CHAPTER 13

Growth Coloration Revisited: Assessing Shell Fishing Seasonality in Coastal British Columbia

DAVID MAXWELL

Introduction

Estimates of the season of shellfish collection or shellfish death (herein referred to as seasonality) have been made for the past 30 years using a variety of approaches. Despite the number of studies conducted (see Claassen 1998 for a review), few researchers have presented convincing results. Shellfish seasonality studies are still regarded as experimental in many instances, or are described as "having great potential"for future use. "Great potential" more than 30 years after the first study suggests an analytical technique that will never be widely applied, much less widely accepted. Problems frequently stem from a combination of erroneous assumptions about shell growth, analytical techniques, and poor sampling of both modern shellfish populations and archaeological sites.

This paper reviews my own experiments with assessing shellfish seasonality, conducted in the late 1980s with materials gathered on Pender Island in the southern Gulf islands of British Columbia. This research was undertaken using the then relatively new idea of looking at patterns of growth within an entire population of shellfish, rather than studying isolated individuals. I begin this paper with a brief review of shell growth, followed by a discussion of the methods employed in the study, and a discussion of the results. This is followed by a discussion of the role of sampling in seasonality studies, and finally a discussion of why shellfish seasonality studies have never become common place in shell midden archaeology.

Shell Growth

Although still a poorly understood phenomenon, shell appears to be produced by the deposition of calcium carbonate crystals ($CaCO_3$) on to a primarily proteinacious organic matrix known as conchiolin (Wilbur 1964). Both the calcium and carbon dioxide needed for shell growth are taken into the organism from the external environment; they are then moved into the mantle, which covers the inner growing surface of the shell, where they combine to form calcium carbonate. The organic matrix (con ciolin) is deposited as a layer on the inner surface of the shell. The crystalline substance is then deposited onto the organic matrix, with mixture of the two occurring in some species (Crenshaw 1980). Shell formation is not unidirectional, and dissolution or decalcification occurs as well.

Lutz and Rhodes (1977) hypothesize that both calcium carbonate and organic matrix are deposited during aerobic metabolism, when the shell is open to the external medium or gaping, resulting in shell construction. This is typically associated with high tide, when the water is high in oxygen content. When the oxygen content falls, during periods of shell closure, anaerobic respiration begins. This increases internal acid levels in the extrapallial fluid (which covers the mantle); the acid is neutralized by the calcium carbonate in the shell dissolving, leaving a concentration of organic material without calcium carbonate to support it. This process is repeated on a tidal basis, resulting in a growth increment. Other researchers (Day 1984) suggest that both calcium carbonate and conchiolin are deposited throughout the year, but that calcium carbonate is reduced or halted during times of stress, thereby resulting in variations in growth increment width throughout the year.

Myriad environmental factors appear to influence shell growth, and the reader is directed to Maxwell (1989) for a more detailed discus-

sion. Minimally, shell growth is influenced by circadian rhythms (cycles of light and darkness), spawning events, temperature fluctuations, seasonal change, tides, and storms. Temperature fluctuations brought on by seasonal change are obviously those of the greatest interest to most archaeologists; traditionally, archaeological estimates of seasonality are based on the assumption that shell growth will be greatest during the summer, when water temperatures are highest. Some species do seem to respond in this fashion while others do not (see Evans 1975). Other authors (House and Farrow 1968) note little or no variation in growth rates throughout the year, regardless of temperature fluctuations. Thus, seasonal fluctuations in growth appear to be species specific, and cannot be generalized.

Methods

Claassen (1998) argues that here are essentially three ways of assessing the season of death for shellfish: (1) using oxygen isotopic data, (2) using growth increment data, and (3) using population data. These methods all have varying strengths and weaknesses, and only the latter methods are of interest here. The method employed in my Pender Island study is best described as a combination of methods 2 and 3, that is, using growth incremental data in a population of shellfish. Essentially I looked at monthly variation in growth coloration using a population of shellfish gathered on Pender Island.

Growth increment data is probably the means of assessing seasonality most widely employed by archaeologists. This has varied from studies as relatively simple as counting growth rings on shell surfaces (Weide 1969), to the more sophisticated variations on this theme involving growth measurements employed by researchers such as Ham (1982), Ham and Irvine (1975), Keen (1979) and Wessen (1982), to extremely detailed analysis of sub-daily lines (Koike 1979, 1980). Another approach has been the comparison of frequencies of growth coloration, advocated by Claassen (1982, 1986, 1991) and Maxwell (1989). Reviews of these varying approaches can be found in Claassen (1998), Maxwell (1989), and Monks (1981).

The Pender Island study employed a technique of thick sectioning (most sections in the 1-3 mm range), employed in the southeastern United States by Claassen (1986) and Quitmyer et al (1985). These sections are cut and the color of the final growth increments on the ventral margin (the leading edge of the shell) are recorded. The margin is either translucent or opaque. Modern specimens are collected on a monthly basis, and broken into percentages of fast and slow growth, which are plotted as bar graphs that characterize the growth pattern for a particular month.

The approach of looking at growth coloration across a population was selected because it offered two distinct advantages over counting growth lines or measuring growth increments. First, this approach compares the growth of an entire population, rather than simply individuals, thus taking individual variation into account; a lack of understanding of individual variability was frequently the weak link in growth increment studies. Second, growth coloration frequencies can be calculated much faster than can comparative data for any other technique, because valve sections do not have to encompass the entire length of the shell to be useable; only the last few millimeters of growth need to be assessed, compared to the entire valve for increment or line count studies. The biggest problems are the requirement that archaeological samples must also be populations; individual shells cannot be assessed, and that the technique tends to be unable to divide the year into more than two seasons (Maxwell 1989).

All shellfish were collected live from Shark Cove, near the Pender Canal on north Pender Island, and adjacent to the archaeological site DeRt-1. Specimens were removed from a variety of areas within this small cove, but covering an area no more than 100 meters in length and 30 meters in breadth. After collection, all specimens were taken directly to SFU where they were killed by freezing; however, this often occurred several hours after collection due to inherent travel time. After a span ranging from several days to several months, specimens were processed through cooking in hot (but not boiling) water, and all soft tissue was removed. The shells were then allowed to air dry for several days prior to sectioning.

Each specimen was mounted in a padded clamp and sectioned using a Buehler Isomet 11-1180 Low Speed Saw with a five inch blade; completed sections were stored in capsules. Initially the shells were sectioned from ventral margin to umbo (hinge); however, this proved very labour intensive with an average cutting time of nearly 1 hour. As the observations of interest only involved growth coloration of the ventral margin, the approach was changed and a small section of roughly 1 cm in length was removed from this area. This required an average of roughly 8-10 minutes. Time needed for assessing each specimen was minimal, and averaged less than 1 minute. Specimens were as-

Table 13:1. Pender Island Comparative Collection by Species and Month of Collection in 1987 and 1988.

Species	Feb 87	Mar 87	Apr 87	May 87	June 87	July 87	Aug 87	Sep 87	Oct 87	Nov 87	Dec 87	Jan 88	Total
Clinocardium nuttalli			7	5	6	2	6						19
Macoma sp.	20	11	8	6	34	13	18	13		2		2	126
Mya arenaria	14	19	12	1	9	15	9	3	13	22		13	126
Protothaca staminea	21	18	13	15	23	21	26	33	10	23	9	20	231
Saxidomus giganteus	12	14		29	7	12	9	14	7	12		11	140
Tresus capax		1		3			2	2		1			9
Totals	67	63	40	59	79	63	70	65	30	60	9	46	651

sessed using an American Optical binocular stereoscope at 30 power. Reflected light provided the best results for distinguishing colour at the ventral margin, although the same results were obtained using both reflected and direct light. The same results were also obtained with a lower magnification, although 30 power made it easier to distinguish margin colour. Specimens were described as *Translucent* if reflected light could penetrate them, *Opaque* if no such penetration occurred, and *Indeterminate* if they proved unreadable.

The Modern Comparative Collection

The modern comparative collection is one of the most crucial components of a shellfish seasonality study, yet, most modern collections are very small and frequently lack specimens from throughout the year. Claassen (1998) lists 35 collections from throughout North America, and only 1 includes more than 500 specimens. Collections encompassing multiple years are exceptionally rare, despite the fact that no single year can be argued as representative of a typical cycle in any region.The Pender Island collection (henceforth referred to as PIC) is large, with 651 specimens collected over a twelve month period of February 1987 through January 1988 (see Table 13:1). However, even this relatively large collection is not without problems. First, six different bivalve species were collected throughout the year; thus, the largest collection for any given species is 231 individuals of *Protothaca staminea*, the native little neck clam. No other species is represented by more than 140 specimens. Second, the collection covers only a single twelve-month period. Finally, the winter collection periods, late November and December, yielded very small samples due to extremely high low tides during the time available for gathering.

The PIC consists of *P. staminea* mentioned above, along with *Saxidomus giganteus*, the butter clam, *Macoma* sp., the bent-nose clams, *Mya arenaria*, the mud clam, *Clinocardium nuttallii*, the basket or heart cockle, and *Tresus capax*, the horse clam. Table 1 details the collection by month. Gathering was conducted following a lunar cycle of roughly 29 days, always during the lowest tide available to the author.

Results

The Overall Pattern

For the initial analysis, all species from each collection interval were combined, resulting in the pattern seen in Figure 13:1. After removing indeterminate specimens (Figure 13:2), the bulk of the collection periods are very similar in appearance, with roughly 60 percent of the collection falling into the opaque category. The only distinctive months are January and February, with opaque values of roughly 25 and 45 percent, respectively; as these collection periods were 12 months apart, it seems unlikely that their similarities are the result of a short-term fluctuation in climate. The growth coloration technique appears to divide the year into two distinct statistical "seasons," defined as winter (January and February) and summer

Table 13:2. Summary of Ventral Margin Colour by Collection Date and Species.

Collection Date	Species	Translucent	Opaque	Indeterminate	Total
February 21, 1987	*Protothaca staminea*	8	12	1	21
	Saxidomus giganteus	3	8	1	12
	Mya arenaria	2	2	10	14
	Macoma sp.	16	0	4	20
March 20, 1987	*Protothaca staminea*	4	10	4	18
	Saxidomus giganteus	2	11	1	14
	Mya arenaria	3	8	8	19
	Macoma sp.	9	0	2	11
	Tresus capax	1	0	0	1
April 21, 1987	*Protothaca staminea*	3	6	3	12
	Saxidomus giganteus	2	11	0	13
	Mya areanaria	2	2	4	8
	Macoma sp.	4	1	2	7
May 15, 1987	*Protothaca staminea*	8	7	0	15
	Saxidomus giganteus	8	21	0	29
	Mya arenaria	0	0	1	1
	Macoma sp.	4	1	1	6
	Tresus capax	1	0	2	3
	Clinocardium nuttallii	0	5	0	5
June 12, 1987	*Protothaca staminea*	2	20	1	23
	Saxidomus giganteus	2	5	0	7
	Mya arenaria	0	4	5	9
	Macoma sp.	16	6	12	34
	Clinocardium nuttallii	0	1	5	6
July 9, 1987	*Protothaca staminea*	1	16	4	21
	Saxidomus giganteus	4	7	1	12
	Mya arenaria	0	7	8	15
	Macoma sp.	10	1	2	13
	Clinocardium nuttallii	0	2	0	2
August 9, 1987	*Protothaca staminea*	2	23	1	26
	Saxidomus giganteus	1	6	2	9
	Mya arenaria	4	0	5	9
	Macoma sp.	13	1	4	18
	Tresus capax	2	0	0	2
	Clinocardium nuttallii	1	2	3	6
September 6, 1987	*Protothaca staminea*	7	22	4	33
	Saxidomus giganteus	2	11	1	14
	Mya arenaria	0	1	2	3
	Macoma sp.	10	0	3	13

Table 13:2. Summary of Ventral Margin Colour by Collection Date and Species (cont'd).

Collection Date	Species	Translucent	Opaque	Indeterminate	Total
	Tresus capax	1	0	1	2
October 4, 1987	*Protothaca staminea*	1	7	2	10
	Saxidomus giganteus	3	3	1	7
	Mya arenaria	3	4	6	13
November 1, 1987	*Protothaca staminea*	5	18	0	23
	Saxidomus giganteus	1	11	0	12
	Mya arenaria	14	1	7	22
	Macoma sp.	0	1	1	2
	Tresus capax	0	0	1	1
December 27, 1987	*Protothaca staminea*	2	3	4	9
January 24, 1988	*Protothaca staminea*	11	2	7	20
	Saxidomus giganteus	2	5	4	11
	Mya arenaria	8	1	4	13
	Macoma sp.	1	0	1	2
Totals		209	296	146	651

NB: Collection was conducted on November 29, 1987 in keeping with the lunar collection schedule; however, only a single specimen (*Protothaca staminea*) was recovered, and the valve was not sectioned.

(the remainder of the year). A chi square test (see Maxwell 1989 for details) demonstrates that there is a highly significant statistical difference between the winter and summer seasons thus created. On this basis, dividing the year into two distinctive, yet uneven seasons seems valid.

Overall, there were far more *Translucent* than *Opaque* specimens. This was true in all species with samples of more than 100 individuals except for the bent nose clam (*Macoma* sp.), where the vast majority of specimens were *Opaque*; reasons for this variation are unknown, but would appear to be a trait of the species in question. Figure 13:3 shows the frequencies of growth coloration for all species in the study; Table 13:2 details the month-by-month frequencies of each growth coloration type. All species were combined in the attempt to find an overall tendency for growth coloration to change seasonally.

Initially, it was hoped that seasonal patterns would be clear regardless of the species under observation. However, combining different species into a single monthly growth sample is problematic, and it is questionable whether these are truly representative of the collection period in general. Using this approach, it would be possible to produce a variety of growth "seasons" by with monthly samples comprised of varying ratios of species, even if all the specimens were collected on the same day.

At first glance, this appears to be a satisfying result, and suggests a potential value for the technique for Northwest Coast seasonality research. However, a closer examination of the variability *within* each species suggests that thereis no validity in combining the different speciescollected on a monthly basis. Figures 13:4-7 illustrate the ratios of *Opaque* to *Translucent* readings by month for *Macoma* sp., *Mya arenaria, Protothaca staminea*, and *Saxidomus giganteus,* respectively. These show that not only is there seasonal variation in growth coloration for each species, but also that this variation appears to be species-specific; there is thus no valid reason to combine the different species and to use these to produce an annual growth curve.

Species-Specific Patterning

Basket Cockle (Clinocardium nuttallii)

The basket cockle, shows a very low percentage of specimens throughout the year which exhibit

translucent growth (9 percent), while 45.5 per cent of the specimens exhibit opaque growth. At the same time, 45.5 percent of the collection is indeterminate; however, the sample size for cockle was only 19 specimens, and the species was only encountered during the summer months (May through August) when the tides were very low. The sample is too small and lacks sufficient seasonal variation to suggest whether it is a reliable seasonal indicator

Bent Nose Clam (Macoma spp.)
Macoma spp. shows a high proportion (68.6 percent) of specimens exhibiting translucent growth; only 9.9 percent of the individuals were opaque, while the remaining 21.5 percent were indeterminate. *Macoma* is included in all collection periods except October and December; Figure 13:4 shows the ratio of opaque to translucent specimens by month. Throughout the year, the proportion of translucent specimens for this species rarely diminishes below 60 percent; June is the only collection period when this occurs. Opaque growth, on the other hand, is limited almost exclusively to the months of April through August (with a single example from November). Indeterminate *Macoma* specimens remain at a more or less constant rate of 18-25 percent throughout the year. *Macoma* does not seem to be a dependable seasonal indicator, expressing too little variation throughout the year. It is possible that the presence of a moderate proportion of specimens with opaque growth is indicative of the summer months; the presence of a single opaque specimen from the November collection casts doubt over this suggestion, and a longer collection period is needed to resolve the issue. A small collection of *Macoma* from San Juan Island (approximately 14 km southwest of Shark Cove) with a collection date of July 28 exhibits atranslucent growth percentage of 82 percent (Claassen 1987: personal communication). While this is based on only 11 individuals, it supports the observation of opaque growth being a summer month phenomenon.

Mud Clam (Mya arenaria)
This species is well-represented with 131 individuals in the collection, and is present in every collection period except December; Figure 13:5 shows the frequencies of all growth coloration readings for *Mya*. Twenty-nine percent died during translucent growth, 22.9 percent died during opaque growth, and 48 percent were indeterminate. These percentages suggest that *Mya* is a poor choice for season of death research in this region, as nearly half of the specimens collected proved unreadable. Of the specimens that could be assessed, there is a trend towards a higher proportion of translucent growth during the winter months (August through April) and a high proportion of opaque growth between May and July. However, the proportion of indeterminate specimens is always above 30 percent, and frequently greater than 40 percent. With such a high frequency of unreadable sections, it seems that *Mya* would be difficult to use in an archaeological collection, especially in light of its highly fragile nature. Itshould be emphasized that these results were obtained using observation of growth at the ventral margin, as both Hancock (1982) and Sanger (1989) report some success using the chondrophore in coastal Maine sites; it may Be worthwhile investigating use of the chondrophore on the Pacific Coast.

Native Little Neck Clam (Protothaca staminea)
The native little neck is by far the most abundant species in the PIC, with 237 specimens present; it is also the only species encountered during every collection period; growth coloration results are presented in Figure 13:6. *Protothaca* yielded 55 specimens that died during translucent growth. These were spread throughout all collection periods, but were concentrated in the winter months of January and February; May also saw a high percentage of translucent growth. 62.9 percent of all *Protothaca* specimens died during opaque growth, which falls into three distinct periods: In January, opaque growth is very low at less than 20 percent; between February and May, this proportion increases to between 45 and 60 percent; the months of June through November see consistently high ratios of opaque specimens, usually between 75 and 95 percent (with September at an anomalous 65 percent). December, with a very small sample size (n=9) shows only 50 percent. Fourteen percent of all *Protothaca* specimens were indeterminate; these were evenly spread throughout the year, with only January and April having frequencies of over 20 percent. These results suggest that *Protothaca staminea* is likely a good indicator of season of death, capable of dividing the year into three distinct time periods.

Butter Clam (Saxidomus giganteus)
The butter clam is also well represented in the PIC with 130 specimens present; *Saxidomus* was represented in every collection period except December. Of these specimens, 23.2 percent died during translucent growth, compared with 70.3 dying during opaque growth and 6.5 per

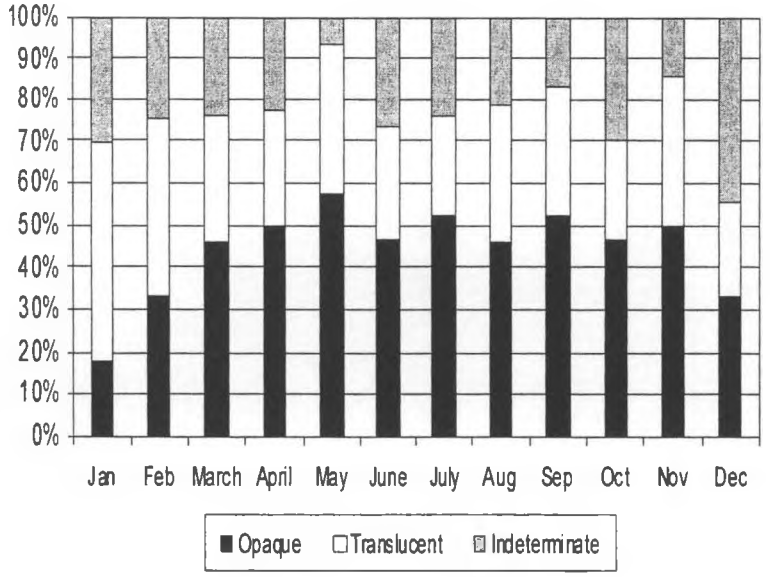

Figure 13:1. **Growth Coloration: All Species Combined.**

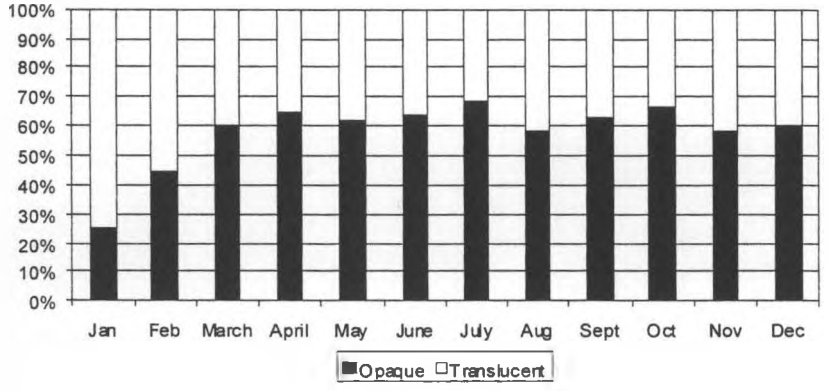

Figure 13:2. **Growth Variation Curve.**

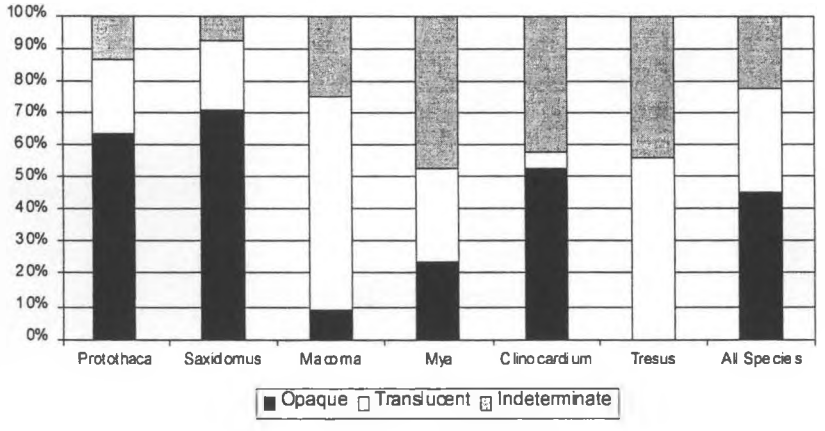

Figure 13:3. **Species Variation in Margin Colour.**

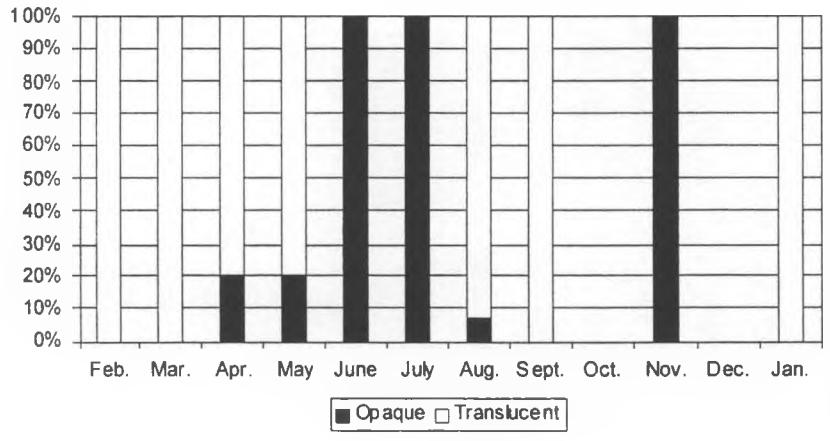

Figure 13:4.
Macoma spp

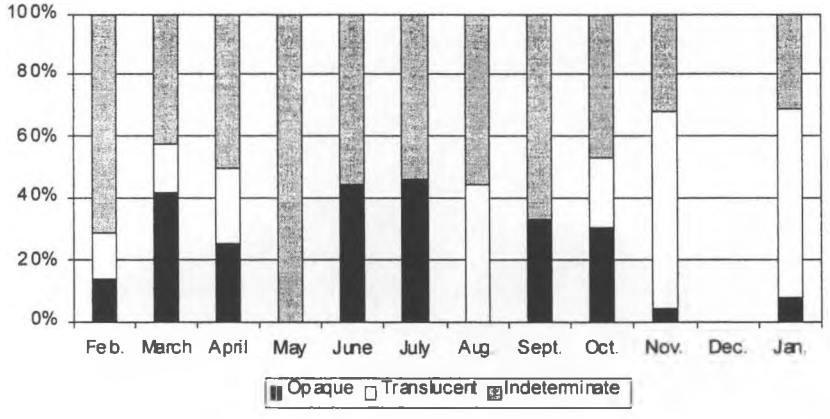

Figure 13:5.
Mya arenaria.

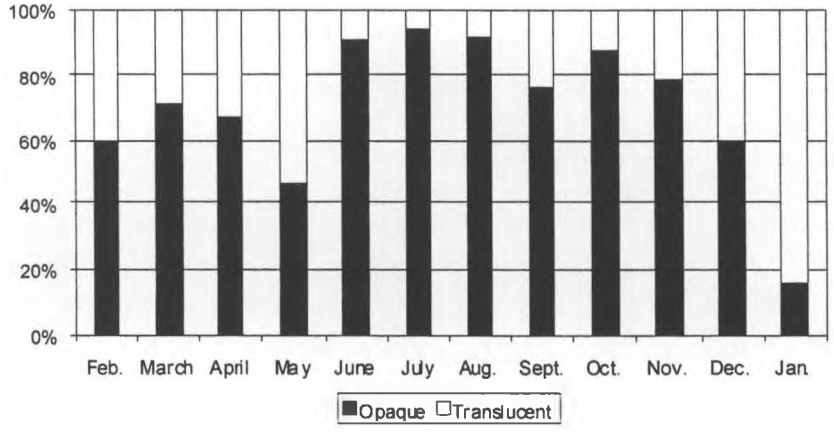

Figure 13:6.
Protothaca staminea.

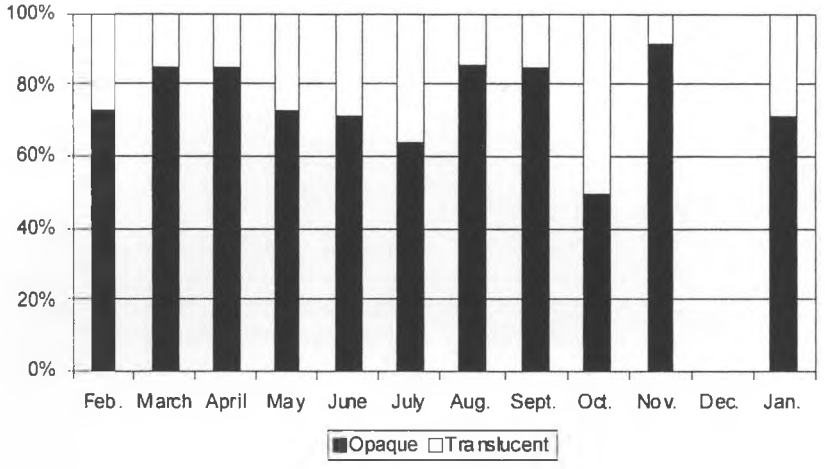

Figure 13:7. Saxidomus giganteus.

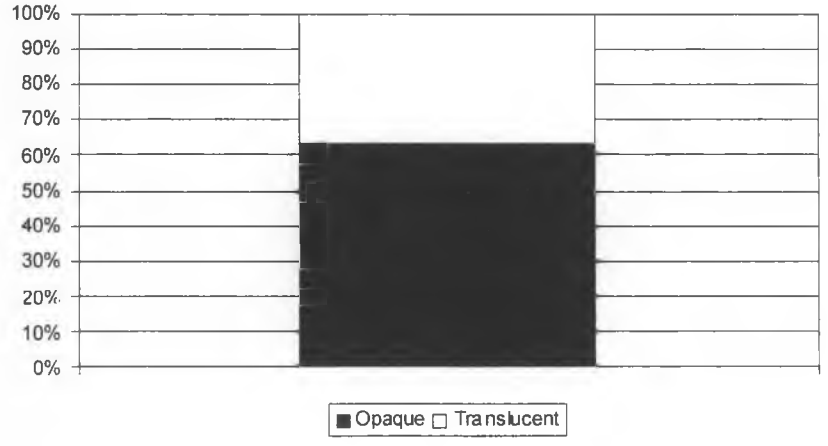

Figure 13:8.* Example 1*: Protothaca staminea.

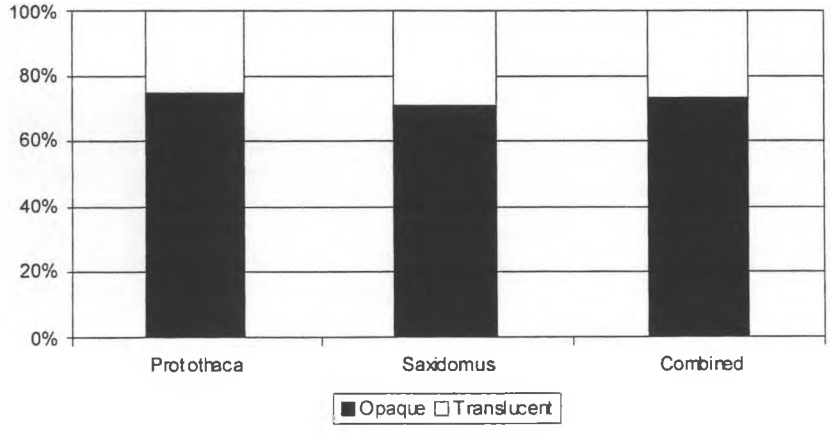

Figure 13:9.* Example 2*: Protothaca staminea* and *Saxidomus giganteus.

cent yielding indeterminate readings; the frequencies of translucent and opaque growth are presented in Figure 13:7. Two trends are detected in the growth curve: Proportions of translucent growth in *Saxidomus* specimens alone are not good indicators of the season of death, as very different times of the year (eg., January and July) appear almost identical; frequencies of translucent specimens fluctuate wildly throughout the year, as can be seen in Figure 13:7. Opaque growth, on the other hand, may be a better season of death indicator, as only the months of January, October, and November have opaque growth frequencies of less than 50 percent (33.3-41.7 percent). The period of February through September shows opaque growth varying between 58.3 and 84.6 percent, with most months showing well over 60 percent opaque. Thus, opaque growth in *Saxidomus* specimens could be used to divide the year into two general seasons: a winter season of October through January, and a summer season of February through September. Unfortunately, the sample sizes for each month are not very large. Indeterminate specimens are uncommon in *Saxidomus*, with only 6.5 percent overall; these are concentrated in the winter and early spring months (October through March), although indeterminate specimens are also present in July and August.

Horse Clam (Tresus capax)

The horse clam is poorly represented in the collection, with only 9 specimens present; the species was encountered only during the spring and summer collection periods. Within this small sample, 5 individuals died during translucent growth, and the remainder were indeterminate. The lack of variability combined with the fact that nearly half the collection was unreadable and only four months of the year are represented in the sample, make *Tresus* a difficult species to interpret. More work is needed before any decision on the practicality of doing season of death estimates on *Tresus* individuals can be assessed.

The Effects of Size on Growth Coloration

Statistical analysis was conducted comparing the relationship of valve length and weight on growth coloration (see Maxwell 1989 for a detailed discussion). This demonstrated that length or weight were only factors in the case of very small valves. Valves measuring less than 30mm in length or weighing less than 6 grams tended to produce a very high frequency of indeterminate sections, indicating suggesting that these should be taken as minimal size values for valves to be employed in seasonality studies. For larger specimens, the size of the valve under study does not seem to exert any undue influence on the coloration of the ventral margin, and is thus not likely to be a confounding variable.

Reliability

The ability to replicate results is an important consideration in any experimental technique, and two tests were conducted to determine reliability in recognizing growth coloration, the first using a non-random sample and the second a random sample. The first test involved re-examining the results for the June 1987 sample, and achieved an accuracy rate of only 63.2 percent determined by replicating the original colour designation; this is a statistically significant change in observations (see Maxwell 1989 for a detailed discussion of how reliability was measured). The second test, using a random sample of 48 specimens, yielded an accuracy rate of 77 percent, and no significant difference in observational changes. These two studies suggest that recording growth coloration can be done with an acceptable degree of accuracy; the most common change in both studies was from indeterminate to either opaque or translucent, indicating a greater familiarity with assessing sections. The June sample (non-random) was one of the first collection periods analyzed, and the low replicability of the second pass on this material is thought to demonstrate an initial lack of familiarity with assessing specimens. Results of the random sample suggest that, with practice, determining growth coloration can be achieved with an acceptable level of reliability.

Discussion

The technique of constructing a seasonal growth sequence through examination of the growth coloration of the ventral margin of marine bivalves has a number of advantages and disadvantages.

Perhaps the foremost advantage to using the growth coloration ratio technique is its inherent speed. The average amount of time needed to section a specimen ranges from 6 minutes and 40 seconds to 9 minutes and 48 seconds. The amount of time needed to assess or "read" a section ranges from 29 to 44 seconds. Thus, the technique is productive from the perspective of research time; it is possible to section fifty or more valves in one day, and to analyze three to four hundred in the same time period, allowing for the rapid analysis of large numbers of

specimens. This is essential, as large numbers of specimens are needed for modern comparative data to be reliable. The speed of this technique makes it conceivable that large numbers of specimens - in the order of thousands - can be removed from archaeological contexts and analyzed, which is essential if season of death estimates are to be of use in the understanding of midden formation or changes in seasonal occupation.

A second advantage of this technique is its reliability. While the percentage of agreement from reliability tests done on this material is not as high as one might hope (i.e.: less than 90 percent), they do suggest that the technique is reliable enough to warrant further experimentation. With practice, the researcher can become quite proficient and consistent at recognizing growth coloration. At the same time, there is a certain amount of bias inherent in the technique. There is a high degree of subjectivity in interpreting the growth coloration of a valve, with a tendency for valves to appear indeterminate on first examination and either opaque or translucent on the second examination. Although the reliability study of the random sample shows that this bias is not statistically significant, it is still worth noting. While it would be possible to measure the degree of bias imparted by the researcher, it is difficult to suggest a solution to the problem. Perhaps presenting a digital image of each specimen would be useful, although it may would be cost-prohibitive.

Another problem inherent in the technique is its destructive nature. Sectioning a shell is destructive, and while the damage is minimal in most cases, it can be problematic in others. Although some would not consider this to be important for archaeological specimens, especially in light of the number of shells typically contained in a midden, it does pose problems, as fragmentation of the shell can render it unsuitable for other types of analysis. Approximately 16 percent of the modern shells used in this study fractured in one manner or another during section preparation. One would expect that the proportion would be at least as high or higher with prehistoric shells, due to their often friable nature (Muckle 1985). This potential for destruction of materials will require large samples of archaeological shell, in order to carry out types of analysis other than season of death estimates.

The biggest disadvantage to using this technique is its inability to divide the year into short, discrete seasons. Research on the Atlantic coast has demonstrated that this technique and others similar to it typically divide the year into only two seasons, usually not of equal duration (Claassen 1989; Sanger 1989; Belcher 1989: Personal Communication). This appears to be the case on the Pacific coast as well. When all species are combined, only two seasons can be distinguished. Even *Protothaca staminea*, apparently the most seasonally-sensitive species in the study, can only be broken into three distinctive seasons. It seems unlikely that comparing ratios of translucent, opaque, and indeterminate valves will ever provide a highly sensitive means of looking at short-term seasonal change.

Estimating the Season of Collection of a Prehistoric Shell Deposit

After the growth coloration ratios have been determined for the year, the researcher can use them to make an estimate of the season of collection of prehistoric materials. Two hypothetical examples will be used to demonstrate the procedure.

For the first example, a sample of forty specimens of prehistoric *Protothaca staminea* were removed from a single depositional context of a shell midden. After sectioning, this sample yielded 12 specimens (30 percent) that died during Translucent growth, 21 specimens (52.5 percent) that died during Opaque growth, and 7 (17.5 percent) specimens that were indeterminate (Figure 13:8). The procedure is to compare these ratios with the modern data, and determine which month they most closely resemble. After comparing with the values in Figure 6, it is appears that this hypothetical collection falls somewhere in the early spring, between the months of February and April. Thus, this collection period would be suggested, with March appearing to be the most similar month.

For the second example, a collection of 31 prehistoric specimens of *Saxidomus giganteus* and 51 *Protothaca staminea* are removed from the same context of a shell midden. After sectioning, the *Saxidomus* specimens contain 8 translucent specimens, 19 opaque, and 4 indeterminate specimens; the *Protothaca* specimens contain 11 translucent, 33 opaque, and 7 indeterminate examples. Again, these values would be compared with the modern data. For all individuals combined, there are 23.2 percent translucent, 63.4 percent opaque, and 13.4 percent indeterminate specimens. By species, *Saxidomus* is 25.8 percent translucent, 61.3 percent opaque, and 22.7 percent indeterminate;

Protothaca is 21.6 percent translucent, 64.7 percent opaque, and 13.7 percent indeterminate. These are shown graphically in Figure 13:9.

The specimens can be compared both as a combined sample, or as an individual sample. Combined, these ratios do not match any collection period, and would likely be assigned to the period between March and October, due to the high proportion of opaque specimens. Treated individually, *Saxidomus giganteus* could be assigned to any month between February and September, with May through July being the most similar months. *Protothaca staminea* would appear to fall between February and November, with March being the closest match.

The technique of comparing prehistoric to modern coloration ratios is quite simple in theory, and considerably more complicated in practice. It is difficult to suggest whether it is more important to closely match translucent or opaque ratios. The ratios used in the examples do not closely match any of the modern values, likely because the modern data provided was compiled during a single year. Annual variations in growth ratios are thus not taken into account. A multi-year study would be needed to establish the range of variability to be expected during any given collection period.

It seems that *Protothaca staminea* is the species most sensitive to seasonal change, as its growth coloration patterns break the year into three distinctive seasons. It is also a productive species in terms of preparation and analysis time. *Protothaca* requires the least amount of time to analyze, and does not require significantly more time to section than any other species. Finally, *Protothaca* was easily obtained, being the only species encountered during every collection period.

Both *Macoma* and *Saxidomus* also seem to be potentially useful for season of death studies. While neither has the sensitivity to change found in *Protothaca*, it is possible that they could be used for supplemental data. *Macoma* is capable of dividing the year into two seasons, and is most abundant during the summer months. This is useful, as it is apparently during the summer that the most distinctive seasonal coloration change occurs. *Macoma* also has the advantage of being one of the easiest species to section, although conversely it is one of the more difficult species to analyze. If specimens of *Macoma* are available for study, they should be utilized; unfortunately, *Macoma* tends to be uncommon in archaeological contexts. *Saxidomus*, while much less sensitive to change than *Protothaca*, appears generally to parallel the latter's growth pattern. Thus, *Saxidomus* could be another species useful as a supplement.

Saxidomus valves tend to be slow to section, but easy to analyze. Frequently encountered in midden sites, *Saxidomus* seems another good choice for study. The other species under study are less useful. I recommend that researchers avoid both *Clinocardium nuttallii* and *Mya arenaria*. *Mya* is a poor choice, having an extremely high proportion of indeterminate specimens, and a high fracture rate during both collection and specimen preparation; only the chondrophore is commonly encountered archaeologically. *Clinocardium* is also difficult to analyze and section, due the its pronounced ridges. This is unfortunate, as large lenses of *Clinocardium* valves are an occasional occurrence in Gulf of Georgia shell middens. *Tresus capax* was not gathered in sufficient numbers to properly analyze its potential as a seasonal indicator. However, further work on this species could be worthwhile, as it is frequently found in association with burials in the Gulf of Georgia, and could potentially be used to assess the season of inhumation.

Caution should be used when only one or a limited number of species is used for making season of collection estimates of archaeological shell. If, for example, *Protothaca staminea* is chosen as the modern species to be monitored at a particular site, any estimates of season of collection will only be applicable to this species. It would be erroneous to apply seasonal data from one species to another, regardless of how similar their ecology may be. It would also be erroneous to assume that all species of shellfish were collected at the same time (and only at the same time) as littleneck.

The effects of geographic variation on seasonal growth patterns also need investigation. The PIC used in this study comes from a single locality, meaning that there is no way of determining whether the results can be applied to any other locality. What is needed is a research project that will collect specimens from several different locations - preferably all at the same time - to assess the degree of difference or similarity in seasonal growth patterning. The PIC can only be used for other regions if it can be demonstrated that there is no significant difference in the growth patterning of the region. Further, it must be remembered that only a very particular activity is being monitored through this type of study, and not the full range of cultural activities that occurred at a site. Even if the season of collection of all species of shellfish at a given site could be precisely determined, it would still be invalid to assign an estimate of the period of site utilization on the

basis of only shellfish data; other activities undoubtedly occurred on-site, and these may or may not have corresponded with periods of shellfish collection. Assigning a season of utilization to a multi-component site on the basis of an estimation of the season of shellfish collection is even more misleading; an estimate would be needed for every occupation to even have an inkling of how the site fit into the seasonal round, and how this fluctuated through time.

It may be necessary to re-examine the entire concept of seasonality with regard to shellfish. It is important to remember that while we are asking questioned based on what could be called cultural seasonality - such as a seasonal collection round - we are attempting to answer these questions through the use of data that is indicative of non-cultural seasonality. Shellfish will respond in the same fashion to ecological stimuli regardless of whether or not they are a food source to humans. Therefore, it seems logical that archaeologists content themselves with what information can actually provide about the season of their death, at least for now. Dividing the year into two unequal growth seasons may not be as satisfying as knowing the exact date of an occurrence, but it is the best we can do at present.

Requirements for Archaeological Samples: Midden Sampling

Obviously, there is no single "correct" way to sample a shell midden site, and the goals of the research design will determine how such sampling will proceed. However, if assessing shellfishing seasonality is a goal, there are certain considerations that should be kept in mind, in order to obtain samples that will be useful. The ideal situation would consist of a combination of cluster and stratified random sampling, with at least two clusters removed from each sampling strata. Cluster sampling is used because the samples comprise more than one shell, and therefore a cluster; stratified random sampling is also recommended as it will ensure coverage of all areas of the site, but will give greater emphasis to those areas of primary interest. Most excavation projects will probably not allow for the ideal situation; the following offer some guidelines for minimal recovery requirements.

First, shell samples from different areas of a midden should be retained for analysis; ideally this will allow for an understanding of intra-site variation in seasonal behavior; minimally, it will increase the chances of producing a useable sample. Samples should come from a variety of vertical locations to assess changes through time. At least two samples are required to assess variability; however, if this is not feasible, the sample studied *must* come from a single context, and *cannot* be a combination of different contexts, as combining different events to form a single sample would effectively render any analysis meaningless. The researcher must be reasonably sure that all the shells come from one depositional episode. Recognizing single depositional episodes within a midden is a thorny issue, although this has been achieved with some success (Stein 1992; Maxwell et. al. ND). The researcher must know the location of the depositional episode within the site. Three dimensional proveniencing of the shell cluster as a whole is essential, and shells of unknown provenience should never be included in a seasonality study.

Second, the nature of the deposit itself must be considered. It is essential to record whether the shells came from a feature such as a pit or burial, from primary refuse context or highly disturbed area of the site, from a homogeneous context or an isolated deposit. Consideration of where the sample originated is essential for interpretation of the seasonal estimate. Features of great interest to the project - such as burials, houses, and storage pits - should be sampled if they yield sufficient shell; they should not, however, be taken to represent the site as a whole. Burying a body is probably a much more unusual occurrence than gathering shellfish.

Finally, there must be an adequate number of shells for study, meaning *usable* shells. All samples must meet the criteria for study necessary for the analytical technique to be employed; thus, if ventral margin coloration is the technique to be used, then all the shells in the sample must have an intact ventral margin. Large column samples may allow for an easy way to collect shells for seasonality study; it is important not to combine shells from different levels of the column. If growth coloration is the analytical technique to be employed, then sample size requirements are always large, as there must be at least 40-60 readable shells in the sample; producing this sample size will require the recovery of considerably more shells. The minimum value of 40 is not arbitrary, as a sample of this size should allow for a normal distribution of sampling error (Thomas 1986). If multiple clusters can be removed from the site, then the clusters should all be approximately the same size, to avoid statistical problems.

Conclusion

At first glance, the growth coloration method appears to be straightforward and sufficiently productive to warrant routine use in the Northwest. There are at least 2 species, Butter Clam (*Saxidomus giganteus*) and Native Little Neck Clam (*Protothaca staminea*) that are both very common midden constituents, and both have some degree of sensitivity to seasonal fluctuations in environmental conditions such as water temperature. The approach requires the recognition of a discrete shell deposit within a midden, but under most circumstances this should not be beyond the capabilities of anyone with experience in shell midden archaeology. Given these factors, the question then is: why is shellfish seasonality not routinely studied in Northwest Coast archaeology? There appear to be two possible explanations, both closely related.

First, there is general dissatisfaction in all techniques for determining the seasonality of shellfish remains - particularly among the researchers studying these techniques - primarily due to the general inability of any approach to accomplish more than providing a very gross estimate of the time of year that a particular shell deposit was made. The results from the study described herein make it quite clear that dividing the year into uneven segments is probably the best we can hope for; similar results have been found elsewhere (see Claassen 1998), suggesting that this is not a regional problem. This puts the researcher in the position of having to justify (if only to themselves) investing time and money collecting large quantities of shell from a site, digging in such a manner as to allow the recognition of discrete shell deposits, and paying to have seasonality estimates done when the most likely result will tell them that collection occurred somewhere between March and December.

The second problem lies directly in the fact that the PIC, like virtually all other reported collections (Claassen 1998) covers a very short period of time: only a single calendar year. Global patterns of variation in water temperature such as *El Niño* and *La Niña* events (Rollins et. al. 1986) demonstrate that it is impossible to understand annual variation in such factors as water temperature on the basis of a single year or even several years. The only way in which to ensure that the pattern seen in the PIC is representative is to collect for many years. Finding funds and researchers to conduct such collection will not be easy, particularly with no guarantee of anything in the way of meaningful results at the conclusion. Claassen (1995, personal communication) informs me that samples taken from the same location for multiple years on the Atlantic coast show that seasonal variations in shell growth tend to average out over time. If this holds true on the Pacific coast, then the sharply demarcated winter variations noted in the PIC are very likely to blur over time, possibly resulting in two seasons of roughly equal duration, or possibly resulting in such interannual variation as to make it impossible to recognize any portion of the year.

As stated above, seasonality studies using shellfish remains still have "potential" some 30 years after they were introduced to coastal archaeology. Despite the shortcomings of the growth coloration technique and the PIC described in this study, I still feel that there is reason for both optimism and additional research. Optimism is appropriate, as the study results do suggest that it is possible to recognize the seasonality of a collection of shellfish using the growth coloration technique. Additional research is certainly appropriate if only to determine whether the patterning noted in the PIC is the result of a seasonal phenomena or is a product of sampling error, either within the collection or in the choice of years to collect. Long-term research is the only way to determine whether the growth coloration technique really works; until such research is undertaken, studying shellfishing seasonality will remain a technique with potential.