A Test of Three Shellfish Seasonality Methods: Preliminary Results

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THIS paper reports preliminary results of investigations into the use of bivalves as seasonal indicators in archaeology. Specifically, it addresses three proposed methods used for deriving seasonality for the southern California coastal region (Drover 1974; Lyons 1978; Macko 1983) based on external shell features. Basic to each of these seasonality methods is the premise that each year, usually during winter, *Chione* species bivalves will form an externally visible growth-cessation band (often termed the "winter" or "annular" break ring or band) along the outermost margins of their shells. As the bivalve resumes growth during the remainder of the year, this "annular" band is incorporated as a feature of the external shell structure of the bivalve. It is assumed that these "annular" bands therefore are permanent marks recording each year in the life of a bivalve across the surface of its shell from the hinge to the margin, and that the growth between each band occurred in one year. Based on this premise, three methods (each simply variations on the same theme) have been proposed to obtain seasonal data from shell remains recovered from archaeological sites on the southern California coast. A fourth method (Weide 1969) employing Pismo clams is not considered here because that species is somewhat sparse in most southern California shell middens.

REVIEW OF PROPOSED METHODS

Drover (1974) was the first worker in southern California to suggest, with some reservations, the use of *Chione* species bivalves as indicators of seasonality for local archaeological sites. This method was simple; a winter death was ". . . marked by the presence of a readily discernible incipient annual groove comprised of extremely thin growth laminae" (Drover 1974:227). Determination of death during other seasons was not as easy, and required dividing the distance between annular rings by three (see Barker, below). Citing numerous biological inconsistencies observed by other workers, Koerper (1980) noted problems with Drover's work and cautioned against using methods not tested locally.

In 1978, Lyons advanced a method whereby, through a series of equations and formulae, a table of seasonality was constructed that assigned a season of death according to the number of raised "fortnightly" growth bands evident on the exterior shell surface. According to Lyons (1978:36), all any worker had to do was count each of the raised concentric bands of the wavy *Chione* from the hinge to the margin and use that total count to place the shell within the correct season of death. Numerous problems and faulty assumptions underlie Lyons' methods, and these were briefly touched upon by Koerper et al. (1984) and reiterated by Lyons (1984).

Both Drover and Lyons based their techniques on Barker's (1964, 1970:178) study of 98 species of bivalves, and specifically his work on *Chione undatella*. Barker had determined yearly growth averages for this species based on studies of specimens grown in Cholla Bay, Mexico. These averages were 16.9 mm. of shell for the first year's growth, 8.8 mm. for the second, 4.5 mm. for the third, and 4.0 mm. for the fourth year. The reliability of these averages when used in a

location far removed from Cholla Bay has yet to be tested.

Finally, in 1983, Macko offered an improved version of Drover's method by suggesting that the majority of growth took place during the spring and summer, rather than throughout spring, summer, and fall. Citing Coutts and Higham's (1971) work with a western Pacific species *Chione stutchburyi* in south New Zealand, the growth increments documented by Barker in Mexico were estimated for *Chione undatella* in southern California by Macko to be 35% of the total yearly growth for spring, 50% for summer, and 15% for fall.

Problems with Macko's study limit its utility. Specimens used in Coutts and Higham's study, upon which he relied, were not all "zeroed" or marked prior to the final collection, making it difficult to measure the amount of growth that had actually occurred in a year. Moreover, the shellfish populations Coutts and Higham studied were located across the Pacific on a shoreline that not only exhibits a different tidal regime and currents, but also has seasons in the reverse of those in southern California. Whether or not such issues are relevant to seasonality inferences in southern California remains untested at present.

METHOD

For this study, one population of *Chione* consisting of the species *C. undatella*, *C. californiensis*, and *C. fluctifraga*, and two populations of *Protothaca staminea* were used. Between April and June, 1985, the shellfish were captured, measured, weighed, marked, notched, and released into special retaining pens at their capture sites in Newport Bay, California. They were recaptured in June, 1987. A population consisting of the three *Chione* species (n = 148) and *Protothaca* (n = 458) were placed in Pen No. 1, which faced the main channel of the bay. Another population consisting only of *Protothaca* was placed in Pen No. 2 on the floor of the bay opposite the main channel. The placement of the captured populations reflected their normal distributions in the bay. Only the *Chione* specimens in Pen No. 1 are discussed in this report.

The method for numbering the specimens involved the use of indelible marking pens of different colors drawn as a line on the bivalve shell, with each color representing a digit from 0 to 9 (e.g., blue = 0, green = 3, etc.). A single line of color drawn on the shell surface represented a single digit number from 1 to 9 (depending on the color), two lines of any of the colors can create a double digit number from 10 to 99, and three lines a number from 100 to 999. It was necessary to use such a technique for the *Chione* species because of the high relief of their exterior shell features.

Shell margins were notched with a triangular file to create a mark in the outer margin of the shell. This created a "zeroing point" from which the total shell growth and the number of annular growth increments that occurred during the study period could be measured. All measurements and counts are taken from the notched point (the shell margin at the beginning of the experiment) to the shell margin present after two years of growth.

The retaining pens were of a special design to assure that the pens themselves did not alter environmental conditions in the study area. They consisted of four walls made of 12.70 mm. (1/2-in.) mesh aviary netting and measured 3 m. square and 25.4 cm. high. The pens retained a sample of the study population without impeding growth of individuals by affecting environmental parameters conducive to growth. That is, the pens did not restrict reproduction, feeding, food supply, tidal current, surface irradiation, temperature, or salinity. They were

large enough to not restrict the rate of growth due to overcrowding.

At the end of the two-year period, 21 *Chione* and 169 *Protothaca* were recovered. The actual number of *Chione* used in this study is 19, because two specimens were recovered dead. For the *Chione*, this represented a 12.8% return; for the *Protothaca*, a 36.9% return. Although the recaptured *Chione* are small in numbers, the 12.8% return is high compared to previous studies where returns were 8% or less (cf. Merrill et al. 1965; Ropes and Merrill 1970). Attempts to find the *Chione* outside of the pens (because *Chione* remain on or just below the surface of the substrate) proved futile. It is believed that the *Chione* may have migrated below the lower tide level, a characteristic behavior of older individuals (Ricketts et al. 1985). Pens used in this study were constructed 1 inch above the surface of the substrate. Thus, with silting factors and high tides, some specimens of the *Chione* population escaped because they typically occur either on the substrate or just under it.

The recaptured specimens were remeasured and reweighed, and the meat was removed from the shell and stored for future histological research. Weights and measurements are not considered in this study, and will be addressed in detail in a separate paper on growth rates and shell-to-meat weight ratios.

Detailed comparisons and statistical analyses have not yet been applied to these data. However, certain preliminary results are evident and are presented in Table 1. Each *Chione* specimen recovered live is listed by its assigned number in the left column of the table. The right column shows the number of "annular" bands (the winter "break" visible on the shell) counted from the notch (the old shell margin) to the shell margin when recovered.

The number of "annular" bands indicated in the right column of Table 1 also is the inferred number of "annual growth increments" using the reasoning heretofore employed in seasonality studies on *Chione* shellfish in southern California. The total number of specimens apparently representing each annual growth increment from 0 to 2 years is shown at the bottom of the table. As shown, 4 specimens exhibit no new "annular" bands, 12 specimens exhibited 1 new "annular" band, and 3 specimens exhibited 2 new "annular" bands. Thus, for the entire sample, 21% exhibited less than one year's growth, 63.2% exhibited at least one year's growth, and 15.8% exhibited at least two year's growth as indicated by the number of "annular" bands.

Table 1
WINTER GROWTH ARRESTMENT BANDS ON SPECIMENS OF *CHIONE UNDATELLA* RETRIEVED AFTER A TWO-YEAR GROWING PERIOD

Specimen Number	Number of Bands = Apparent Number of Years Represented
206	1
356	1
382	1
388	2
390	1
406	1
407	1
413	1
417	1
418	0
419	0
431	1
449	2
459	2
463	1
465	0
466	0
474	1
479	1

Totals for each year represented:

0 years = 4 specimens (21.0%)
1 year = 12 specimens (63.2%)
2 years = 3 specimens (15.8%)

DISCUSSION

The results shown in the table are self-evident. The basis for each of the seasonality methods briefly described above is the formation of "annular" growth bands readily visible on the external shell structure. If seasonal inferences are to be made with any degree of reliability, then organisms from which such data are derived must exhibit growth patterns assumed by the method used to determine seasonality. That is, for each year throughout the life of the bivalve (in this instance during the winter), a single new "annular" band must be formed, and this must occur with a high degree of regularity across a population in order for the bands to be considered reliable for use as seasonal indicators.

In this two-year study, two "annular" bands should have formed on each of the specimens in the sample. As shown in Table 1, not all of the specimens exhibit two growth-arrestment bands indicating that two winters had elapsed during the two-year study period. In fact, only 15.6% of the sample exhibited the expected addition of two "annular" bands.

Of great interest are the specimens that did not add any "annular" bands over the two-year study period. If no "annular" band has been formed, the only possible explanation, according to the assumptions inherent in previous southern California archaeological studies, would be that the bivalve died before reaching the first winter. Yet all of the specimens listed in Table 1 were recovered alive after having been growth-marked two years earlier.

Equally important are the specimens that added only a single "annular" band. These inconsistencies invalidate assumptions of "annular" band growth. According to the basic assumption in each of the methods reviewed above, two annular lines should have been deposited on the shell exterior after the "zeroing" notch. The fact that almost 85% of the specimens did not add two "annular" bands is a most significant argument against the reliability of external surface observations for determining season of death of *Chione* clams. Kennish (1980:269) summed it up for all researchers when he stated that "It is nearly impossible to identify the diverse origins of growth breaks by examining only the exterior of the shell."

The preliminary results of this two-year growth study of *Chione* species clams render the three southern California studies of archaeological seasonality based on the external shell features of bivalves highly suspect, if not invalid. Methods proposed by Drover (1974), Lyons (1978), and Macko (1983) depend on the addition of an "annular" band being formed on the external shell structure during winter. Because this preliminary investigation shows that such lines are not consistently annular in nature, at least when inspected externally, serious doubt is placed upon the reliability of these methods to generate appropriate seasonal data, and on any conclusions of seasonality based on them. It also follows that any attempts to identify seasons other than winter are equally unfounded. At our present level of understanding, studies of archaeological seasonality based solely on observations made on the external surfaces of bivalves should be suspended, if not abandoned entirely for the southern California coast. Previous conclusions based on these methods for deriving seasonal data should be considered invalid.

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Salinan Linguistic Materials

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AT the time of European contact in the eighteenth century, Salinan was spoken along the south-central coast of California from just north of the present town of King City south to Paso Robles and east to Coalinga. Randall Milliken's work with the California mission registers and recent archaeological studies by Gibson (1975, 1982) and Breschini and Haversat (1980) have refined Kroeber's (1925) geographic distribution of Salinan speakers. The most significant change from