CHAPTER 5

Salmon Studies

Salmon was a key element in the Namu economy. Therefore, a study was undertaken to determine whether the salmon remains could provide any additional information concerning the nature of the salmon fishery. The initial study concentrated on variations in the size of salmon vertebrae, which would indicate changes in the average size of fish. There was visual evidence of size differences in the vertebrae from different excavation levels, which might have indicated changes in fishing techniques (e.g. from spear to net) or salmon species. Variation in salmon size also could have represented significant shifts in the contribution of salmon to the subsistence economy. Although systematic measurements did not reveal any long-term trends in salmon size, the effort to explain the observed variability in salmon size provided evidence of the probable species composition and timing of the Namu salmon fishery.

SIZE ESTIMATION

To obtain an accurate estimate of the variability in salmon size, it was necessary to obtain samples of vertebrae from discrete temporal units. The period assemblages were too large to be useful in monitoring systematic patterns of change. Therefore, arbitrary excavation levels were used as the sampling units. Arbitrary levels cannot be placed within an absolute chronometric framework, but they represent a chronological progression, and they were convenient analytical units since the initial recovery of salmon remains was by 10 cm. excavation levels and the major stratigraphic divisions within levels. The salmon vertebrae from each excavation level were considered representative of the vertebrae from an associated time period, which could be roughly scaled against the chronometric framework of the dated carbon samples. The absolute time depth represented by each level varied, but this was not important for the analysis of long-term trends.

Analysis was restricted to a single 2x2 metre excavation unit (68-70S, 4-6W) from the Rivermouth Trench; it represented a long time span and was water-screened, which allowed for the maximum recovery of salmon vertebrae. This unit yielded the largest number of vertebrae per excavation level, and the larger sample was considered more representative of the overall salmon catch for an associated time period.

The quantity of vertebrae recovered from each level ranged from less than one hundred to several thousand, but it was only necessary to measure a small sample of the recovered vertebrae. Only caudal vertebrae were used in the analysis to avoid the introduction of size variation associated with different vertebra types. Based on the number of caudal vertebrae recovered from each level, and an estimate of the coefficient of variation in vertebra diameter obtained from test samples, a sample size was chosen that would provide a mean diameter estimate that was accurate to within 5% of the true mean with a reliability of 99.7% (Yamane 1967:88). The required sample sizes for this estimate ranged to no more than 92 for any one level. The vertebrae sample was selected by using a standard two-way soil-sample splitter to repeatedly divide the vertebrae sample until a number close to the required number was obtained. In every case the actual sample size was equal to or greater than that required for the desired accuracy.

A transverse measurement to within .005 mm was made on each of the selected vertebrae, and the median vertebra width was determined for each level. The median width was converted to an estimate of median fish weight through application of a generalized regression formula for predicting fish weight from the width of Oncorhynchus sp. vertebrae (Casteel 1974:178). This generalized formula does not account for the many factors that might influence the vertebra width/fish weight relationship (e.g. slight species or population differences), but it provides a reasonably accurate scale for measuring the relative differences in fish weight between levels. Because the relationship between vertebra width and fish weight is exponential, a relatively minor difference in vertebra diameter represents a proportionately much greater difference in fish weight. The estimate of mean fish weight therefore gives a better impression of salmon size variation between levels. The median weight of salmon from each excavation level is listed in Table 17 and plotted in Figure 5.

Figure 5 shows considerable variation in the median weight of salmon from different levels, but except for a pattern of periodic rise and fall, there is little indication of any shift in size over time that might indicate a change in climate, species composition, or fishing techniques. There were significant fluctuations in fish size, but to account for these it was necessary to consider more specific and shorter-term causal factors.

AGE AND GROWTH STUDY

Having determined that there were fluctuations in the average weight of salmon from different excavation levels, the next step was to determine the specific causes of this variation. Any number of factors might have been responsible, but the first and most obvious possibility was that the variation in weight was due to variation in the ages of the salmon. Salmon spawn at different ages within and between species, and the weight of a spawning salmon is directly related to its age (Henry 1954:18-21). If the age structure of the Namu salmon was consistent over time, then some outside factor (i.e. some feature of the environment) would have to have been responsible for variation in salmon growth rates. It was therefore necessary to estimate the average age of salmon from each excavation level and compare the age and weight estimates.

The counting of annuli (annual growth rings) on scales is a standard method for determining the age of fish. The technique has been applied in a large number of studies of contemporary salmon populations. Fish are also aged by growth rings visible on otoliths and vertebrae (see Chugunova 1963; Casteel 1976). For the present study only vertebra centra were available, but the annuli on salmon vertebrae are not clearly visible unless the vertebra is sectioned or specially treated. It was not practical to apply these methods to obtain an accurate reading of several hundred vertebrae, so an experimental study was undertaken to view growth rings through radiographic analysis (Cannon 1988).

The portable x-ray unit (Fischer model FP200) at the Department of Archaeology, Simon Fraser University was used for this purpose. A number of power, distance, and exposure time combinations were tried, but the best results were obtained with a radiographic output setting of 70 KVP at 20 MA for a 0.5 second exposure, with the vertebrae set directly on the x-ray film plate at a distance of 64 mm. from the x-ray tube. The developed plates showed that each vertebra displayed a number of clear, bright concentric rings interspersed with wider dark bands (Fig. 6). The narrow bright bands were interpreted as winter growth in contrast to the wider, dark summer-growth bands. The denser winter slow-growth rings were more radiopaque than the broader less-dense summer bands.

From the radiographs it was relatively easy to count the winter growth rings to determine the age of the fish. However, because the method was new and experimental it was necessary to conduct a number of test studies to determine whether the radiographically visible rings were seasonal growth annuli. A number of specific tests and evaluations were conducted toward this end. The first was a comparison with written descriptions of growth annuli (Chugunova 1963; Casteel 1976:78-83); these described structures that were very similar to the radiographically-visible rings.

Table 17. Median Estimated Fish Weight (kg.) and Age Profile of Salmon for 10 cm. Excavation Levels (in cm. Depth Below Surface (DBS)) of Unit 68-70S,4-6W (weight estimate based on Casteel 1974).

Level (cm. DBS)	Sample Size	Median Weight	Age Profile (% per Age Category)		
			1 winter	2 winters	3 winters
40 - 50	2	-	0	100	0
	36	5.87	5.5	86.1	8.3
	32	5.41	0	84.4	15.6
	23	5.20	0	87.0	13.0
	52	4.625	6.3	89.6	4.2
90 - 100	30	3.925	10.0	83.8	6.7
	41	4.89	2.4	92.7	4.9
	32	5.725	3.1	87.5	9.4
	68	4.625	1.5	97.1	1.5
	68	3.89	0	98.5	1.5
140 - 150	95	3.32	3.2	86.3	10.5
	92	3.69	1.1	81.5	17.3
	97	3.95	3.1	85.6	11.3
	89	5.61	1.1	88.8	10.1
	92	5.655	0	90.5	9.5
190 - 200	85	6.22	1.1	86.3	12.7
	92	4.66	3.3	96.7	0
	80	4.02	0	91.5	8.5
	80	4.97	2.5	92.5	5.0
	106	5.01	2.8	85.8	11.3
240 - 250	65	5.61	0	87.7	12.4
	72	4.515	0	90.3	9.7
	78	3.79	6.4	88.5	5.1
	94	2.75	7.5	90.3	2.2
	80	3.08	1.1	92.4	6.5
290 - 300	62	3.56	1.6	95.2	3.2
	47	3.32	4.8	83.3	11.9
	68	3.56	0	100	0
	15	3.32	0	100	0
	1	-	0	100	0
340 - 350	1	-	0	100	0

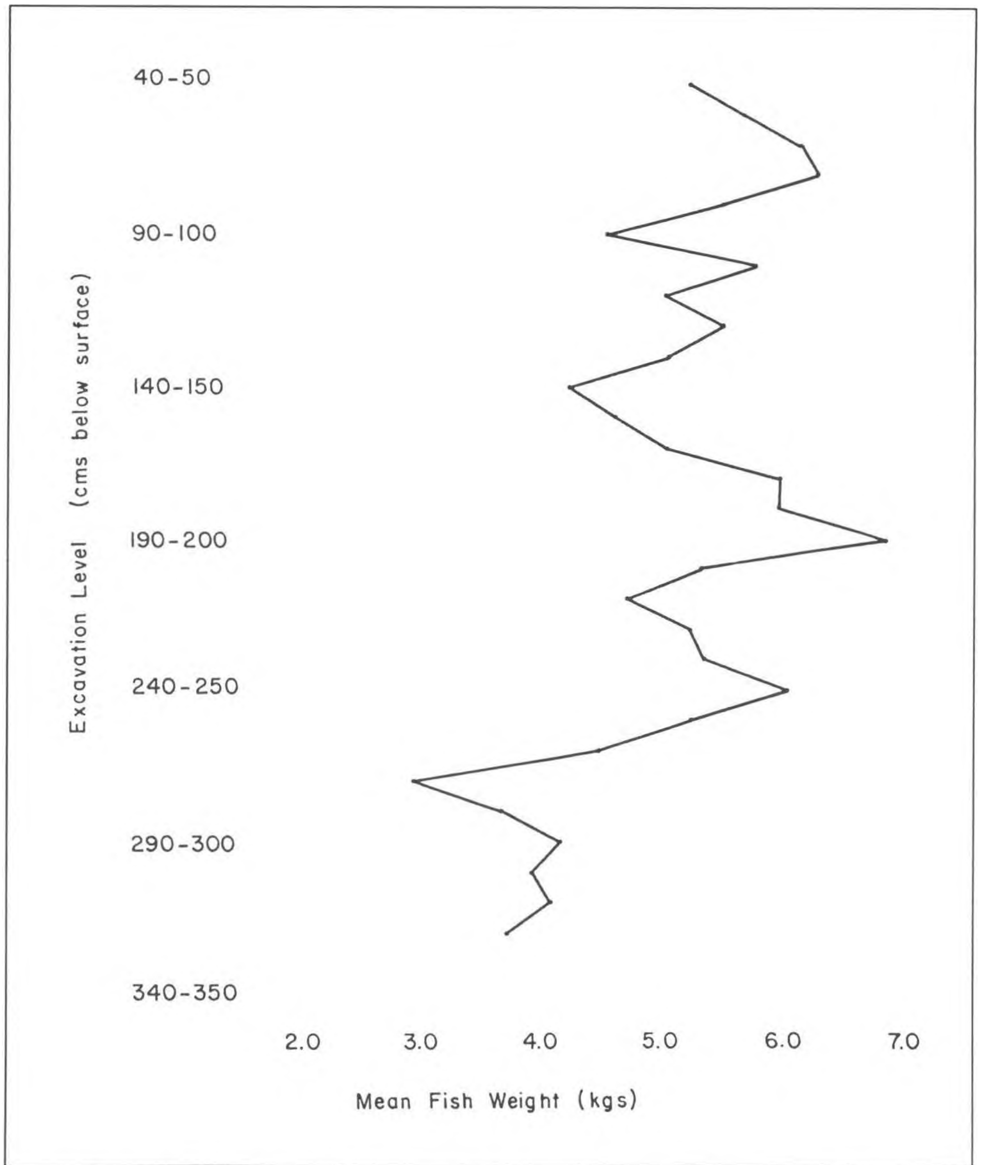

Figure 5. Variation in Median Salmon Weight by Excavation Level.

A number of comparative specimens of different salmon species were examined with the radiographic method; these included: 1) a specimen of chum salmon *(O. keta)*, which exhibited two winter-growth rings; 2) a specimen of pink salmon *(O. gorbuscha)*, which exhibited one winter-growth ring; and 3) a specimen of chinook salmon *(O. tschawytscha)*, which exhibited five winter rings. Each of these age determinations fell within the normal age range for mature individuals of these species. As a further test, two other specimens of chum salmon (*O. keta)* were aged by examining the winter growth checks on their scales. In both cases later radiographic age determination of the vertebrae agreed with the age estimate obtained from the majority of the readings from six different scales.

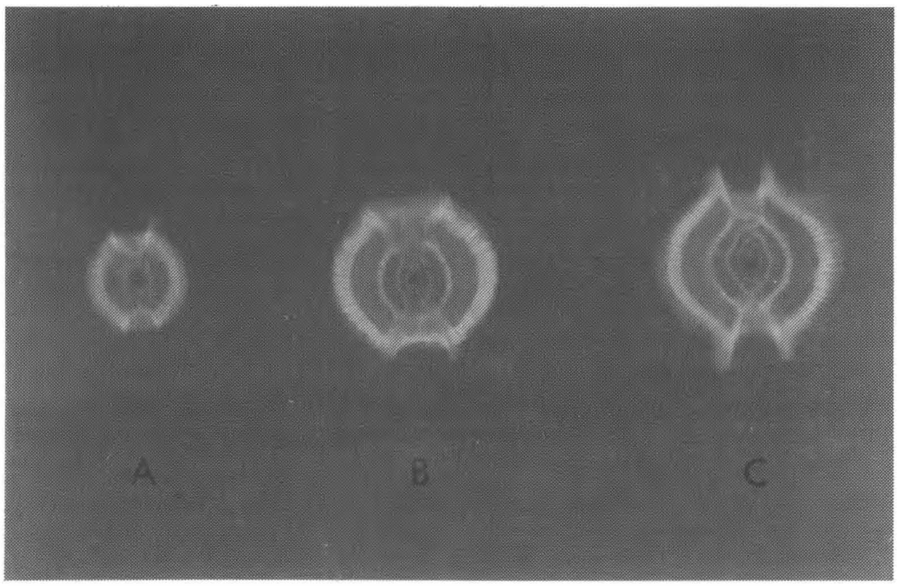

Figure 6. Radiograph of *Oncorhynchus sp.* Vertebrae Exhibiting: A - One Winter's Growth; B - Two Winter's Growth; C - Three Winter's Growth.

A final evaluation of the radiographically visible rings followed Chugunova's (1963:24) recommendation to estimate fish weight from the width of the first complete annulus. The generalized Oncorhynchus sp. vertebral width/fish weight regression formula (Casteel 1974:178) was used to convert the first annulus diameter to an estimate of fish weight. These weights were in complete agreement with observed average weights of Central Coast chum salmon at the end of their first winter's growth (Ricker 1964:917).

Although the radiographic method worked very well for salmon species, it was not at all successful when applied to other species of marine fish. Specimens of Gadidae (cod), Pleuronectidae (flatfish), Hexagrammidae (greenling), and *Sebastes sp.* (rockfish) were radiographically examined, but it was not possible to discern contrasting bands comparable to those visible in salmon. Without more detailed physical and chemical analysis it is impossible to determine why the method apparently only works for species of Oncorhynchus. It is possible that differences in bone density between salmon and other fish might in some way be responsible, but in the absence of further investigation this is only speculation.

Once it was determined that the rings visible on the Namu salmon radiographs were annual growth rings, the entire sampled and measured collection was radiographically examined. The winter-growth rings visible on each vertebra centrum were counted, and the age composition of each sample was determined. All of the Namu specimens were either two, three, or four years old. The percentages of age groups by excavation level are presented in Table 17. The majority of salmon were three years old, but the percentages of two and four year old salmon are more significant for explaining the observed variability in fish size. The variation in median salmon weight is clearly a function of the age composition of the sample. If there is a high percentage of two-year-old salmon and/or a low percentage of four-year-old salmon, then the median weight is low. If there is a low percentage of two-year-old salmon and/or a high percentage of four-year-old salmon, then the median weight is high. The strong association between the radiographically-determined age structure and the median weight estimates adds further credence to the interpretation of the rings as growth annuli.

SPECIES AND SEASONALITY

Based on the age composition of the recovered salmon, and data concerning the age at which different species of salmon mature and spawn, it is possible to determine the probable species composition and season of the Namu salmon fishery. The high percentage of salmon that exhibit two winter's growth were likely coho *(O. kisutch)*. At present, 95% of British Columbian coho salmon spawn at three years of age (i.e. after one winter of freshwater life and 1 winter of marine life) (Godfrey 1965:7). Coho are the most widespread of Pacific salmon in British Columbia, and they are common in small coastal streams like the Namu River (Aro and Shepard 1967:261).

Other species of Pacific salmon spawn at ages that do not closely match the Namu salmon age profile. Pink salmon *(O. gorbuscha)* almost invariably mature and spawn at two years of age (i.e. after one winter's growth period) (Hunter 1959:837; Hart 1973:110). The very small number of two-year-old salmon in the Namu midden indicates that very few pink salmon are represented. Sockeye salmon *(O. nerka)* normally spawn at four or five years of age (three or four winters' growth). The majority of sockeye spawn in only a few major river systems (Aro and Shepard 1967:232, 239); it is unlikely that they would be present in the Namu assemblage in appreciable numbers. Chinook salmon *(O. tschawytscha)* also tend to spawn in major rivers; they mature late in life, and normally spawn at between three and eight years (two - seven winters). The majority mature in their fourth or fifth years (Hart 1973:125). The absence of any salmon older than four years in the Namu midden means it is unlikely that chinook are present. At present chinook salmon are extremely rare in the small streams of the Central Coast region (Rohner 1967:45; Pomeroy 1980:175).

Chum salmon *(O. keta)* are a more likely component of the Namu salmon fishery. Although the majority of chum in contemporary populations mature and spawn at four years of age (Henry 1954:7-10; Hunter 1959:838), substantial numbers spawn at age three. Chum can mature at ages varying from two to seven years, but the numbers that mature at less than three or more than five years are insignificant (Neave et al. 1976:31). If chum salmon were exploited at Namu, there remains a serious problem in explaining the relative lack of four-year-old individuals among the salmon remains. This age group should have been a dominant portion of a normal chum spawning population. Nevertheless, there are good reasons for considering the possibility that chum salmon contributed to some portion of the Namu salmon fishery.

The Bella Bella area is currently the largest producer of chum salmon in northern British Columbia (Aro and Shepard 1967:286), and chum salmon commonly spawn in small coastal streams such as the Namu River. The potential for chum in the Namu collection is also given weight by ethnographic evidence that suggests a cultural preference for chum salmon. Chum salmon smoke well and are prized by contemporary Native fishermen for this reason (Hart 1973:114). In the past chum salmon were even more significant because they are the least fat of Pacific salmon species, and when dried for winter storage they last for the longest time without spoiling (see Romanoff (1985:154) for numerous ethnographic references concerning this point). Other species of salmon were more likely to be eaten fresh. Cultural preference and presumed availability argue in favour of the exploitation of significant numbers of chum salmon at Namu, and there should be evidence of this in the recovered salmon remains. In contrast, the absence of chinook and sockeye salmon at Namu is not difficult to explain; their spawning populations have a restricted distribution and they commonly spawn during the summer months, when Namu may have been unoccupied (see Chapter 6).

It is more difficult to explain the relative absence of pink and four-year-old chum salmon. Initial consideration was given to the possibility of systematic error in age determinations based on the experimental technique of radiographic analysis. Although tests confirmed that the radiographically-visible rings were annuli, it was still possible that systematic errors in counting the annuli resulted in either over-representation or under-representation of the number of fish in particular age categories. It is extremely unlikely that the number of annuli was overestimated, since in all but a few cases at least two bright winter-rings were clearly visible. Therefore, the low representation of pink salmon is not a function of observation errors. The distribution of pink salmon spawning populations is more restricted than that of chum and coho, though not as restricted as the distribution of sockeye or chinook. Pink salmon also run earlier in the year than chum or coho. The timing and restricted distribution of pink salmon may have been partly responsible for their under-representation in the Namu fishery.

There was a greater possibility of under-representing four-year-old chum through consistent under-counting of annuli. It was often difficult to determine the first true annulus. Many vertebrae counted as three years old had a very narrow and often irregular bright ring well inside the first counted annulus. If this inside ring was a true annulus then a much greater proportion of fish would have been four years old. This possibility was considered in the course of analysis.

Examinations of fish-scale annuli have shown the common presence of a juvenile ring not far from the focus, but well inside the first annual zone. This is often confused with the first annulus (Chugunova 1963:23-24). Juvenile rings often could be distinguished on the radiographs because they were narrow, irregular, and sometimes discontinuous. Following Chugunova (1963:24), a further check was made by estimating the weight of the salmon from the width of the suspected juvenile ring. In each of the test cases the estimated weight was far below the normal weight at the time of the first annulus formation. Weights estimated on the basis of the first clear annulus corresponded closely with the weight expected by the end of the first winter's growth. It is unlikely that the first annulus was mistaken for a juvenile ring in any appreciable number of cases, and as analysis progressed it became easier to distinguish between the juvenile ring and the first annulus. The correspondence with age determinations from scale readings and the consistency of counts from unintentional repeat readings of samples provided further support for the accuracy of annuli counts.

The discrepancy between the proportion of three-year-old fish in the Namu assemblage and the normal age composition of contemporary chum spawning runs could mean that: 1) the majority of the fish were coho, and only a small number were pink or chum; or 2) environmental or biological factors in the past restricted the number of four-year-old chum in the spawning population; or 3) there was a cultural selection factor that prevented inclusion of four-year-old chum salmon, either because they were not caught or because their remains were not preserved. The most parsimonious explanation is to assume that the majority of the Namu salmon were coho and that other species were simply not fished in appreciable quantities. However, chum should have been available, and the small but significant percentage of four-year-old salmon in the assemblage indicates that they were caught in limited quantities. Although pinks are less widely distributed, they also should have been more strongly represented in the Namu fishery.

There are alternative explanations for the Namu salmon age profile, but most are more complex than one that assumes predominance of coho. The proportion of three-year-old chum in contemporary spawning populations varies, and the possibility of long-term change in the normal age-profile was considered as a potential explanation for the Namu findings. Researchers have noted a tendency for a north-to-south gradient in the age of chum salmon, with younger fish occurring in greater percentages in the south, but this gradient does not hold for every locality, and three-year-old fish remain a minority in every location (Henry 1954:24). Although there is considerable annual variation in the proportion of three-year-old chum in the spawning population at a single locality (Henry 1954:9), four-year-old fish almost always predominate. The reasons for variation in age composition are unknown, but there is nothing in contemporary observations that would suggest environmental or biological reasons for the long and consistent lack of four-year-old chum salmon in the Namu population. Cultural factors remain as the only probable explanation.

If the past spawning population of Namu chum salmon contained a large proportion of four-year-old fish, then there are few probable causes that would account for their absence from the midden deposits. It is unlikely that there was a deliberate selection of three-year-old salmon from among the entire spawning run. Four-year-old chum are larger and represent a food resource that would not have been ignored had it been available to the Native population. Salmon fishing techniques also would not select against larger fish. Therefore, either the prehistoric residents were unable to catch four-year-old fish or the older and larger fish were prepared in a way that destroyed their vertebrae.

An explanation based on differential preservation requires that one method have been used for the preparation of pink and older chum salmon, while a second method, which did not involve destruction or loss of vertebrae, was used for the preparation of smaller chum and coho. Scattered ethnographic information does indicate differential treatment of the higher-fat-content backbone of salmon (Romanoff 1985:154). The Kwakiutl sometimes consumed the backbone immediately rather than preserve it (Boas (1921) cited in Romanoff (1985)). Therefore, preservation of larger, older chum and fatter pink salmon may have involved removal of the high-fat backbone, while this was unnecessary for the preservation of smaller chum, but there is no specific ethnographic record of such a practice. Without detailed comparison of the fat content and preservation qualities of pink salmon and different age and size categories of chum salmon, it is impossible to evaluate the likelihood that different preparation techniques were responsible for the age composition of the Namu salmon remains.

The more likely explanation is that pink and four-year-old chum salmon were unavailable because the site was unoccupied at the time these fish entered the river to spawn. In a long-term study of salmon spawning in Hooknose Creek, a nearby coastal stream, which is very similar to the Namu River, it was observed that pink salmon were the earliest to spawn, followed by older chum, and finally younger chum salmon (Hunter 1959:837,849). In the Bella Bella region, most pinks presently spawn in September, chum follow in September and October, and coho, the latest-spawning Pacific species, reach their peak spawning in October (Aro and Shepard 1967:282,286,289).

If the Namu residents consistently arrived at the site late in the salmon fishing season they only would have had the younger chum and coho available to them in large numbers. Late arrival also would account for the general lack of pink salmon in the midden. Any fluctuation in the arrival time of either the residents or the salmon would increase or decrease the relative proportion of two-year-old (pink) salmon and four-year-old (older chum) salmon in the assemblage. It is possible that the seasonal round of subsistence activities placed the Native population at other locations up until the latter part of the chum salmon run. Better fishing for pink salmon at other locations would be sufficient reason to delay arrival at Namu.

A variety of seasonal indicators show that the site was consistently occupied from early autumn through spring (see Chapter 6); it is likely that Namu was occupied autumn, winter, and spring throughout the period from 7000 to 1800 cal. B.P. The seasonal interpretation of the salmon age profile ties the autumn arrival to a very precise date in late September or early October. This pattern shows remarkable consistency over the economic prehistory of Namu. It extends from before the establishment of peak salmon productivity (prior to 6000 cal B.P.) to well after the peak in local productivity between 6000 and 4000 cal. B.P.

The age and growth study of salmon vertebrae gives a reasonably precise reckoning of the species composition of the Namu salmon fishery, and it provides a good indication of the probable timing of site occupation. The presence of chum and/or coho salmon indicates an autumn presence at the site, and if the recovered remains are representative of the salmon that were caught, then the more precise indication is of consistent arrival at the site sometime in late September or early October. The problem with seasonal indicators is that they only indicate the seasons of definite site occupation. Inferences of seasonal absence must be based on negative evidence such as the lack of pink salmon and four-year-old chum salmon. As is discussed in the following chapter, these are problems that are common to all seasonal inferences from faunal remains.