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# The Opercular Bone As An Indicator of Age and Growth of the Carp Cyprinus carpio Linnaeus

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# The Opercular Bone As An Indicator of Age and Growth of the Carp *Cyprinus carpio* Linnaeus[1]

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## Abstract

As part of an investigation of the non-game fish resources of Utah, a study of the age and growth rate of the carp was instituted. A preliminary investigation indicated that the opercular method was superior to several other methods of determining age and growth in the carp. Age and growth were calculated from the opercular bones of 330 carp collected at Ogden Bay Refuge in 1950-51. Distances to annuli were measured directly. The relationship between the posterior radius of the opercular bone and the standard length of the carp was curvilinear. Past growth was calculated with a logarithmic nomograph. Expected number of annuli on opercular bones of known age carp, agreement of ages assessed by length frequency modes and those assessed from opercular bones of the same fish, agreement of empirical and calculated

lengths for the first three years of life, agreement between ages assessed by scales and opercular bones, and increase in age with increase in size were accepted as evidence of the validity of the opercular method. Decrease in growth rate at any year of life for successive age groups is attributed to a gradual change of the environment.

## Introduction

An investigation of the non-game fish resources of Utah, by the Wildlife Management Department of Utah State Agricultural College, was begun in 1948 to determine the ecological and economic status of the large numbers of non-game fish known to exist in the valley waters of Utah. The creation of many artificial impoundments has greatly augmented the habitat of the non-game species, especially the carp *Cyprinus carpio* Linnaeus. There are few suitable habitats in which the carp is not found. Sigler (1949) estimates that there are at least one million acres of potential carp range in Utah. Many marginal waters, where other species will not thrive, produce large numbers of carp. Some are utilized in Utah for domestic animal food. Small quantities are also shipped to the west coast for human consumption (Sigler 1949). The carp in Utah is largely an untapped resource.

As part of the investigation of the non-game fish resources of Utah a study of the life history of the carp was initiated. One of the more important aspects of the life history study of any fish is the rate of growth. Scales of fish have been most frequently used in determining age and growth. Although the first conclusive evidence for the validity of the scale method was obtained from a study of carp scales by Hoffbauer (Van Oosten 1929), the scales of carp from several habitats in northern Utah were unsuitable for the determination of age and growth. It was necessary that a method other than the use of scales be employed to determine the age and growth rate of the carp in Utah. Several alternate methods of age and growth determination exist.

When measurements of lengths of fish, all captured at the same time, are analyzed, such measurements often tend to group around certain modes. The modes have been interpreted as indicating age classes (Schultz 1930), (Applegate 1943), (Hardisty 1944).

Various skeletal parts of fish, other than scales, have been used to determine the age and growth rate. Boyko (1940) determined the age of several species of fish, including the carp, by annuli present on sections of fin rays. Vertebrae have been used to age tadpole madtoms _Schilbeodes mollis_ Hermann (Hooper 1949), and the northern black bullhead _Ameiurus melas melas_ Rafinesque (Lewis 1949). Age of the paddlefish _Polyodon spathula_ Walbaum has been determined from growth rings of the otoliths and dentary bone (Adams 1942). Age and past growth have been determined from the opercular bones of the yellow perch _Perca fluviatilis_ Linnaeus by Le Cren (1947).

Preliminary investigation indicated that of the available methods of age and growth determination the opercular method was most suited to the carp.

## Description of the Habitat

Ogden Bay Migratory Waterfowl Refuge, the source of the carp used in the age and growth determination, was instituted as a waterfowl refuge in 1937.[2]

[2] Ogden Bay Migratory Waterfowl Refuge will be referred to in the remainder of this study as Ogden Bay Refuge.

The state of Utah constructed Ogden Bay Refuge on the delta formed by the entrance of the Weber River into Ogden Bay of Great Salt Lake. Impoundments, referred to as units, were formed by constructing dikes.

Unit 1, the section of Ogden Bay Refuge from which the carp were collected, is probably the most productive unit of the refuge. The impoundment of Unit 1 is a shallow lagoon approximately $\frac{1}{2}$ mile by 2 miles. The water levels are caused to fluctuate at different seasons of the year by spring floods, irrigation demands on the Weber River in late summer, and waterfowl management practices that occur throughout the year. The mean water depth over most of the lagoon is probably about 2 feet. Water depths up to 6 feet occur in the borrow pit at the periphery of the impoundment, and up to 9 feet in some of the connective waterways that supply and drain the impoundment.

Water temperatures, in the connective waterways and borrow pits of Unit 1, have been recorded during 1950 as follows: 40°F. in March, 51°F. in April, 72°F. in June, 78°F. in July, 74°F. in August, and 36°F. in December. The ice was gone by mid February in 1950 and 1951.

The area now occupied by Ogden Bay Refuge was originally a salt flat with little vegetation on it. Unit 1 is now completely vegetated however. By diverting the waters of the Weber River over the refuge much of the salt was leached from the ground. The Weber River has also contributed nutritive materials in the form of municipal sewage, and irrigation runoff water. The principle emergent plants are *Scirpus Olneyi* A. Gray, *Scirpus paludosus* A. Nels., *Scirpus acutus* Muhl., and *Typha latifolia* L.. The dominant submergents are *Zannichellia palustris* L., *Potamogeton richardsonii* (Ar. Benn.) Rydb., and *Potamogeton pectinatus* L.

The numbers of carp at Ogden Bay Refuge far exceed those of any other species of fish present there. The Utah chub *Gila atraria* Girard is common. White suckers *Catostomus commersonnii* Lacepede, green sunfish *Lepomis cyanellus* Rafinesque, and black bullheads *Ameiurus melas melas* Rafinesque are encountered occasionally.

## Materials and Methods

The relationship of the opercular bone to the standard length was established from the measurements of 401 carp and their corresponding opercular bones. The opercular bones from 330 carp were used in the age and growth determinations. Additional small numbers of carp from several habitats were used for comparisons.

The carp from Ogden Bay Refuge were collected with seines. Small, young carp were taken with a ten foot minnow seine. The carp used in the age and growth determinations were collected with a 100 foot seine having three quarter inch, bar measure, mesh. The wide range of sizes taken in the 100 foot seine indicates that the gear used was not excessively selective as to the size of carp caught.

The standard, fork and total legnths (Carlander 1950) were taken to the nearest millimeter on a conventional measuring board. Length conversion factors are as follows: standard length in millimeters to total length in millimeters equals 1.2512, standard length in millimeters to total length in inches equals 0.04934, and standard length in millimeters to fork length in millimeters equals 1.0862.

The scales from the area between the end of the pectoral fin and the beginning of the dorsal fin, and lying immediately above the lateral line, were removed from each carp. The scale samples were taken from either side.

Sex was determined by examining the gonads. Carp having well developed gonads, but judged not to be ready to spawn for the first time until the following season, were classified as sub-adult. The majority of the carp classified as sub-adult could be sexed macroscopically. Carp with small and sexually undifferentiated gonads were classed as juveniles and their sex was not determined.

The entire opercular assembly was removed from each carp. The first step in the removal was the severing of the skin which comprises the dorsal attachment of the opercular assembly. The branchiostegal rays at the ventral border of the opercular assembly were cut next, leaving the opercular assembly attached at the anterior border. The opercular assembly was then bent sharply forward to disarticulate the ball and socket joint by which the opercular bone is attached to the cranium of the carp. With the opercular assembly still held forward, a knife blade inserted along the anterior border severed the skin connection. The opercular assembly was then free and was removed.

The opercular assemblies were frozen if they were not to be cleaned immediately. Freezing was necessary to prevent drying or decomposition. The unwanted parts of the opercular assembly, consisting of flesh and skin, and bones other than the opercular bone, were removed by placing the entire assembly in boiling water for about one minute. The unwanted parts were then easily pulled away from the opercular bones with the fingers. Persistent pieces of skin were removed by scrubbing with a stiff bristled brush. Opercular assemblies that had been allowed to become dry were much more difficult to clean. When the opercular bones were clean, they were set aside until dry enough to store.

The measurement of growth to each annulus was made from the posterior margin of the fulcrum to the posterior-most point of the annulus (fig. 1). Cross sections through the fulcrum indicate that the posterior margin of the fulcrum is directly over the origin of growth of the posterior field of the opercular bone. Le Cren (1947) arrived at the same conclusion for opercular bones of perch. The distances from the fulcrum to the annuli were measured directly with a draftsman's compass-pen employed as a pair of dividers (fig. 2). The nibs of the pen were easier to place on the posterior margin of the fulcrum than the single point of conventional dividers or calipers.

Distances set off with the compass-pen were transferred to a millimeter scale (fig. 3). The scale used was constructed with an upturn at the zero end on which the nibs of the compass-pen were placed when measuring distances. The position of the compass-pen on this scale approximated the position of the compass-pen when the nibs were placed on the posterior rim of the fulcrum of larger opercular bones (figs. 2 and 3). The upturn on the scale assured that the nibs of the pen were elevated above the scale a distance equal to that between the posterior rim of the fulcrum and the origin of growth of

Figure 1. Opercular bones of a 4 year old female carp with a standard length of 567 millimeters, collected at Ogden Bay Refuge July 9, 1951. The posterior rim of the fulcrum (A) is outlined on the right opercular bone. (B) is the posterior margin of the opercular bone, (C) the dorsal margin, and (D) the line along which measurements were made. The line D bisects the posterior-most point of each annulus.

Figure 2. Compass-pen employed as dividers to measure distances to annuli. Note position of nibs of the pen on posterior rim of the fulcrum.

Figure 3. Distances set off on the compass-pen transferred to a millimeter scale. Note position of nibs on upturn of the scale.

the posterior field which lies directly beneath the posterior rim of the fulcrum. If a flat scale were used, the distance measured would not be the true distance from the origin of growth to the annuli, instead it would be the longer, angular distance from the posterior rim of the fulcrum to the annuli. To construct the ruler, a plastic millimeter scale was cemented to a strip of aluminum sheeting 5 inches by 1 inch and 0.030 inches in thickness. A right angle bend was made at one end of the aluminum strip and trimmed so that it extended 7 millimeters above the upper surface of the aluminum strip. The plastic scale was cemented to this strip with the zero end against the right angle bend. A 7 millimeter bend was found satisfactory for all opercular bones with radii exceeding 25 millimeters. For all opercular bones with radii less than 25 millimeters a flat scale was satisfactory. Measurements made in this fashion were recorded to the nearest half millimeter.

## Determination of Age

The annuli are distinct, narrow bands parallel to the posterior margin of the opercular bone. Each annulus also extends along the dorsal and anterior margins but the bone in these areas is too thick and opaque to permit easy observation (fig. 1). The area enclosed by each annulus is of the same shape as the opercular bone; this suggests that the annulus was the margin of the opercular bone at some earlier time in the life of the carp. Each annulus is composed of two parts; anteriorly it is a thin line that is darker than the surrounding area, and posteriorly it is a slightly wider band which is noticeably more translucent than the rest of the opercular bone. The annuli of the carp opercular bones are essentially the same as those on the perch opercular bones described by Le Cren (1947).

Transmitted skylight was the best light for observing the annuli. Light from a tungsten lamp was usable but was too highly diffused as compared with skylight. Le Cren (1947) used polarized light to aid in distinguishing the annuli of opercular bones of perch. The annuli on the opercular bones of carp viewed by polarized light were no more easily seen than annuli on the opercular bones viewed by skylight. Photography, with infrared sensitized film, exposed through a wratten number 87 filter, failed to give any more differentiation of the annuli than photography with ordinary panchromatic film.

The majority of the opercular bones could be aged with little difficulty. The last two or three annuli were often crowded on the opercular bones of carp over five years of age. This crowding did not offer serious difficulty to age evaluation. By tracing each annulus from the dorsal margin of the opercular bone to the anterior margin where it disappeared, it was possible to determine the limits of most of the crowded annuli. False annuli, those deposited for reasons other than the cessation of growth in winter, were evident on many of the opercular bones. These were usually incomplete, appearing only in a sector of the posterior field of the opercular bone. The false annuli were fainter and did not exhibit the distinct dark and translucent zones evident in the true annuli.

The annulus laid down during the first winter of life could not be accurately located on about half of the opercular bones used in the age and growth study. The first annulus was not a sharp, definite line on many of the opercular bones of carp three years of age and younger. The change from the end of the first year's growth to the beginning of the second year's growth was apparent as a wide band containing many small accessory marks. This difficulty in locating the first annulus was further complicated on large opercular bones by buttresses radiating posteriorly from the fulcrum (i.e., the point of articulation to the cranium). The buttresses often covered the area where the first year mark would normally appear. Similar difficulty in locating the first annulus was encountered by Weymouth et al (1925) on the shells of the pacific razor clam Siliqua patula Dixon, and by Le Cren (1947) on the opercular bones of the yellow perch.

The loss of data on the first year of growth was not serious; the important problem was to determine whether the first visible annulus was deposited at the end of the first or the second year of life. Examination of the modes of length frequency, for both calculated and empirical lengths, indicates that there are few fish in the 176 - 200 millimeter length group (fig. 4). Accordingly it was assumed that few one year old carp were longer than 176 millimeters and few two year old carp were smaller than 200 millimeters. The latter assumptions were borne out by examination of the opercular bones from rapidly growing carp known to be two years old. The known age carp were all above 275 millimeters in standard length when captured at the end of the second year of growth. Growths calculated from the first annulus on opercular bones of the known age carp were all less than 176 millimeters. From the foregoing observations it was decided that annuli,

Figure 4. (A) Frequency of empirical lengths of carp collected in December 1950 and March 1951 at Ogden Bay Refuge.
(B) Frequency of calculated lengths of carp in age classes I, II, and III, collected at Ogden Bay Refuge during 1950 and 1951.

from which a standard length longer than 200 millimeters could be calculated, were probably formed at the end of the second year of growth; and annuli, from which a standard length of less than 200 millimeters could be calculated, were probably formed at the end of the first year of growth. An arbitrary division based on the foregoing evidence was employed to determine whether the first visible annulus was the first or second one deposited. Some degree of inaccuracy was probably introduced by rapidly growing one year old fish, and very slowly growing two year old fish. It is believed, however, that the error is small since only 20 percent of the calculated lengths for the first and second years of life is between the wide limits of 176 millimeters and 225 millimeters.

## Calculation of Past Growth

When calculating past growth of fish from annual rings observed on scales, a prime assumption must be demonstrated to be true. The assumption is that a definite and determinable relationship exists between the size of the scale and the length of the fish (Van Oosten 1929). The first growth studies were made by assuming that a direct proportion existed between some measurement of the scale and the length of the fish. This body-scale relationship was represented graphically by a straight line with zero as the origin. Later workers concluded that a direct proportion relationship was not as satisfactory as several other mathematical relationships. Creaser (1926) and Van Oosten (1929) give excellent, detailed discussions of the earlier methods used to calculate past growth. More recent work on body scale relationships is concisely outlined by Carlander (1950) and Lagler (1949).

The problems pertinent to computing growth from scales are essentially the same as those for computing growth from other skeletal structures. The relationship between the posterior radius of the opercular bone and the standard length of the carp from Ogden Bay Refuge, is represented by the formula: $L = K \times R^n$, where L is the standard length, K is a constant, R is the radius of the opercular bone, and n is a constant exponent (fig. 5). This type of formula has been used to describe the body-scale relationship of several species of fish by Monastrysky (Lagler 1949). Hile (1941) determined that a formula, similar to the one herein derived for the carp of Ogden Bay Refuge, was useful in computing the growth of rock bass _Ambloplites rupestris_ Rafinesque. Weymouth and McMillan (1931) used this type of formula to describe the relationship between the length and width of the shell of the Pacific razor clam. Le Cren likewise (1947) demonstrated that the relationship between the length of the body and the length of the opercular bone of the yellow perch was best represented by this same type formula. Thompson (1945) questions Huxley's use of this formula to describe the relationship between many animals and their component parts beyond the early stages of development. This criticism does not seem to apply to the carp of Ogden Bay Refuge as the calculated lengths agree closely with the empirical lengths for the range of sizes included in this study.

When logarithms of standard length are plotted against logarithms of the posterior radius of opercular bones, the points lay along a straight line. Accordingly the formula

$$L = 6.854 \times R^{1.139}$$

Figure 5. Opercular bone-body length relationship established from measurements of 401 carp collected at Ogden Bay Refuge during 1950 and 1951. The formula for the best fit line is $L = 6.854 \times R^{1.139}$. Dots are based on average standard length and average posterior opercular radius for 25 millimeter length groups.

was computed by the method of averages.

The actual calculations of growth were made by using a logarithmic nomograph essentially the same as the one described by Hile (1950).

## Validity of Aging

In an effort to determine the degree of correlation existing between ages assessed by the opercular method and those assessed by the scale method, scales from all carp in the study were examined. Only 20 percent of the scales examined could be aged with confidence. Some of the difficulties encountered were: cloudy centers which often obscured the first two annuli, many false annuli that were difficult to differentiate from the true annuli, and crowded annuli past the fourth year that could not be distinguished. Moen[3] concluded that the scales from Utah carp were very difficult to age after examining a large sample. This may be a peculiarity of the carp of Utah as Shoffman (1942), and Eddy and Carlander (1942) reported no difficulty in aging carp by the scale method. Hoffbauer and Walter (Van Oosten 1923) determined that scales from carp less than four years of age were true indicators of age but scales from carp known to be four years or older often developed false annuli and were too thick to permit observation of the annuli.

Sixty-six percent of the scales from the carp of Ogden Bay Refuge that could be read gave the same age as the corresponding opercular bones. Twenty-five percent of these scales indicated ages that were

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3 Personal communication.

within one year of those determined from the corresponding opercular bones. Only 9 percent of the scales disagreed by two years or more. Of the scales that did not indicate the same ages as the corresponding opercular bones, 73 percent indicated lower ages. Attempts to discover the source of this discrepancy indicated that the annuli that could be clearly seen on the margin of the opercular bones of some of the older carp, were indistinguishable on the scales. When scales and opercular bones from the same carp were examined side by side practically all differences in age assessment could be reconciled. The fact that 66 percent of the scales read indicated the same age as the corresponding opercular bones and 91 percent agreed within one year was accepted as evidence that the same growth phenomenon was responsible for annuli on both.

The right and left opercular bones from a carp consistently indicated the same age. Furthermore, past growth calculated from a right opercular bone agreed closely with past growth calculated from the corresponding left one. A high degree of symmetry was exhibited between all right and left opercular bones, even to the production of identical deformities (fig. 1).

Opercular bones fromcarp of known age, recovered at the end of the second year of life, had one annulus. This annulus was evidently deposited during the first winter of life. Although these carp were recovered on March 27, 1951, the annulus for the current winter was evident on the margin of some of the opercular bones. Early resumption of growth was probably due to the presence of warm springs in the pond where the carp were recovered. Temperatures up to 57° F. were recorded in late February 1951.

It was noted earlier that the annulus deposited at the end of the first year of life was not evident on the opercular bones of many of the carp from Ogden Bay Refuge. The opercular bones of known age carp not from Ogden Bay Refuge all had a clear, first annulus. It seems possible that different habitats might affect the way in which the first cessation of growth was registered on the opercular bone. At present, however, no definite explanation can be offered.

## Accuracy of the Growth Calculations

Length frequency histograms for carp collected at Ogden Bay Refuge during the winter of 1950-51 indicate that there are three modes of length for carp under 500 millimeters in standard length. The conjecture that these modes represent three age groups is substantiated by the fact that ages of these carp, as suggested by the modes, is the same as the ages indicated by the opercular bones. A comparison of this histogram with one for the calculated lengths of the carp determined to be one, two, and three years old shows that the modes for both are at approximately the same lengths (fig. 4). This approximate agreement between empirical and calculated lengths of fish in the same age classes suggests that the calculated lengths are correct. The mean calculated lengths for the first three years of growth of all age groups also agree fairly well with the modes of empirical length frequency (table 1).

The averagecalculated lengths for the first year of life show a gradual increase with increasing age of the fish (table 1). The increase

Table 7. Summary of the mean standard lengths and annual length increments in millimeters calculated from the opercular bones of carp collected at Ogden Bay Refuge in 1950 and 1951

| Age group | Number of fish | Standard length at capture | Calculated length at end of year of life | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| I | 33 | 231 | 114 | | | | | | | |
| II | 37 | 377 | 116 | 268 | | | | | | |
| III | 69 | 494 | 129 | 287 | 427 | | | | | |
| IV | 64 | 574 | 144 | 287 | 423 | 520 | | | | |
| V | 81 | 605 | 154 | 283 | 413 | 509 | 561 | | | |
| VI | 33 | 614 | 153 | 277 | 390 | 489 | 540 | 580 | | |
| VII | 11 | 614 | 171 | 260 | 367 | 462 | 519 | 552 | 582 | |
| VIII | 2 | 609 | ... | 232 | 330 | 422 | 485 | 541 | 551 | 575 |
| Grand averages and total | 330 | | 138 | 281 | 414 | 506 | 551 | 572 | 577 | 575 |
| Increments of growth | | | 138 | 131 | 131 | 97 | 53 | 39 | 27 | -2 |
| Equivalent total lengths in inches | | | 6.8 | 13.9 | 20.4 | 25.0 | 27.2 | 28.2 | 28.5 | 28.4 |
| Number of fish | | | 164[1] | 297 | 260 | 191 | 127 | 46 | 13 | 2 |

[1] Due to the difficulty in accurately locating the first annulus, the first year's growth for all age classes was calculated from 164 carp of the total of 330.

in calculated lengths is probably due to the fact that the buttresses at the fulcrum of the opercular bones progressively covered more of the area in which the first year of growth would be recorded. Because of the buttresses only annuli of the most rapidly growing fish were visible on opercular bones. Le Cren (1947) observed a similar increase in growth rate for the first year for the perch and attributed it to selective mortality which favored the more rapidly growing fish. A differential mortality may also have contributed to this difference in size at the end of the first year of growth of the carp from Ogden Bay Refuge.

The length attained at the end of any year of life past the first becomes progressively shorter for each succeeding age class (table 1). This is probably associated with a gradual change of environment at Ogden Bay Refuge since the area was first flooded. An increasing degree of commercial seining in recent years may have reduced the number of carp present and thereby improved growing conditions for those carp remaining. It is possible that commercial seining may also have had a selective effect on the size composition of age groups since commercial seiners prefer large carp to smaller ones. Carlander (1949), suggests that where selective sampling does not occur a change in growth rate may be due to the removal of the faster growing fish and to the tendency for slow growing individuals to live longer. McHugh (1941) noted that older whitefish Prosopium williamsonii Girard were the individuals that had grown more slowly.

## The Application of the Opercular Method to Carp Other Than Those From Ogden Bay Refuge

Opercular bones were taken from carp from (1) Mier's Pond in Cache County, (2) an unnamed overflow slough of the Little Bear River in Cache County, and (3) Goring's Pond in Box Elder County. All three are located in Utah north of Great Salt Lake. None of these habitats has a surface area larger than two acres.

The opercular bones from the carp of Mier's Pond indicate that the older carp had grown rapidly in the first few years and then grew more slowly in later years. The opercular bones from the younger carp indicated good growth in the first and second year but additional annuli were crowded. Although the opercular bones from carp of Mier's Pond were more difficult to age than those from Ogden Bay Refuge, they were still usable. Because the carp of Mier's Pond were irregularly scaled, little could be determined from examining their scales.

The unnamed overflow slough was approximately one-third of an acre in area and at no place was it over two feet in depth. When poisoned with rotonone this pond produced forty-eight adult carp that averaged 3 pounds each. The over-crowded condition was reflected in the opercular bones of these fish. The annuli were spaced so closely that ages could only be estimated. It was judged that the maximum ages were between six and ten years for the population. False annuli were numerous.

The carp of Goring's Pond exhibited the same growth pattern as those from Mier's Pond. The opercular bones indicated that the most rapid growth of all fish was that attained by the older fish during the first three or four years of life. Younger fish grew at a moderate rate for the first two years of life and then the growth rate slowed considerably. The opercular bones from these fish exhibited many false annuli. It is probable that the number of false annuli on opercular bones of carp is influenced by the rate at which the carp grow.

## Conclusions

The opercular method in determining age and growth of carp has several important advantages to recommend it. Ages are read with greater confidence from the opercular bones than from the scales. The annuli are definite and in most cases only one interpretation of age can be made. Age and growth is readily determined past the fourth year from the opercular bones; this is not true of the scales. The preparation of the opercular bones fro study is much less time consuming than that for scales. It is necessary to make temporary wet mounts of scales as neither the glycerin gelatin or the dry method of mountaing carp scales is satisfactory. The opercular bones on the other hand are simply dried after cleaning and may be used this way without further preparation.

There is much less variation of the opercular bone-body length relationship than of the scale-body length ratio. When calculating past growth the use of opercular bones is, in effect, about the same as using key scales. Back calculation of growth from opercular bones of carp does not require optical equipment since measurements may be made directly from the opercular bone.

Although the validity of the opercular method for determining age and growth of the carp has not been established conclusively it is believed that there is significant evidence in favor of it.

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