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ARCHAEOLOGICAL ASSESSMENT OF SEASONALITY FROM FRESHWATER FISH REMAINS: A QUANTITATIVE PROCEDURE

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ABSTRACT.–Reliable, replicable procedures for archaeological assessments of seasonality in North America are needed. This paper presents a procedure for determining season of death of archaeological freshwater catfish *(Ictalurus)* based on analysis of measurements on incremental growth structures in pectoral spine thin sections from modern catfish from the Middle South. The measurements are regressed with the date of death of each specimen, resulting in a quantitative model for predicting the date of death of specimens for which this is unknown. The predictive reliability of the model is assessed with a "blind" test on modern specimens. Evaluation of modern specimens from regions north of the Middle South suggests that predictive error results when specimens from more northerly latitudes are assessed, though results are still usable. The procedure is applied to a sample of pectoral spines from the Schmidt site (25HW301), a late prehistoric Central Plains Tradition settlement in central Nebraska. This site was the object of a larger study of subsistence and seasonality among horticulturalists in the Central Plains. Without this analysis little reliable seasonal evidence would have been available.

INTRODUCTION

Seasonality studies are assuming an important role in current archaeological research (cf. Monks 1981 and references contained therein). In spite of a growing interest in archaeological seasonality studies, reliable, replicable procedures for assessing seasonality are generally lacking in North America. However, recent research is helping to correct this problem. For example, procedures have been developed for determining seasonality of large scale aboriginal bison kills in the North American Plains (e.g. Frison and Reher 1970; Reher 1974; Frison 1978). Unfortunately, the data base upon which this work rests is unavailable to most archaeologists. Research being conducted in coastal areas around the world is also producing reliable procedures for assessing seasonality through analysis of incremental growth structures in the hard parts of archaeologically represented marine organisms (e.g. Coutts 1970; Coutts and Higham 1971; Coutts and Jones 1974; Ham and Irvine 1975; Aten 1981).

Although the procedures developed for assessing seasonality from remains of marine organisms have produced sound results, they have no direct application in non-coastal situations. Moreover, comparable (i.e. reliable) procedures for assessing seasonality from incremental growth structures in non-marine organisms have not been developed. Archaeologists have attempted to derive seasonal information from incremental growth structures in mammal teeth (Benn 1974; Kay 1974; Spiess 1976, 1978, 1979; Lippincott 1976; Adair 1977; Bourque et al. 1978; Monk and Bozell 1980; Bozell 1981), fish scales (e.g. Artz 1980; Peterson 1980) and fish vertebrae (Casteel 1972). No one has demonstrated that seasonal interpretations based on mammal teeth are reliable and even the fish studies, which are clearly promising, suffer from subjective evaluation criteria and a lack of demonstrated validity.

Seasonal analysis of archaeological fish remains has been inspired largely by the existence of established criteria for aging modern fish from scales. The principles underlying aging techniques (and, by extension, techniques for deriving seasonal information) have been summarized many times (e.g. Lagler 1956; Casteel 1976; Bagenal and Tesch 1978; Peterson 1980). Briefly, fish are poikilotherms; their metabolic rate fluctuates in relation to the surrounding water temperature. Thus, growth rate decelerates during cold periods (late fall and winter) and accelerates during warm periods (spring and summer). Undoubtedly other factors such as food availability, population density and local water conditions also affect seasonal growth rate. The end of a period of decelerated growth is visible on a fish scale as a narrow zone of closely spaced circuli, the outer edge of which is called an arrest line or annulus. By determining what stage of growth is represented on the outer edge of the scale when the fish died, an estimate of season of death can be made.

Fish scales present some problems. First, they are not readily preserved in or recovered from archaeological contexts. Even when preserved they are fragile and easily damaged by routine field and laboratory processing procedures. In addition, one fish may have hundreds of scales and, therefore, there is no reliable way of estimating how many fish a series of scales represents. It is logical, therefore, to assume that fish bones might provide an appropriate and more readily usable medium for assessing seasonality.

Fortunately, investigating seasonality from fish bones does not require starting from scratch. Fish of the North American family Ictaluridae (catfish) are scaleless; yet there exists substantial literature on aging modern catfish from bones, principally vertebrae and pectoral spines (Lewis 1949; Appelget and Smith 1951; Sneed 1951; Schoffman 1954, 1955; Forney 1955; Marzolf 1955; Jenkins 1956). Three important points emerge from this research: (1) when viewed properly, catfish vertebrae and spines exhibit arrest marks analogous to arrest marks on fish scales, (2) these arrest marks are formed annually (one each year) with a high degree (perhaps 85%) of reliability (cf. Appelget and Smith 1951; Sneed 1951; Marzolf 1955) and (3) on average, catfish grow at approximately the same rate from year to year throughout life (Appelget and Smith 1951; Sneed 1951). With regard to the latter point, while extensive data compiled in Carlander (1969:538-554) also suggest that this is generally true, some catfish populations do show variability in yearly growth rates (usually decelerated growth), especially among older age groups (about 7-8 years and older).

Ictalurids have several additional things to recommend them for archaeological analysis. Catfish are abundant and widespread and are commonly represented in archaeological contexts in many parts of North America. Their cranial elements and spines are easily recognizable and comprehensive osteological guides are available (Mundell 1975; Grizzle and Rogers 1976:74-85). If specific identification is desired several keys may be consulted (Paloumpis 1963, 1964; Calovich and Branson 1964; Krause 1977).

Correct interpretation of seasonal growth in archaeological samples of any species depends on (1) an understanding of seasonal growth patterns in modern individuals and (2) the validity of the necessary analogy between modern samples and archaeological samples. Therefore, in 1980 a study of seasonal growth in modern catfish was initiated (Morey 1981), leading to the development of a procedure for assessing seasonality from archaeological catfish remains (Morey 1982:76-102).

ANALYSIS OF SEASONAL GROWTH IN MODERN CATFISH SPINES

This research is based on analysis of seasonal growth in pectoral spines of modern channel catfish *(Ictalurus punctatus)*. Pectoral spines are paired in each individual (Fig. 1); they are compact and durable and are as likely to preserve archaeologically as most other animal bones. The modern sample consists of 97 specimens from fish taken from one of three locations in the Middle South[1]: the impounded Tennessee River in Decatur County, Tennessee (n-55); the unimpounded Duck River in Maury County, Tennessee (n=27); and the impounded Cumberland River in Trigg County, Kentucky (n=15). The years 1978, 1980 and 1981 are represented. Based on annuli counts, 80 of the 97 (82.5%) fish represented were six years old or less when they died. Linear regression is used to compare two variables, the date of death and a calculated growth index from each specimen[2].

Growth Index.—In order to calculate the growth index it is necessary to obtain thin sections of each pectoral spine. Figure 1 shows a pectoral spine with the sectioning point illustrated. The sectioning point follows Marzolf (1955) and Sneed (1951). One spine,

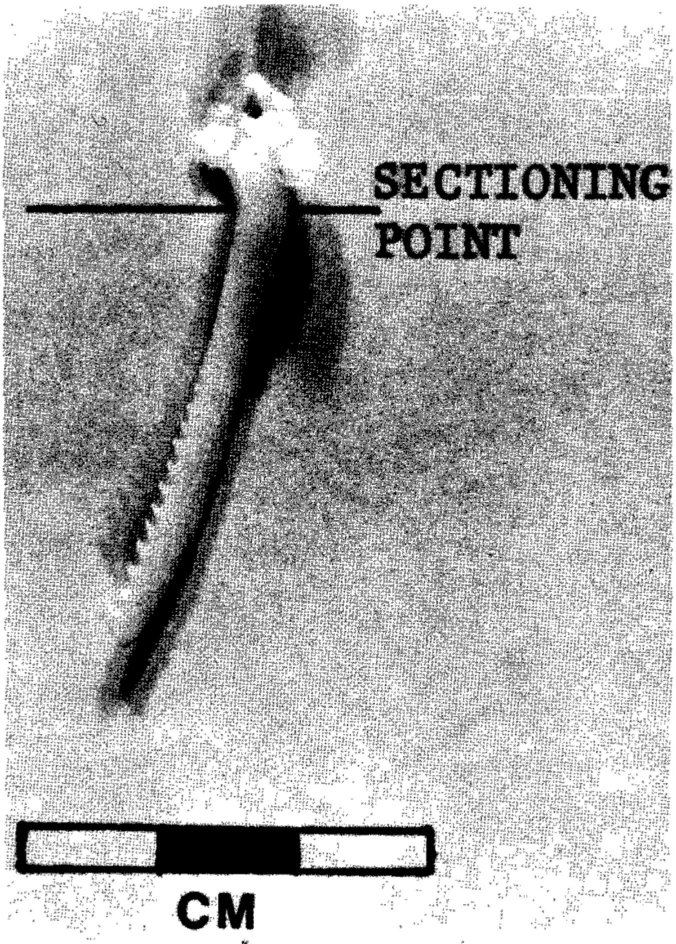

FIG. 1.—Photograph of a catfish pectoral spine, showing the sectioning point.

usually the right, is used from each modern fish. They are cut on a Buehler Isomet low speed wafering saw. Thickness is not critical; most sections used vary between 200 and 400 microns. No grinding, polishing, embedding or chemical staining is necessary with modern specimens; untreated sections are stored in a small vial containing a mild water/ethanol solution. To view them they are removed from the solution, dried, and placed on a glass slide.

When viewed microscopically with polarized transmitted light the sections show arrest marks which appear as continuous, narrow, dark blue bands visible on all portions of the section. These reflect arrested growth during winter/early spring. Following Marzolf (1955), the entire darkened arrest line is regarded as an annulus. Areas reflecting accelerated growth are visible as wider, whitish zones between annuli. In most fish the transition between arrest lines and zones of accelerated growth is distinct. Figure 2 shows a schematic view of a pectoral spine thin section. Arrest lines (i.e. annuli) are illustrated with reference to two measurement locations, A and B, on the posterior portion of the section. The two lines which encompass B represent the most recent *full* yearly growth increment. The measurement points are from *inner edge to inner edge* of the last two annuli. Measurement A represents the most recent *partial* yearly growth increment. It is taken from the inner edge of the last annulus to the edge of the spine. The measurements are taken with an ocular micrometer in units of .01 mm.

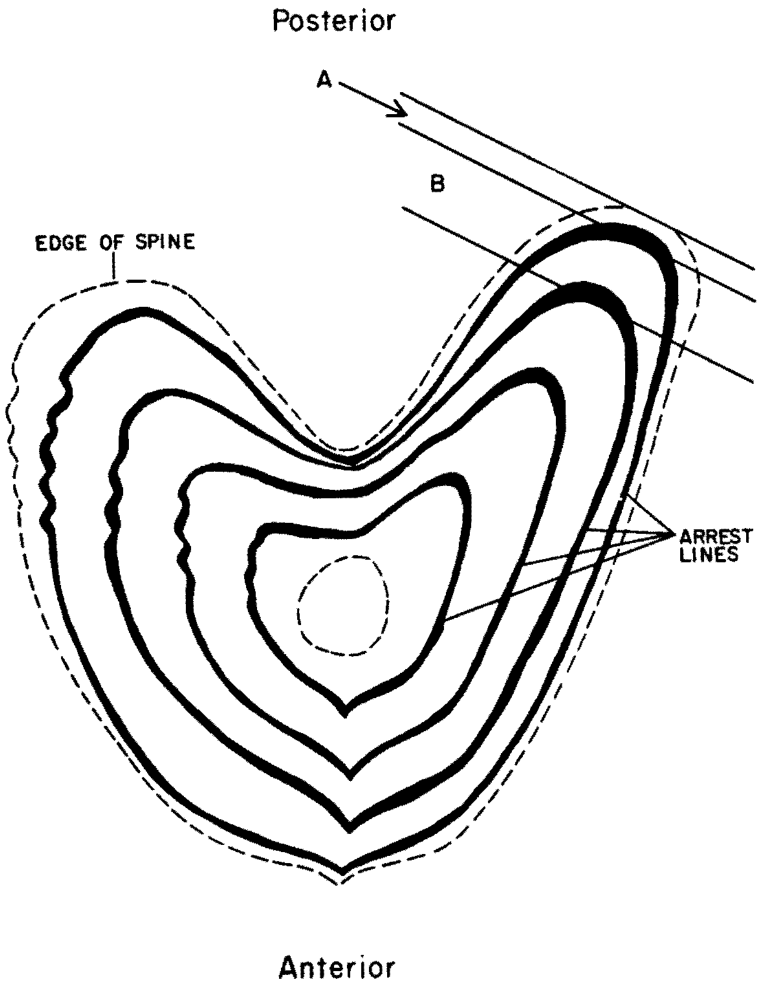

FIG. 2.–Schematic view of a catfish pectoral spine thin section, showing the location of measurements A and B.

Measurements A and B are used to calculate the growth index:

$$\text{Growth Index} = \frac{A}{B} \times 100$$

Figure 3 shows two photomicrographs of a pectoral spine thin section from a Duck River (Maury County, Tennessee) catfish that died on July 12, 1980. The location of measurements A and B is illustrated.

As previously noted, earlier research suggests that channel catfish tend to grow at approximately the same rate from year to year (Appelget and Smith 1951; Sneed 1951). If this is the case, it is reasonable to expect a regular decrease in the absolute distance between annuli from year to year since the structure being added to is progressively larger each year. This prediction can be tested by defining a new variable, P. P, for any given full increment, is the ratio of its own width to the width of the previous full increment, expressed as a percent. If the prediction holds, the mean value of P for all year classes should be about the same. To insure adequate sample sizes these data have been

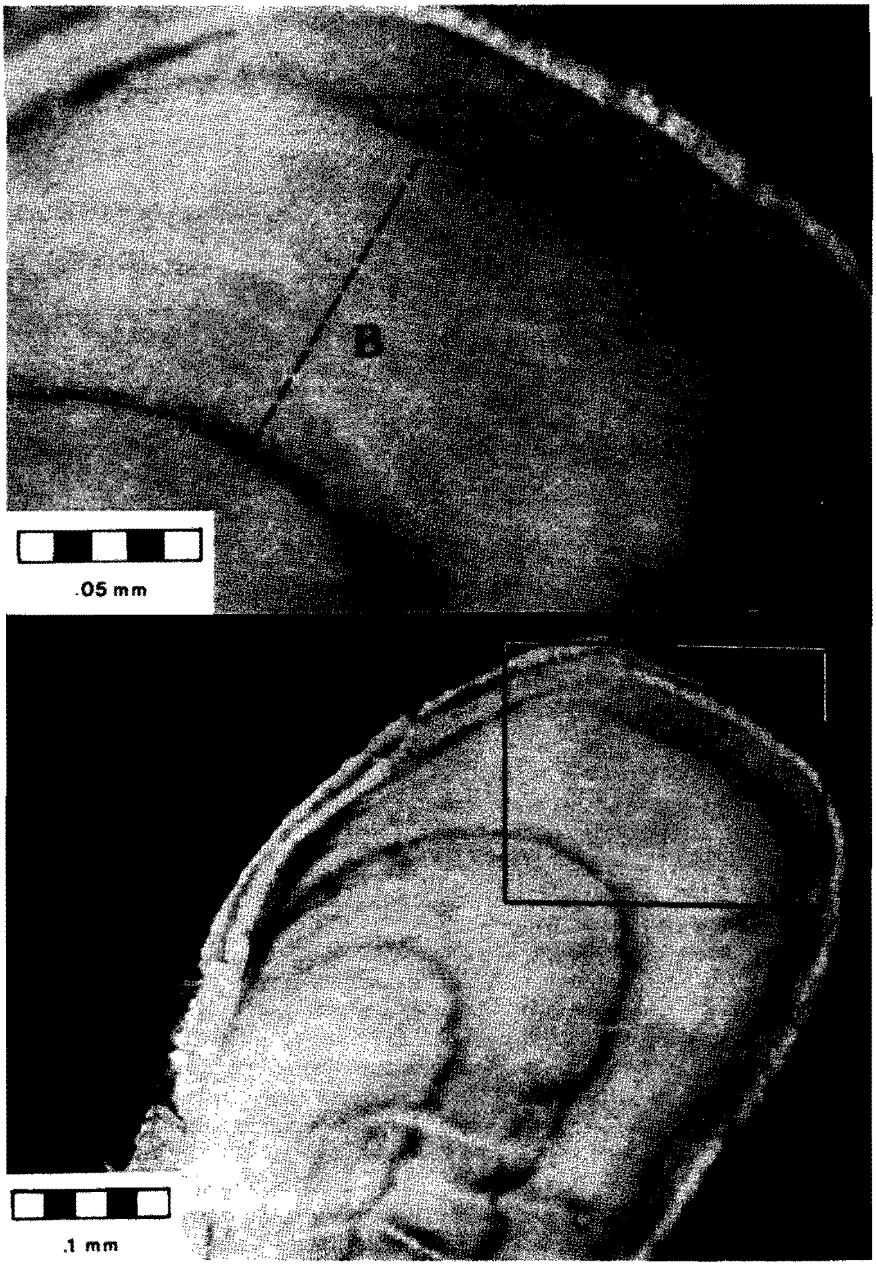

FIG. 3.–Two photomicrographs of a pectoral spine thin section from a Duck River (Maury County, Tennessee) catfish that died on July 12, 1980, with the location of measurements A and B illustrated. The upper half is an enlargement of the contained area in the lower half.

assimilated for all year classes with 25 or more observations, which includes year classes 2-5. The mean value of P for these year classes is presented below:

Year Class	Mean of P
2	85.32
3	83.36
4	76.19
5	81.15

These data suggest that, at least during years 2-5, a fish is likely to produce an increment with a width of approximately 75-85% of the previous increment. In other words, a spine from a three year old catfish with a growth index of 30 is probably comparable to a five year old catfish with a similar growth index.

Date of Death.—Date of death for each specimen is recorded as a whole number from 1-52. A fish that died in the first week of January is assigned a value of 1, a fish that died in the second week a value of 2, and so on through 52 for a fish that died in the last week of December. The starting point for this scale is more than a matter of convenience; a sample of mid-January fish consistently showed the initial stage of annulus formation on the outer edge of the spine whereas a mid-December sample from the same calendar year did not. Recognizing that there is undoubtedly year to year variation in the time when annuli begin to form in most fish, January 1-7 is a reasonable estimate based on the data at hand. Annulus formation in catfish pectoral spines seems to take several weeks, beginning in mid-winter and terminating in the spring, perhaps in April, when accelerated growth resumes.

Aberrant Specimens.—Overall, approximately 15-20% of the modern specimens examined were rejected due to aberrant irregularities in growth. Sometimes annuli are too indistinct to permit reliable measurement. Occasionally a fish produces an arrest mark that is not annual, called a false annulus. False annuli are usually less distinct than true annuli and result in obvious departure from the normal pattern (i.e. gradual reduction in absolute increment width from year to year). Fish showing a false annulus in either of the increments used to calculate the growth index are rejected.

Sometimes a fish shows irregularities which cannot clearly be attributed to false annuli (i.e. the arrest marks are uniformly distinct). During the course of this research such specimens were accepted or rejected on the basis of my subjective impression as to their degree of regularity. Anticipating archaeological application, this may be operationalized to produce a replicable rejection criterion. To do this it is necessary to return briefly to a consideration of the variable P. The means of P for year classes 2-5 are comparable; therefore, the raw data have been pooled to produce a grand mean of P for these year classes which is 79.7. The standard deviation of the pooled data is 27.558. By considering 1.5 standard deviations (41.3), an arbitrary decision, it can be stated that approximately 87% of the P values from fish considered acceptable fall within a range of 79.7 + 41.3 if a normal distribution is assumed (cf. Arkin and Colton1963:119). Therefore, a rejection criterion for future specimens is proposed. A specimen with an irregular growth pattern not clearly attributable to false annuli is rejected if it has a value of P for any increment below 40 or exceeding 120. This conservative rule can only increase the predictive reliability of the final model when it is applied to archaeological specimens.

Figure 4 shows an example of another type of aberration. This specimen shows an arrest mark on the outer edge of the section with a width already exceeding the entire previous year's growth. The reason for this aberration is unknown. This type of aberration was encountered in only one sample of fish (to be discussed).

The Regression.—The regression will serve as a model for predicting date of death for archaeological specimens. Figure 5 shows a plot of growth index by date of death for the 97 modern specimens. It is obvious that a simple linear function will not adequately describe these data. Moreover, the plot verifies an expected problem involving non-constancy of the error variance without residual analysis. The error variance is expanding as the X term (date of death) increases. This sort of phenomenon is commonly encountered in time-related regression problems (cf. Neter and Wasserman 1974:101-104) and must be corrected since linear regression assumes constancy of the error variance.

Data transformations can often help stabilize non-constant error variance. The transformation applied here is based on Taylor's power law (Taylor 1961) which states

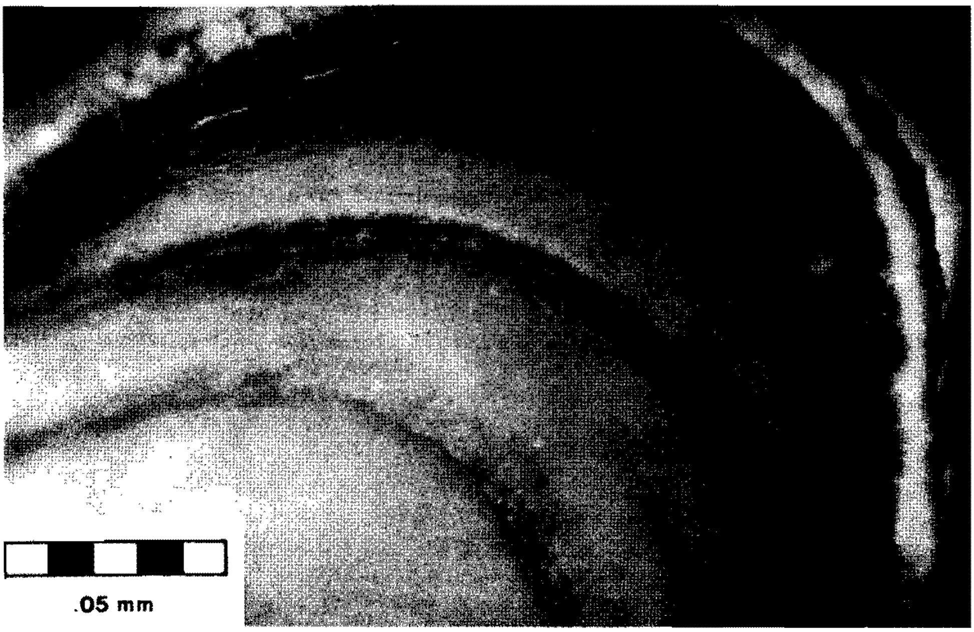

FIG. 4.—Photomicrograph of a rejected pectoral spine thin section from a Fort Loudoun Lake (Blount County, Tennessee) catfish that died on July 4, 1980.

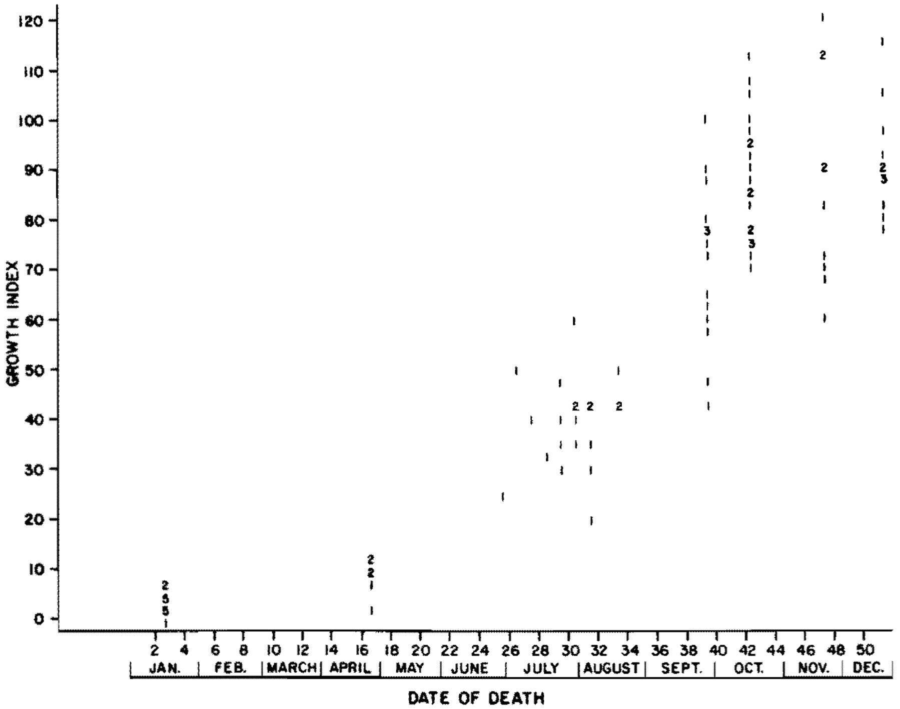

FIG. 5.—Plot of pectoral spine growth index by date of death for 97 modern channel catfish from the Middle South. 1 = one observation, 2 = two observations, etc.

that the variance of a population is proportional to a fractional power of the mean. The appropriate transformation is to raise each original observation (growth index) to the fractional power 1 - b/2, where b represents a slope coefficient (cf. Elliot 1977:71-73). The value of b is derived as follows. First the mean and variance of each discrete sample in the data set is obtained. Examination of Figure 5 shows six discrete (i.e. single date of death) samples from January, April, September, October, November and December. By pooling observations from a three week period in July (date of death 29-31) to obtain a much needed variance term from the scattered summer series, a seventh discrete sample is approximated. The seven mean and variance terms are then transformed to their common log values. The resulting terms are regressed (log variance by log mean) and a least squares line fit to the data. It is the slope coefficient from this regression that is needed. In the present case the slope coefficient is 1.274 which, when substituted for b (recall 1 - b/2), yields a value of .363. This value is the desired fractional power; when each original growth index is raised to the .363 power the results are as shown on Figure 6. This plot suggests that the error variance has been effectively stabilized, a preliminary evaluation confirmed by analysis of residuals after an appropriate analytical function has been fit (see below).

Though inconvenient, the desired function must be obtained with growth index treated as the Y (predicted) variable since it is measured with error. The alternative procedure will produce invalid results. There are two curves in the transformed data, suggesting that a third order polynomial might provide an appropriate curvilinear function. This is accomplished by squaring and cubing the X term (date of death) and adding the two new terms to a simple linear model. The form of the polynomial model is

$$Y = B_O + B_1X + B_2X^2 + B_3X^3$$

where B_O is the intercept and B_1, B_2 and B_3 are slope coefficients. Calculations for

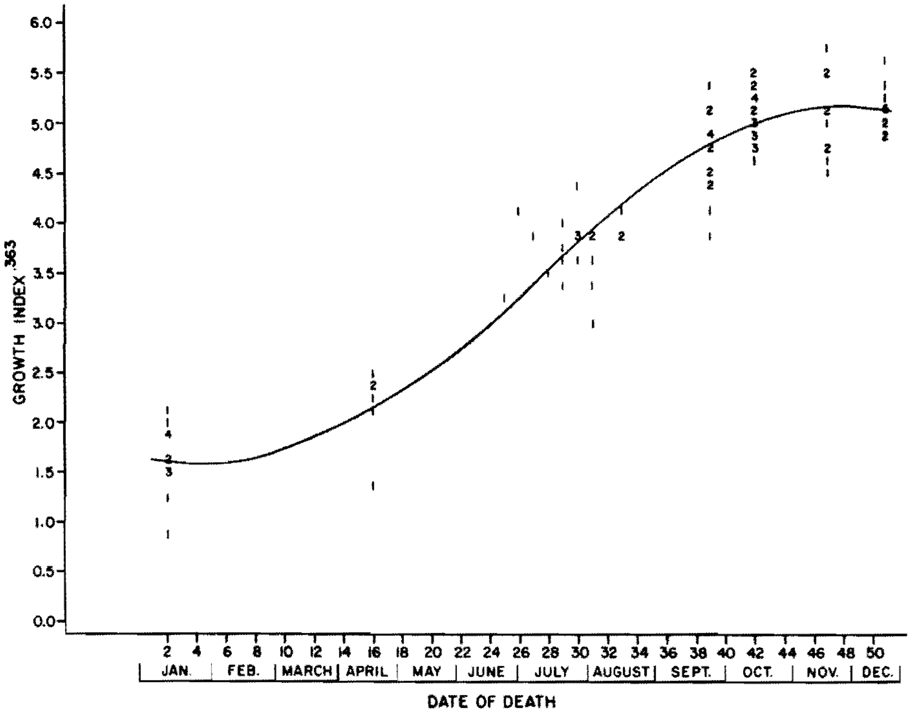

FIG. 6.—Plot of transformed pectoral spine growth index by date of death for 97 modern channel catfish from the Middle South. 1 = one observation, 2 = two observations, etc.

this regression were done at the University of Tennessee Computing Center, using SAS, PROC GLM (SAS Institute 1979).

Applying the above model to the transformed data yields positive results. F ratios indicate that all terms in the model are significant at the .05 level. Residual analysis (Fig. 7) indicates that the curve fits nicely; points are distributed approximately evenly on either side of the zero point axis with no pattern evident. Figure 7 should also be inspected with reference to the error variance problem. The R^2 coefficient of correlation between the two variables is .928.

The polynomial model fit to these data yields the following function:

$$Y = 1.74863 - .0583847X + .00678332X^2 - .0000851173X^3$$

The curve produced by this function is shown on Figure 6. It should now be evident why treating growth index as the predicted variable is inconvenient. To predict the date of death of an "unknown" specimen, a transformed growth index must be obtained and X solved for on the right-hand side of the equation. Fortunately, a less tedious procedre is available that produces the same results. Consider, first, that only whole number values of X from 1-52 are of interest. Using the polynomial to solve for all 52 values of X, 52 corresponding solutions for Y may be derived. This step has been taken, producing the results shown on Table 1. With this table it is possible to predict the date of death of "unknowns" without again referring to the polynomial equation. To accomplish this the transformed growth index of a given specimen is compared to the values of Y on Table 1 to determine which one is the closest. The value of X corresponding to this Y is the predicted date of death. This simple procedure yields the same results as deriving the tedious solution for the growth index and then rounding X to the nearest whole number.

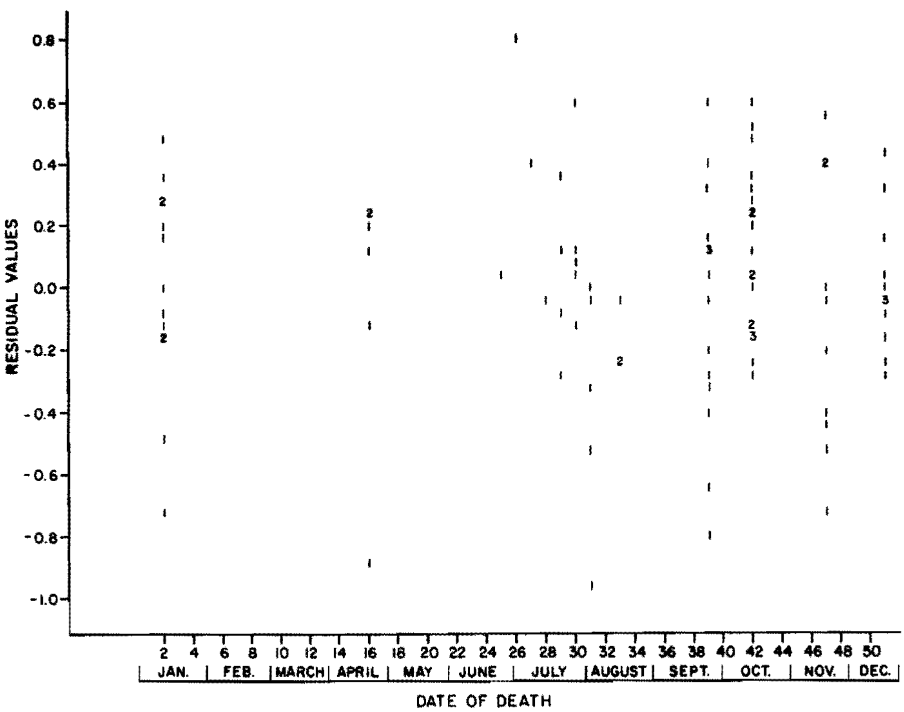

FIG. 7.–Plot of the residual values from the polynomial regression model by date of death. 1 = one observation, 2 = two observations, etc.

TABLE 1.—*Solutions for Y (growth index$^{.363}$) for every value of X (date of death, 1-52) based on the polynomial function.*

X (corresponding week)	Y	X (corresponding week)	Y
1 (Jan. 1-7)	1.69694	27 (July 2-8)	3.44191
2 (Jan. 8-14)	1.65831	28 (July 9-15)	3.56349
3 (Jan. 15-21)	1.63228	29 (July 16-22)	3.68430
4 (Jan. 22-28)	1.61818	30 (July 23-29)	3.80389
5 (Jan. 29-Feb. 4)	1.61565	31 (July 30-Aug. 5)	3.92173
6 (Feb. 5-11)	1.62413	32 (Aug. 6-12)	4.03730
7 (Feb. 12-18)	1.64312	33 (Aug. 13-19)	4.15009
8 (Feb. 19-25)	1.67211	34 (Aug. 20-26)	4.25959
		35 (Aug. 27-Sept. 2)	4.36531
any Y less than 1.70 is predicted as January-February		36 (Sept. 3-9)	4.46672
		37 (Sept. 10-16)	4.56329
		38 (Sept. 17-23)	4.65454
9 (Feb. 26-Mar. 4)	1.71056	39 (Sept. 24-30)	4.73997
10 (Mar. 5-11)	1.75799	40 (Oct. 1-7)	4.81902
11 (Mar. 12-18)	1.81388	41 (Oct. 8-14)	4.89122
12 (Mar. 19-25)	1.87773	42 (Oct. 15-21)	4.95605
13 (Mar. 26-Apr. 1)	1.94902	43 (Oct. 22-28)	5.01299
14 (Apr. 2-8)	2.02722	44 (Oct. 29-Nov. 4)	5.06155
15 (Apr. 9-15)	2.11184		
16 (Apr. 16-22)	2.20235	any Y greater than 5.07 is predicted as November-December	
17 (Apr. 23-29)	2.29829		
18 (Apr. 30-May 6)	2.39909		
19 (May 7-13)	2.50429	45 (Nov. 5-11)	5.10119
20 (May 14-20)	2.61332	46 (Nov. 12-18)	5.13143
21 (May 21-27)	2.72571	47 (Nov. 19-25)	5.15173
22 (May 28-June 3)	2.84097	48 (Nov. 26-Dec. 2)	5.16160
23 (June 4-10)	2.95853	49 (Dec. 3-9)	5.16052
24 (June 11-17)	3.07992	50 (Dec. 10-16)	5.14799
25 (June 18-24)	3.19862	51 (Dec. 17-23)	5.12348
26 (June 25-July 1)	3.32013	52 (Dec. 24-31)	5.08649

Table 1 also allows further assessment of the aptness of the polynomial model. The 52 solutions of Y for X yield 52 coordinates for the curve fit to the data on Figure 6. Table 1 and Figure 6 show that the curve is literally going backwards during the first four weeks and then again during the last four weeks. Interpreted literally, Table 1 and Figure 6 indicate that as the date of death increases the growth index gets smaller during the first four weeks of the year and then again during the last four weeks. In both cases these are misfits of no real significance. First, the magnitude of the errors is very small. Second, from inspection of Figure 6 it is clear that there is decreased predictive resolution during these periods. The misfits both encompass eight weeks; therefore, summary rules of evaluation for these periods appear at the appropriate junctures on Table 1. No accuracy has been sacrificed.

A complication potentially affecting the predictive reliability of the model can be detected by comparing Figure 5 with previously presented data on the variable P. Data on P suggest that fish who have completed their yearly growth but do not show evidence of annulus formation should tend to produce a growth index in the range of about 75-85. Yet, from Figure 5 it is apparent that the late fall/early winter samples (mid-October, mid-November, mid-December) produced growth indices tending to fall above this range. The mean growth index for each of these samples is 87.87, 91.006 and 91.04, respectively. These three samples are from the same year (1981) and from the same general location from the Tennessee River in Middle Tennessee. The year 1981 was evidently an exceptionally "good" year for growth among catfish in this portion of the Tennessee River.

From the above discussion it is reasonable to suspect that "unknowns" that died during the late fall will tend to be slightly underpredicted. However, this problem is minimized by the polynomial function. From the residual plot (Fig. 7) it can be seen that approximately two-thirds of the mid-October observations fall above the curve, indicating that the specific fit of the curve will help compensate for this source of error. For example, if a specimen with a growth index equal to the mean of the mid-October sample (87.87) is evaluated, it will be more accurately predicted in the November-December range. Any fish with a growth index in the range of 75-85 will be predicted as October, which is entirely rational based on analysis of the variable P. It must be borne in mind, however, that fish with a growth index in the range of 75-85 could have died in November or perhaps December.

More importantly, it must be realized that there is always decreased predictive resolution during periods of decelerated growth. Data presented here suggest that weekly predictions in the mid-October to mid-April range must always be evaluated cautiously. The empirical distinction between fish with a high growth index (75+) and fish showing the initial stage of annulus formation allows reliable separation between late fall/early winter and late winter/early spring fish. However, specific weekly predictions during these periods are undoubtedly subject to substantial error. For this reason the summary rules of evaluation for November-December and January-February estimates (Table 1) are especially useful since they encompass that period of the year when confusion is most likely.

Overall, this procedure provides an efficient predictive tool. There is no danger of misleading extrapolation beyond the range of the data set, a common problem with polynomial regression (cf. Neter and Wasserman 1974:275). By definition, X has a finite range; it can never be less than 1 or exceed 52. The summary rules of evaluation on Table 1 prevent mathematically feasible but logically impossible predictions outside this range.

A Test of Validity.—The only real test of this methodological tool is whether or not it works. This cannot be assessed with archaeological specimens since it is impossible to know the true date of death. However, tests can be conducted on modern specimens. To do this 17 pectoral spines from 17 modern channel catfish with known dates of death were evaluated. However, this was a "blind" test; the dates of death were unknown to me at the time of evaluation. All 17 specimens are from the impounded Tennessee River in Blount County, east Tennessee, a source different than any in the regression series.

Nine of the 17 specimens were immediately rejected. Figure 5 shows one of these rejected specimens. This fish, with abnormally wide annuli, died on July 4 and would be predicted incorrectly by several months. Six additional specimens showed a similar abnormality. Two more had annuli too indistinct to permit reliable measurements. Table 2 summarizes results on the remaining eight. One specimen (LL-108) was missed completely. It showed no significant irregularity, had developed an arrest mark on the outer edge, and was measured accordingly. The arrest mark was evidently non-annual. Unfortunately, when such specimens occasionally do occur, an unavoidable risk of significant error results. Predictions on the remaining seven are relatively close; all are predicted correctly to general season, five within one month. Age at death of the eight fish represented ranges from two to seven years and there is no apparent correlation between age and accuracy of prediction.

Two important points emerge from this test. First, the procedure works; seven of eight specimens show a good correlation between predicted and actual date of death. Second, knowing when to reject specimens is as important as knowing how to measure them.

TABLE 2.—*Comparison of regression-based predicted week of death and actual date of death of eight channel catfish from Fort Loudoun Lake, Blount County, Tennessee, based on pectoral spines.*

Specimen	Growth Index	Growth Index$^{.363}$	Predicted Week	Actual Date of Death	Error
LL-108	5.79	1.8917	March 19-25	September 12, 1978	6 months
LL-154	29.03	3.39636	July 2-8	June 9, 1980	+3-4 weeks
LL-156	52.50	4.21132	August 20-26	June 8, 1980	+6-7 weeks
LL-158	31.25	3.48843	July 2-8	June 9, 1980	+3-4 weeks
LL-159	7.27	2.05465	April 2-8	April 21, 1980	–2-3 weeks
LL-160	9.42	2.25725	April 23-29	April 21, 1979	+0-1 week
LL-162	54.05	4.25603	August 20-26	June 9, 1980	+10-11 weeks
LL-163	18.35	2.87541	May 28-June 3	June 9, 1980	+1-2 weeks

Additional Tests on Modern Specimens.—Because this procedure will have application outside the Middle South it is desirable to explore the possible effects of latitude on its predictive accuracy. Two additional series of modern catfish spines were obtained, one from the Sangamon River drainage in Cass and Mason counties, west-central Illinois, and the other from the Missouri River on the Nebraska-South Dakota border. All specimens were five years old or less when they died and the date of death was known when they were evaluated.

Tables 3 and 4 summarize results of these tests. The correlation between predicted and actual dates of death is good. The reader should note that six of these specimens (Table 3) are black bullhead *(Ictalurus melas)* rather than channel catfish *(I. punctatus).* Overall, the bullheads were predicted as accurately as the channel catfish. Since all fish in the Illinois series died within three days of each other, Table 3 presents an evaluation based on the mean growth index. The error factor associated with this group prediction (−1-2 weeks) is very small. Nine of the 11 specimens were underpredicted; the error factor associated with the group prediction might be larger if not for the remaining two specimens which were overpredicted by surprisingly high margins considering the tendency of the other nine to be underpredicted. Overall, this test suggests that evaluating fish from about 350 km north of the Tennessee/southern Kentucky region may introduce a tendency toward underprediction.

Moving farther north, the tendency toward underprediction with the Missouri River series (Table 4) is more pronounced. The correlation between underprediction and more northerly latitude makes intuitive sense. It is likely that fish in this region start their yearly growth cycle later than fish in the Middle South since winter (i.e. lower temperatures) lasts longer. According to Weatherly and Rogers (1978:67), "Growth is 'released' in fish at various species-specific threshold temperatures below which it cannot occur and above which an optimum will be located." Whatever the threshold temperature is for catfish, it is surely reached sooner in the spring in Middle South waters than in more northerly waters.

Evaluations on four of the eight specimens on Table 4 are based on dorsal rather than pectoral spines. Dorsal spines were the only bones available from these specimens and it is assumed that their seasonal growth is similar to that of pectoral spines. Like pectoral spines, they were sectioned near the base and measured on the posterior portion of the sections.

Results of the above tests suggest a tendency toward underprediction with increasingly northerly latitude. Modest correction factors for specimens from Nebraska (see below) are considered reasonable, though tentative.

AN ARCHAEOLOGICAL APPLICATION FROM CENTRAL NEBRASKA

The Schmidt site (25HW301), which represents a late prehistoric horticultural settlement, is located on a terrace overlooking the North Loup River in central Nebraska. The site clearly falls within the Central Plains Tradition (cf. Brown 1966; Krause 1969; Lehmer 1971:99-105; Blakeslee 1978) and has been tentatively assigned to the Loup River phase (Ludwickson 1978). The Loup River phase is a taxon which some investigators (e.g. Ludwickson 1978) believe represents lineal antecedents of the historic Pawnee. Intermittent excavations conducted at the Schmidt site from 1976 to 1978 by crews from the University of Nebraska-Lincoln and local amateurs yielded an abundance of well preserved faunal remains from eight house structures and 22 associated major features.

The Schmidt site was the object of a study of subsistence and seasonality among horticulturalists in the Central Plains[3] (Morey 1982). In this study ethnohistoric information on the Pawnee, Omaha and Ponca Indians was consulted as a source of ideas bearing on the seasonality of the Schmidt site. Information on the seasonal subsistence activities of these groups was integrated into a model of subsistence and seasonality among Central Plains villagers. The model specifies fall and spring village occupation with

TABLE 3.—*Comparison of regression-based predicted week of death and actual date of death of eleven channel catfish (Ictalurus punctatus) and black bullheads (Ictalurus melas) from the Lower Sangamon River drainage in Cass and Mason counties, Illinois, based on pectoral spines.*

Specimen/Species	Growth Index$^{.363}$	Predicted Week	Actual Date of Death	Error
LSD-11-16/*I. punctatus*	4.35792	Aug. 27-Sept. 2	September 7, 1971	–1-2 weeks
LSD-11-11/*I. punctatus*	4.33918	Aug. 27-Sept. 2	September 7, 1971	–1-2 weeks
LSD-11-9/*I. punctatus*	4.38329	Aug. 27-Sept. 2	September 7, 1971	–1-2 weeks
LSD-11-4/*I. punctatus*	4.01878	Aug. 6-12	September 7, 1971	–4-5 weeks
LSD-11-8/*I. punctatus*	3.65071	July 16-22	September 7, 1971	–7-8 weeks
LSD-17-2/*I. melas*	4.42047	Sept. 3-9	September 10, 1971	–0-1 week
LSD-17-3/*I. melas*	4.31812	Aug. 27-Sept. 2	September 10, 1971	–1-2 weeks
LSD-17-4/*I. melas*	4.35792	Aug. 27-Sept. 2	September 10, 1971	–1-2 weeks
LSD-11-2/*I. melas*	4.91262	Oct. 8-14	September 7, 1971	+5-6 weeks
LSD-17-5/*I. melas*	4.06695	Aug. 6-12	September 10, 1971	–4-5 weeks
LSD-17-1/*I. melas*	5.32108	Nov.-Dec.	September 10, 1971	+7-16 weeks
Mean Evaluation	4.41261	Aug. 27-Sept. 2	September 7-10, 1971	–1-2 weeks

TABLE 4.—*Comparison of regression-based predicted week of death and actual date of death of eight channel catfish from the Missouri River along the Nebraska-South Dakota border, based on pectoral and dorsal spines.*

Specimen/Spine	Growth Index$^{.363}$	Predicted Week	Actual Date of Death	Error
SUSD-72-1/pectoral	4.46396	Sept. 3-9	September 16, 1972	–1-2 weeks
SUSD-72-2/pectoral	4.96436	Oct. 15-21	October 10, 1972	+1-2 weeks
SUSD-72-3/pectoral	3.95824	July 30-Aug. 5	September 16, 1972	–6-7 weeks
SUSD-72-4/pectoral	3.72206	July 16-22	September 16, 1972	–8-9 weeks
SDFR-66-2/dorsal	3.01081	June 11-17	July 13, 1966	–4-5 weeks
SDFR-66-1/dorsal	3.09629	June 11-17	July 13, 1966	–4-5 weeks
SDFR-66-4/dorsal	3.0686	June 11-17	July 13, 1966	–4-5 weeks
SDFR-66-5/dorsal	3.53252	July 9-15	July 13, 1966	

complete abandonment for communal bison hunts during the winter and summer. The modeled seasonal pattern is believed to have had its roots well back into precontact times in spite of the various effects of Euro-American contact, including the introduction of the horse.

The long term stability of the modeled seasonal pattern resulted because Central Plains villagers, both prehistoric and historic, responded to similar environmental circumstances. Specifically, a restricted growing season of 100 to 140 days during most years resulted in a high level of dependence on food storage strategies among these groups, a circumstance which favored extended communal bison hunts during summer and winter (Morey 1982:60-66). Prehistoric Central Plains horticulturalists were surely no less affected by the restricted growing season and procurement requirements of bison, the critical animal food resource in this region. Therefore, it was proposed that seasonal evidence from the Schmidt site should indicate that it was occupied only during the spring (April-late June) and fall (September-October) (Morey 1982:66).

Seasonal Evidence from the Schmidt Site.—The major source of seasonal evidence from the Schmidt site is a series of catfish pectoral spines from several provenience units. Archaeological catfish spines are embedded in epoxy prior to sectioning; otherwise, preparation is identical to that of modern specimens. The rejection rate on archaeological specimens is similar to that of most modern samples (15-20%) if none are burned; burned specimens are presently unanalyzable. Figure 8 shows an archaeological spine section from a Schmidt site specimen in which the arrest lines, which are clearly visible, are identified.

The most useful series of spines from the Schmidt site are 15 specimens from the second arbitrary level (15 cm) of a large undercut pit. At least eight individuals are represented; they are tentatively identified as *Ictalurus melas* (black bullhead). All 15 spines are from fish three years old or less when they died. Table 5 summarizes results of evaluation of these specimens. The estimates clearly cluster in the late April-May-June range. Several lines of evidence suggest that it is reasonable to assume that a single procurement episode, perhaps a single day, is represented. They are all from a single arbit-

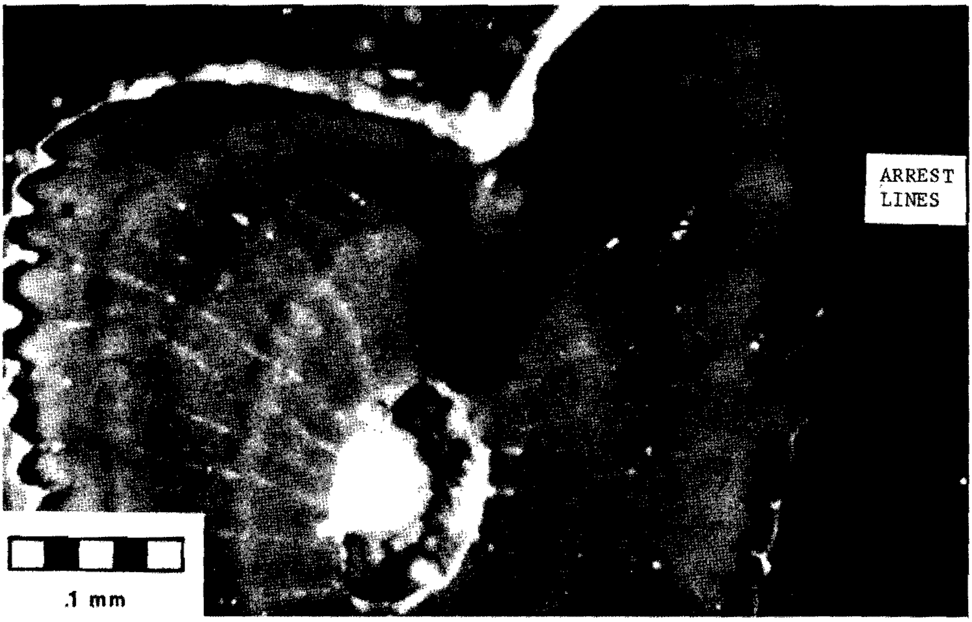

FIG. 8.—Photomicrograph of a thin section from a Schmidt site catfish pectoral spine (specimen 207-1).

rary level of a feature, are of uniformly small size, and their state of preservation is identical. Moreover, the unimodal distribution of predicted dates of death supports this assumption. Therefore, Table 5 includes an evaluation based on the mean growth index of the series that yielded a predicted week of death of May 21-27. For a series from this latitude, falling early in the year, a correction factor of adding 1-2 weeks is tentatively suggested. This places the series squarely in the first half of June.

Several other provenience units yielded five isolated spines that were measureable. Age at death was four years old or less for all five specimens. Table 6 summarizes results

TABLE 5.—*Regression-based predicted week of death for 15 bullhead (Ictalurus cf. melas) pectoral spines from a single arbitrary level (15 cm.) of a large undercut pit at the Schmidt site.*

Specimen	Growth Index	Growth Index$^{.363}$	Predicted Week
282-1	12.22	2.48089	May 7-13
282-2	11.11	2.39659	April 30-May 6
282-4	13.95	2.60304	May 14-20
282-6	22.50	3.09629	June 11-17
282-7	10.14	2.31842	April 23-29
282-8	25.0	3.21701	June 18-24
282-9	18.88	2.90528	May 28-June 3
282-10	29.03	3.39636	July 2-8
282-11	7.34	2.06181	April 2-8
282-12	13.04	2.54007	May 7-13
282-13	14.14	2.61585	May 14-20
282-16	23.08	3.12503	June 11-17
282-17	11.30	2.41139	April 30-May 6
282-18	10.71	2.3649	April 30-May 6
282-19	27.63	3.33596	June 25-July 1
Mean Evaluation	16.67	2.77699	May 21-27

TABLE 6.—*Regression-based predicted week of death for five catfish (Ictalurus sp.) pectoral spines from several provenience units at the Schmidt site.**

Specimen	Growth Index	Growth Index$^{.363}$	Predicted Week
96-1	66.67	4.5929	Sept. 10-16
17-1	60.78	4.44125	Sept. 3-9
207-1	46.48	4.02919	August 6-12
290-1	48.15	4.08115	August 6-12
290-2	51.11	4.17049	August 13-19

*Specimens 96-1, 17-1 and 207-1 were recovered from three different large undercut pits at the Schmidt site — see text for explanation of specimens 290-1 and 290-2.

of evaluation of these specimens. The estimates clearly fall in the late summer/early fall range. Correction factors of + 2-3 weeks for the mid-August estimates and + 1-2 weeks for the September estimates are tentatively suggested. This places estimates on two specimens (96-1 and 17-1) in late September and estimates on the remaining three during late August/early September.

Specimens 290-1 and 290-2 are problematical in that they are from the third level of the same feature as the previously described series of 15 specimens. However, field notes on file at the Department of Anthropology, University of Nebraska-Lincoln provide evidence of a stratigraphic separation between levels 2 and 3. Level 1-2 fill was evidently looser and less compact than level 3 fill. In any case, predictions on the level 3 specimens are inconsistent with predictions on the level 2 series and it is assumed that a different procurement episode is represented.

It is assumed that Middle South catfish start their yearly growth slightly earlier than Central Plains catfish. Yet, it is also reasonable to assume that the average value of P from spines of Middle South and Central Plains catfish is the same, leading to the conclusion that Central Plains catfish must have a slightly more rapid growth rate than Middle South catfish at some point, probably during mid- to late summer. Perhaps the average temperature of Middle South waters during this period exceeds the optimum for catfish growth (cf. Weatherly and Rogers 1978:67). Moreover, there is no evidence that suggests the overall growth rate of catfish varies systematically between different regions in North America (Carlander 1969:550). Therefore, it is likely that predictive error between the two regions will be greatest during mid-summer (July to mid-August) when Central Plains catfish are "catching up" in growth. Error should be least pronounced in spring and fall. This is the reason for variation in the suggested correction factors for Schmidt site specimens. It should be emphasized that the proposed correction factors are tentative estimates with no statistical basis; they are considered subject to amendment if additional data suggest that this is warranted.

SUMMARY AND CONCLUSION

This paper has presented a reliable, replicable procedure for archaeological assessment of seasonality from freshwater catfish remains based on analysis of incremental growth structures in pectoral spines of modern channel catfish. The reliability of the procedure was assessed with a "blind" test on modern specimens. Tests on modern specimens from locations north of the Middle South suggest that patterned predictive error results when such specimens are evaluated.

Although there are potential problems with any archaeological seasonality study (cf. Monks 1981) evaluation of archaeological catfish spines provided the most reliable evidence bearing on the seasonal occupation of the Schmidt site. As predicted, analysis of Schmidt site catfish spines suggests, minimally, fall and spring occupation on the site. Moreover, other traditional lines of seasonal evidence, though more tenuous, are consistent with evidence from the catfish spine analysis. Specifically, age-at-death estimates on deer and bison mandibles based on tooth eruption and wear schedules and inferred periods of maximum availability of several groups of migratory birds represented at the Schmidt site suggest fall and spring occupation (Morey 1982:128-133). All evidence considered compares favorably with a model of seasonal site occupation in the Central Plains generated from ethnohistoric information (Morey 1982). It is true, of course, that an argument for *only* fall and spring occupation of the Schmidt site requires an appeal to negative evidence. Additional sources of seasonal information, if available, might suggest summer and/or winter occupation. Thus, an important task facing archaeologists interested in the reconstruction of settlement-subsistence systems is to develop additional methodological tools for assessing archaeological site seasonality.

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I am, of course, solely responsible for the contents of this paper.

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NOTES

1. The Middle South includes the states of Tennessee, southern Kentucky, northern Georgia, northern Alabama and northern Mississippi.
2. Raw data on all specimens used in this study are presented elsewhere (Morey 1982).
3. The Central Plains includes the states of Nebraska, the northern two-thirds of Kansas, eastern Colorado, southeastern Wyoming, extreme western Iowa and extreme northwestern Missouri.