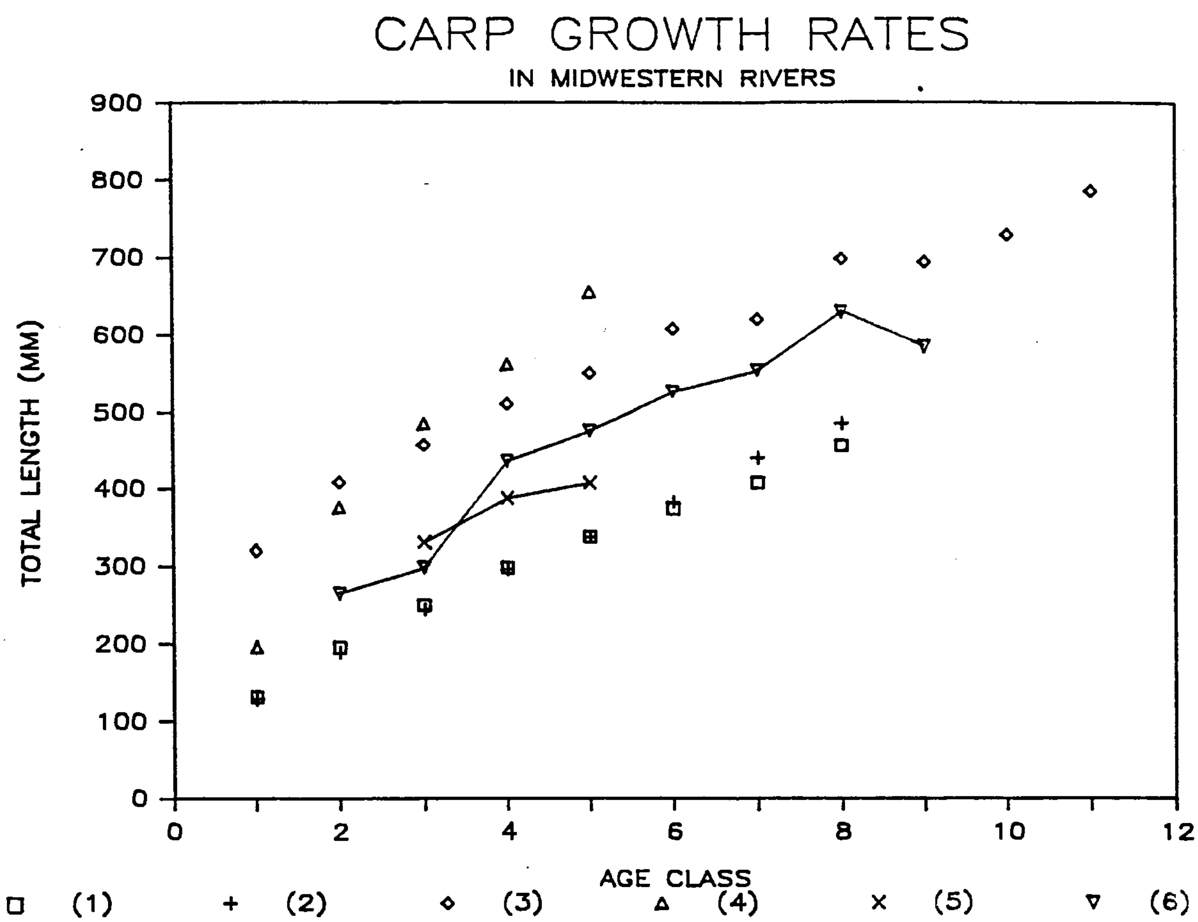


Figure 7. Comparison of carp population age structure, Pool 19, Mississippi River (1982), with that of Pool 8, Illinois River (1983).



(1) Stucky and Klassen (1971): length at age, fish collected in un-impounded Missouri River, 1967-68.

(2) Stucky and Klassen (1971): length at age, fish collected in impounded Missouri River, 1967-68.

(3) Starrett and Fritz (1965): length at capture, fish collected in Lake Chautauqua, Illinois River, 1957-58.

(4) Christenson and Smith (1965): length at age, fish collected in Pool 5, Mississippi River, 1948-49.

(5) Lubinski and Jackson (this study): length at age fish collected in Pool 8, Illinois River, 1983.

(6) Lubinski and Jackson (this study): length at capture, fish collected in Pool 19, Mississippi River, October, 1982.

Figure 8. Carp growth rates in midwestern rivers.

reported for carp in Pool 5 of the Mississippi River. Additionally, the rates for Pools 19 and 8 reported here were considerably below those reported for Pool 6 on the Illinois River in 1957-58.

Little difference appears to exist in current (1982-83) growth rates of Illinois and Mississippi River carp younger than 3 years. However, above this age, Mississippi River carp grow faster than their Illinois River counterparts.

DISCUSSION

Others have attempted to age carp using different structures (Frey 1942, McConnell 1952, English 1952, Starrett and Fritz 1965). Most reseachers found scales to be excessively difficult primarily because of common "false" annuli, particularly on scales of carp older than 2 or 3 years. Starrett and Fritz (1965) favored dorsal spines as carp aging structures over the opercular methods described by McConnell (1952) and English (1952), because in examining 263 spines they disagreed on only 10 ages. Otoliths have recently come into extensive use as aging tools, but we found the time required to process the large otoliths common to carp to be excessive, especially since they did not yield higher percentages of agreement than the other structures used. Once we became familiar with reading carp scales, they yielded percentages of agreement at all levels that were equal to or higher than those of other structures (Table 2, Figures 1-6). Additionally, they required little time and did not necessitate sacrificing carp. We therefore decided to use scales as primary aging structures and opercles and dorsal spines as reference structures when "false" annuli limited the readability of scales. Use of otoliths was discontinued.

Only a small percentage of the total number of scales anticipated for this study have been read. However, clear differences in carp population age structures between the Mississippi and Illinois rivers have been observed. Illinois River carp grow slower after their third year than those in the Mississippi, and they live much shorter lives. These conditions are probably associated with poorer food resources in the Illinois River since the late 1950's. Starrett and Fritz (1965) believed that the virtual disappearance of fingernail clams in the middle and upper river in 1953 adversely affected carp growth. Mills et al. (1966) suggested that much of the post-1950 decline in the commercial fishery of the Illinois River had resulted from the scarcity of commercial size carp (17 inches or more in total length), and that while small carp were often abundant in the middle river, most of them disappeared before attaining commercial size. They attributed the lack of commercial size carp to declines of fingernail clams and low dissolved oxygen concentrations in the river. Upon investigating the food habits of carp in the Illinois River further, Starrett (1972) noted that fingernail clams formed 50.2% (by volume) of carp food items below Beardstown, but that only one clam was found in the food contents of carp examined from upstream reaches. Carp collected from the lower section of the river (i.e., with clams) were deeper bodied than those taken upstream (Mills et al. 1966). Bellrose et al. (1977) correlated improved carp condition factors with areas of higher bottom fauna density. Jackson and Lubinski (1983) found that carp conditions factors in 1982-83 had improved in parts of the lower and upper rivers but were unchanged in reaches of the middle river.

The present study suggests that mechanisms affecting both growth and average life span are producing the observed carp population problems in the Illinois River. Growth of fish under 3 years of age does not seem to be affected as much as that of older fish. Younger carp may therefore be effectively supplementing their diet with other available foods, such as zooplankton and periphyton. Older fish may not be able to use these food sources as easily without expending more energy than they gain.

Another contributing factor affecting carp condition factors and growth is the habitat type. Carp collected from below Mississippi River dams are typically thinner than those taken from more lentic areas, presumably due to the higher amounts of energy required for them to maintain position in higher velocities. As another example, Illinois River backwaters are now typically very shallow and saucer-like in morphometry. Few deep water refuges are available for fish to use to escape hot temperatures in the summer. As a result, Illinois River carp may have to endure much warmer temperatures and subsequent higher metabolic demands than Mississippi River carp. We have not yet been able to determine to what extent these variables have affected our comparisons of river carp populations.

While Mississippi River Pool 19 carp grew faster than their present day Illinois River counterparts, they did not grow as fast as carp collected in Pool 5 of the Mississippi River in the late 1940's or carp collected from the Illinois River in the late 1950's. We do not know if this reflects a long-term gradual decline in Mississippi River food resources or habitats or a transient, short-term situation. The benthic food resources of Pool 19 are believed to be quite high (Wenke 1965; Jude 1968; Gale 1969, 1975; Thompson 1973).

The remaining months of this study will be spent adding to the number of carp collected from both rivers and making a final assessment of river carp populations. In addition, we will review recent annual water level regimes on the rivers and the literature relating water levels to carp recruitment to explore the hypothesis that recent years of high water have affected carp populations or carp catches.

PRELIMINARY RECOMMENDATIONS

1. Slow growth rates and short life expectancies of carp in the Illinois River appear to be related to a poor food base and possibly to decreasing habitats. General efforts to improve environmental conditions (i.e., dissolved oxygen concentrations and substrate composition) for fingernail clams and other benthic macroinvertebrates in the river will subsequently be reflected in improved carp population parameters.

2. We need to address the question, "What densities of benthos are required to maintain optimum carp growth and extend carp life spans to more than 10 years?" We are beginning some small-scale experiments to address this question.

3. Moderate growth rates of carp in Pool 19, Mississippi River, despite relatively high densities of benthos, are cause for concern. Growth rates in this reach of the river should be monitored to determine whether there is a gradually declining benthic biomass or some unknown long-term change in the river.

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Table A-1. Summary of 1983, middle and lower Illinois River carp collections.

Illinois River Pool	Coll. Method(1)	Coll. No.	River Mile	Habitat Code(2)	Date	Total Specimens Collected	Number of Specimens Yielding: SC	SP	OP	OT(3)
6 (Peoria)	E	323.1	163.1	MCB	10/10	3	3	3	0	0
6	E	324.1	163.4	MCB	10/10	4	4	4	0	0
6	E	325.1	170.9	MCB	10/10	0	0	0	0	0
6	E	326.1	171.0	MCB	10/10	19	19	19	0	0
6	E	327.1	170.9	MCB	10/10	18	17	17	0	0
6	E	328.1	215.2	SCB	10/11	17	17	17	0	0
6	E	329.1	215.5	MCB	10/11	15	15	15	0	0
6	E	330.1	215.6	SCB	10/11	2	2	2	0	0
6	E	331.1	203.0	SCB	10/11	20	20	20	0	0
6	E	332.1	202.7	SCB	10/11	1	1	1	0	0
6	E	333.1	203.3	SCB	10/11	7	7	7	0	0
6	E	334.1	207.9	SCB	10/12	2	2	2	0	0
6	E	335.1	193.3	SCB	10/12	26	26	26	0	0
6	E	336.1	193.8	MCB	10/12	5	5	5	0	0
6	E	337.1	180.9	SCB	10/12	37	37	37	0	0
6	E	358.1	180.7	MCB	10/28	8	8	8	8	6
7(LaGrange)	E	338.1	85.9	SCB	10/19	2	2	2	0	0
7	E	339.1	86.9	SCB	10/19	5	5	5	0	0
7	E	340.1	95.2	SCB	10/19	49	46	46	0	0
7	E	341.1	106.8	SCB	10/20	18	18	18	0	0
7	E	342.1	113.3	SCB	10/20	35	34	34	0	0
7	E	343.1	136.9	MCB	10/20	52	12	12	0	0
7	E	344.1	148.4	MCB	10/21	70	70	70	0	0
7	E	359.1	155.0	MCB	10/28	25	24	24	13	13
7	E	360.1	155.2	MCB	10/28	4	4	4	2	2
8 (Alton)	E	239.1	18.6	SCB	7/06	10	10	10	10	10
8	E	240.1	19.2	SCB	7/06	7	7	7	7	7
8	E	241.1	18.3	SCB	7/06	3	3	3	3	3
8	E	243.1	2.9	TSM	7/20	1	1	1	0	0
8	E	302.1	18.8	SCB	9/20	4	4	4	4	4
8	E	303.1	30.4	SCB	9/21	1	1	1	0	0
8	E	304.1	29.5	SCB	9/21	19	19	19	0	0
8	E	305.1	28.2	SCB	9/21	9	9	9	0	0
8	E	306.1	25.9	SCB	9/21	4	4	4	0	0
8	E	307.1	73.0	SCB	9/22	1	1	1	0	0
8	E	308.1	73.0	MCB	9/22	5	5	5	0	0
8	E	309.1	57.6	SCB	9/22	3	3	2	0	0
8	E	310.1	58.8	SCB	9/22	18	18	18	0	0

1) E = Electroshocking (230 v. A.C.); H = Hoopnetting
2) MCB = Main Channel Border; SCB = Side Channel Border; TMS = Tributary Stream Mouth; BWC = Backwater-Contiguous
3) SC = Scales; SP = Dorsal Spines; OP = Opercles; OT = OtolithsTable

Table A-1 (concluded).

Illinois River Pool	Coll. Method(1)	Coll. No.	River Mile	Habitat Code(2)	Date	Total Specimens Collected	Number of Specimens Yielding: SC	SP	OP	OT(3)
8	E	320.1	23.9	SCB	10/07	1	1	1	0	0
8	E	321.1	24.3	SCB	10/07	13	13	13	0	0
8	H	4.1	3.0	BWC	6/07	2	2	0	0	1
8	H	6.1	3.0	BWC	6/10	1	1	0	0	0
8	H	9.1	3.0	BWC	6/17	1	1	1	0	0
8	H	11.1	3.0	MCB	6/20	1	1	0	0	1
8	H	15.1	3.0	MCB	6/24	1	1	0	0	0
8	H	17.1	3.0	MCB	6/27	2	2	2	0	2
8	H	19.1	3.0	MCB	6/29	1	1	1	1	1
8	H	21.1	3.0	MCB	7/01	1	1	1	1	1
8	H	23.1	3.0	MCB	7/05	1	1	1	1	1
8	H	32.1	3.0	BWC	7/15	1	0	0	0	0
8	H	35.1	3.0	MCB	7/18	4	4	4	4	4
8	H	37.1	3.0	MCB	7/20	3	3	0	0	0
8	H	39.1	3.0	MCB	7/22	1	1	0	0	0
8	H	62.1	3.0	MCB	8/15	1	1	1	1	1
8	H	69.1	3.0	BWC	8/30	2	2	2	2	2

1) E = Electroshocking (230 v.A.C.); H = Hoopnetting
2) MCB = Main Channel Border; SCB = Side Channel Border; TMS = Tributary Stream Mouth; BWC = Backwater-Contiguous
3) SC = Scales; SP = Dorsal Spines; OP = Opercle; OT = Otoliths

Table A-2. Age estimates of lower Illinois River carp by two readers using four bony structures.

Coll. Code	Ind. No.	Total Length (cm)	Weight (kg)	Specimen age determined by: Scales R1	Scales R2	Spines R1	Spines R2	Opercles R1	Opercles R2	Otoliths R1	Otoliths R2(1)
E239.1	1	40.1	0.99		4	4	5	4	5	4	6
E239.1	2	42.6	1.24	5	4			5	6	6	6
E239.1	3	45.9	1.52	5	4			5	6	8	6
E239.1	4	34.4	0.66	4	3	3	5	4	5	4	5
E239.1	5	32.9	0.55	3	3	3	5	3	5		
E239.1	6	43.7	1.24	5	4	5	7	4	6	6	7
E239.1	7	37.1	0.83	3	3	4	4	4	5	5	5
E239.1	8	35.8	0.73	4	3	4	5	3	5		
E239.1	9	38.3	1.88	3	3	4	4	4	5	5	4
E239.1	10	37.6	0.86	4	4	6	7	4	5	5	6
E240.1	1	38.4	0.77	3	3	4	4	4	5		
E240.1	2	42.5	1.19	5	4	5	5	6	6	7	6
E240.1	3	39.4	0.90	4	3	4	4	4	5		
E240.1	4	36.3	0.66	4	4	4	5	4	5	5	5
E240.1	5	36.3	0.79	4	4	5	5	3	5	4	5
E240.1	6	40.5	1.03	4	4	4	5	5	6	5	5
E240.1	7	35.2	0.64	3	3	4	4	4	4	4	4
E241.1	1	39.1	0.83	4	4	4	5	4	5		
E241.1	2	29.3	0.38	2	2	2	3	2	3		
E241.1	3	41.3	1.21	4	3	5	4	4	4	6	6
E359.1	1	33.3	0.55	4	3	3	3	4	3	3	4
E359.1	2	32.0	0.47	3	3	3	4	4	4	3	4
E359.1	3	34.0	0.50	4	4	4	4	4	4	4	4
E359.1	4	36.2	0.70	4	3	4	3	4	4	3	3
E359.1	5	35.7	0.62	4	4	4	4	4	4	3	4
E359.1	6	31.2	0.45	4	3	2	2	3	4		
E359.1	7	36.3	0.56	3	3	4	3	3	3		
E359.1	8	26.7	0.25	2	2	2	2	3	2		
E359.1	9	32.7	0.47	4	3	4	4				
E359.1	10	15.0	0.05	0	0	0	0	1	1		
E359.1	11	29.4	0.37	2	2	4	3	3	2		
E359.1	12	28.1	0.39	3	2	3	3	3	2		
E359.1	13	30.0	0.40	3	3	3	3				
E359.1	14	28.0	0.30	2	2	2	2	3	2		
E359.1	15	34.6	0.62	5	4	4	5				
E359.1	16	30.4	0.45	2	3	5	5				
E359.1	17	30.4	0.45	3	3	3	2				
E359.1	18	31.6	0.39	3	3	3	3				
E359.1	19	28.1	0.34	4	3	3	4	3	3		
E359.1	20	35.4	0.66	4	4	3	4				
E359.1	21	27.4	0.31	3	2	2	3				
E359.1	22	30.0	0.42	3	3	3	3				

Table A-2. (concluded).

Coll. Code	Ind. No.	Total Length (cm)	Weight (kg)	Specimen age determined by: Scales R1	Scales R2	Spines R1	Spines R2	Opercles R1	Opercles R2	Otoliths R1	Otoliths R2(1)
E359.1	23	30.4	0.40	3	3	3	3				
E359.1	24	24.6	0.20	2	2	2	2				
E360.1	1	25.0	0.24	3	2	3	3				
E360.1	2	33.6	0.55	3	3	4	4				
E360.1	3	42.8	1.01	5	4	5	5	5	5		
E360.1	4	42.5	1.03	4	4	5	5	5	4		
H 23.1	1	35.2	0.59	3	5	3	4	4	5	3	4
H 32.1	1	45.6	1.12	5	5	5	5	5	5		

1) R1 = Reader No.1, Scott D. Jackson
R2 = Reader No.2, James S. Cassens

Appendix B.

Hartsfield, B., K. S. Lubinski and S. D. Jackson. 1984. Comparison of carp, _Cyprinus carpio_, aging methods using scales, dorsal spines, otoliths, and opercles. Abstract of paper presented at the 22nd annual meeting, Illinois Chapter American Fisheries Society, Urbana, Illinois.

Age characteristics of carp populations in the Illinois and Mississippi rivers are being investigated to explain recent declines in commercial harvests. We compared effort, precision, and special problems associated with four aging methods in order to recommend procedures for a future, large sample size, aging program. Scale annuli counts required little collection or preparation effort and were relatively precise (as measured by agreement between two readers) in spite of the presence of false annuli. Otolith annuli counts necessitated sacrificing fish, the greatest collection and preparation effort, a high degree of technical skill, and were only moderately precise. Dorsal spine sections did not exhibit as many false annuli as did scales, but their annuli edges were less distinct and annuli counts from spines were only moderately precise. Opercle annuli counts required little effort, included some false annuli, were less precise than scale counts, and necessitated the sacrificing of fish. Our recommendations were to use scales as primary aging structures for large numbers of carp, to use spines and opercles as back-up aging structures to verify scale annuli counts, and to discontinue the routine use of otoliths.