Canadian Zooarchaeology

Zooarchéologie canadienne

Number/Numéro 25
2008

CANADIAN ZOOARCHAEOLOGY
ZOOARCHÉOLOGIE CANADIENNE

2008
Number/Numéro 25

anthropology.uvic.ca/canadianzooarchaeology.php

Editors

Kathlyn Stewart kstewart@mus-nature.ca	Canadian Museum of Nature P O Box 3443 STN D Ottawa, Ontario K1P 6P4
Yin Lam ymlam@uvic.ca *Rebecca Wigen* rjwigen@uvic.ca	Department of Anthropology University of Victoria P O Box 3050 STN CSC Victoria, British Columbia V8W 3P5

Editorial Assistant	*Ila Willerton*
Translation of Abstracts	*Ariane Burke*

Cover Photo

Side view of the jaw (height: 24 mm), also referred to as "Aristotle's lantern," of a Pacific purple sea urchin (*Strongylocentrotus fransiscanus* (Agassiz, 1863)) of 127 mm diameter, collected from near Nanaimo, BC. Photo: Greg Campbell.

Published by the University of Victoria

Canadian Zooarchaeology
Zooarchéologie canadienne

2008 Number/Numéro 25

Table of Contents/ Table des matières

Article

Article

A Revised Assessment of Late Period (AD 1 - European Contact) Fisheries at Namu, British Columbia

Aubrey Cannon and Nadia Densmore

Department of Anthropology, McMaster University, 1280 Main Street West, Hamilton, ON L8S 4L9, cannona@mcmaster.ca, densmone@mcmaster.ca

ABSTRACT

Analysis of fish remains from the 1970 University of Colorado excavations at Namu, British Columbia, is the basis for a revised assessment of patterns and trends in the site fisheries over the past 2000 years. The results are consistent with overall patterns at the site but show a previously unrecognized trend of early decline and later recovery of the salmon fishery. They also show a period of overall diversification of the fishery when numbers of salmon were at their lowest levels and confirm the use of ratfish as a marginal food resource in times of salmon shortage.

RÉSUMÉ

L'analyse des restes de poisson provenant de la fouille du site de Namu (Colombie-Britannique) menée en 1970 par l'université du Colorado mène à une révision des modèles d'exploitation de l'industrie de la pêche au cours des derniers 2000 ans. Les résultats de l'analyse de ce site sont consistants avec les modèles généraux mais démontrent aussi une tendance, jusqu'alors insoupçonnée, de déclin et puis de renouveau des pêcheries de saumon. Ils démontrent aussi une période de diversification générale des pêcheries quand la population de saumon est en baise, et confirment l'utilisation de la chimère d'Amérique comme ressource comestible bien que marginale en temps de pénurie.

CANADIAN ZOOARCHAEOLOGY/ZOOARCHÉOLOGIE CANADIENNE
NUMBER/NUMÉRO 25 (2008), 3-13.

The faunal remains from the site of Namu, located within traditional Heiltsuk territory on the central coast of British Columbia (Figure 1), have been well published (Cannon 1991, Conover 1978), and the data have provided the basis for wide-ranging interpretations of economic and ecological trends over the course of the last 7000 years of the site's 11,000 year occupation span. Although no faunal remains are preserved in the earlier deposits dating to 9000-5000 BC, grouping of later deposits and their contents by time period (Carlson 1991, 1996) enabled the identification of major faunal trends over the period from 5000 BC to the time of European contact.

Figure 1: Location of Namu on the Central Coast of British Columbia.

The vertebrate faunal remains recovered during the Simon Fraser University field school excavations conducted by Roy L. Carlson in 1977-78 were identified and reported by Cannon (1991). The mammalian remains recovered from University of Colorado excavations in 1968-70 were identified by Charles Repenning of the US Geological Survey and the avian remains were identified by Howard Savage of the Royal Ontario Museum. These data were reported by Conover (1978). The fish remains from the University of Colorado excavations were reportedly analysed, but the results were never published.

We present the first published account of the fish fauna from the 1970 excavations based on stratigraphically recovered fauna from a single 2x4 m excavation unit, FS 10, described as the Front Trench (Luebbers 1978:20-24) (Figure 2). The significance of these remains is that they represent a part of the site near the foreshore margin of the midden that was not excavated by Simon Fraser University (SFU) in 1977-78. This area contains a 6 m deep midden deposit, which accumulated during a span of ca. 2000 years before European contact.

Although Cannon (1991) defined the focus of faunal resource use for Period 6 for its entire span from AD 1 to European contact, this was based on a much smaller assemblage than was available for earlier periods. Deposits from the last ca. 2000 years of the Namu site occupation, which were very poorly represented in the areas excavated in 1977-78, produced only 567 identified fish remains, compared to totals ranging from 6,417 to 60,882 for earlier periods. Given the small volume, scattered distribution, and relative lack of secure dating of these deposits in the areas excavated by SFU, it was impossible to know if the recovered fauna were representative of the entire span of this last period of pre-European site occupation.

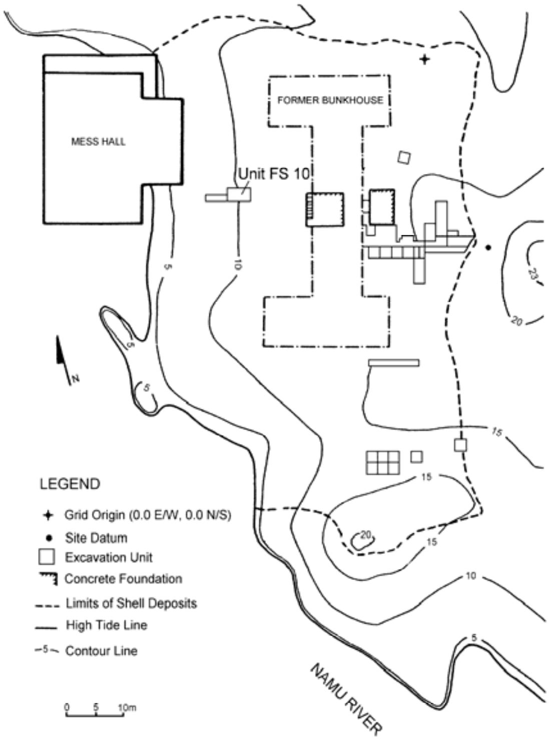

Figure 2: Location of Excavation Unit FS 10.

The identified fish remains from the Period 6 deposits in Unit FS 10 bring the total from that period to 12,214. With these new data we can establish the nature of the later fisheries with much greater clarity and certainty. The data fill in a missing piece in the otherwise extensively reported Namu faunal assemblage. The last phase of pre-contact occupation, after ca. AD 1000, was also described as a period of distinct changes in the nature of the midden and its contents. Deposits dating to this period were characterized by a distinctive pattern of discrete unmixed shell lenses, series of thin horizontal strata, hearth features, and an overall decline in artifacts and mammalian faunal remains (Conover 1978:98). Data on the fish remains provide a further basis for determining whether these characteristics represent a change in the overall pattern of site use or are more a function of site formation and the relatively short time depth of the most recent deposits.

Excavation, Recovery and Identification

Luebbers (1978:22) describes the excavation of the deep FS 10 trench, which attempted to follow major stratigraphic divisions as these were observed in the course of excavation. There was close but not perfect correspondence between strata observed in the field (FS 10.1-17) and those assigned to the deposits on the basis of profile and column sample analysis after the excavation (FSC 1-15) (Figure 3).

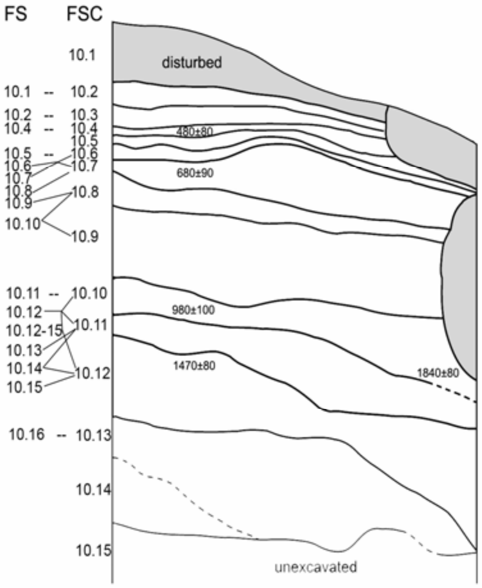

Figure 3: Stratigraphic Profile of Unit FS 10 (after Luebbers 1978:24).

The layers shown in Figure 3 are those assigned following the excavation. The faunal samples are provenienced according to Field Strata 1-16. The correspondence, derived from Luebbers's (1978:20) Figure 14, between the field strata designations and the layers defined after the excavations is shown in the right hand column on Figure 3 and in the second column in Table 1. The lack of one to one correspondence between the strata designations is somewhat confusing, but we use the field proveniences of the fauna in our analyses and subsequent discussions. Their rough correspondence with the stratigraphic divisions assigned later provides an adequate coarse-grained temporal sequence for the interpretation of faunal trends over the last 2000 years.

The entire excavated matrix was screened by water under pressure directed through two screens. The finest mesh was 2 mm. Although this screen should have retained a large quantity of herring bones, it is clear that these were not recovered in representative numbers. Auger sampling undertaken in 1994 (Cannon 2000) showed that herring were numerous in all areas of the Namu midden (Table 2). A combination of insufficient time for the recovery of these numerous small remains, poor visibility among the large quantities of fine shell fragments, and destruction and loss of small bones because of the strong water pressure was likely responsible for the poor recovery of herring. We could also expect these factors to have affected recovery of the small bones of other fish, such as greenling. As similar considerations affected the field recovery of fish bones in 1977-78, we can only assume that the recovery of fish remains was comparable to that from the water-screened portions of the SFU excavations.

We gained access to the FS 10 fish fauna collection fortuitously. It was among other materials from the University of Colorado excavations that had been sent to be archived at the Department of Archaeology at SFU, and were included in a shipment of Namu fauna from SFU to McMaster University. The remains were still in their original field collection bags with the provenience information written on the outside. Not all of the strata recorded for Unit FS 10 were represented among the bags of fish remains. There were no bags for Field Strata 3, 8, 12, or 17, and we presume that either these have gone missing in the years since 1970 or materials assigned to these strata were incorporated into contiguous assemblages. Field Strata 3 and 8 appear to have been very thin and only tentatively identified. Field Stratum 3 did not produce any mammalian faunal remains (Hester and Nelson 1978:124). Field Strata 8 and 12 did produce substantial mammalian assemblages, and presumably fish as well, but these were not available for study and are presumed lost. Field Stratum 17 is not listed in the analysis of mammal remains, and it is likely that materials from this layer were incorporated into those collected as part of Field Stratum 16.

Stratigraphic control in the recovery of fauna appears to have been reasonably well maintained, but the lack of complete correspondence between field and assigned stratigraphic designations means that there is considerable temporal overlap among some of the individual faunal assemblages. The difficulty in assigning materials to individual strata was also clearly recognized in the field, since one bag included material from Strata 12-15. Layers below Field Stratum 17 were not excavated due to the presence of groundwater (Luebbers 1978:30). Stratum 1 deposits reportedly contained materials dating from the early 20th century, but we include the fish from this stratum in our totals for Period 6.

Luebbers provides a total of five radiocarbon dates from the Front Trench. The earliest is 1840±80 radiocarbon years bp for Field Stratum 11, but this overlies Assigned Stratum 12 from which a column sample yielded a date of 1470±80 rybp. Luebbers (1978:62-64) was unable to account for this discrepancy, but suggested stratigraphic mixing in the excavation. He suggested the later date could apply to Field Stratum 10 and the earlier date to Field Stratum 12, although a two sigma calibration of the two dates brings them to within thirty years of one another at around AD 400. These and the other dates from this unit (Figure 3) have been used to suggest more or less continuous deposition in this area of the site from ca. 2000 years ago up until the time of European contact. Although there are no dates from the lowest stratum in Unit FS 10, Luebbers (1978:30) noted the overlap in dates between the upper layers at the rear of the site and the lower layers in FS 10 at around 1900 rybp and noted their similarities in texture, content, and morphology. Our attribution of all the material from this unit to the last 2000 years of site occupation is based on the observations of Luebbers, but we acknowledge the possibility that material from the earliest excavated layer, Field Stratum 16, may date somewhat earlier than this.

Nadia Densmore identified the FS 10 fish remains under the supervision of Aubrey Cannon, using the comparative collection of the McMaster University Fisheries Archaeology Research Centre. The comparative collection is equal in breadth to the collection used by Cannon in 1977-78 in the identification of the fauna from the SFU excavations. As in the earlier analysis, the identifications in Table 1 are reported at the family level for the cods (Gadidae), flatfish (Pleuronectidae), greenlings (Hexagrammidae), skates (Rajidae), and sculpins (Cottidae); the genus level for salmon (*Oncorhynchus*) and rockfish (*Sebastes*); and the species level for ratfish (*Hydrolagus colliei*), dogfish (*Squalus acanthias*), herring (*Clupea harengus pallasii*), and sablefish (*Anoplopoma fimbria*). Other clearly identifiable species were observed within families (e.g. occasional halibut among the Pleuronectidae and lingcod among the Hexagrammidae), but no systematic effort was made to identify species of flatfish, cod, or greenling. The level of identifications reported in Table 1 are the same as those reported by Cannon (1991). Table 1 also shows a category of potentially identifiable but unidentified elements. In most cases these are small fragments of elements, for which taxonomic identification was uncertain or which were eroded or otherwise difficult to identify to element. In a small number of cases these are clearly identifiable elements of taxa that were not available in the comparative collection. Again, we report this category to remain consistent with Cannon’s (1991) original report.

Field Stratum	Defined Stratum	Rajidae	*Squalus acanthias*	*Hydrolagus colliei*	*Clupea harengus pallasii*	*Oncohynchus*	Gadidae	*Sebastes*	*Anoplopoma fimbria*	Hexagrammidae	Cottidae	Pleuronectidae	Non-id
10.1	10.2	0	28	20	0	930 (77.37)	72	78	8	61	0	5	140
10.2	10.3	1	18	0	7	749 (80.19)	39	62	21	31	0	6	79
10.4	10.4	0	7	5	1	695 (92.54)	7	11	13	9	0	3	37
10.5	10.6	0	2	2	0	483 (97.38)	3	5	0	1	0	0	9
10.6	10.6-7	0	1	12	0	739 (95.60)	10	5	0	3	0	3	15
10.7	10.6-7	1	4	16	0	1659 (97.30)	7	5	10	3	0	0	26
10.9	10.8	0	4	68	7	369 (75.15)	9	15	3	13	0	3	31
10.10	10.8-9	0	1	2	0	256 (54.93)	4	192	1	7	0	3	15
10.11	10.10	0	72	173	26	1653 (67.28)	269	5	80	160	0	19	344
10.12-15	10.10-12	0	1	7	0	181 (88.29)	8	5	0	1	0	2	4
10.13	10.11	1	7	40	0	1444 (86.42)	18	128	3	22	0	8	121
10.14	10.11-12	0	3	8	0	258 (88.97)	2	13	2	3	0	1	12
10.15	10.12	0	0	2	0	82 (92.13)	3	1	0	1	0	0	95
10.16	10.13	0	0	0	0	116 (100.0)	0	0	0	0	0	0	0

Table 1: Representation of identified fish taxa in excavation Unit FS 10 by stratum (values are NISP, except for *Oncorhynchus*, which includes NISP and the percentage of all identified fish specimens).

Site Area	Years Excavated	Auger Samples[1]	Sample Volume (l)	Herring NISP	NISP/Litre
Rivermouth	1978, 1994	C, D, E, F	32.0	1331	41.6
Central	1968-70, 1977	G, H	11.5	298	25.9
Front	1970	I, J	19.2	769	40.0

[1] See Cannon (2000: Figure 2) for locations of excavation units and auger samples.

Table 2: Frequency and density of herring remains in auger samples collected in 1994 from locations adjacent to areas of excavation at Namu.

Our objective is to supplement, for comparative purposes, the data relating to the latest period of site occupation. We concluded there was little value in achieving a finer level of identification and reporting for this latest period without undertaking a similar level of analysis and reporting for the entire 1977-78 fish fauna. Although potentially interesting, even in isolation, finer resolution in fish identification for this one unit did not warrant the extra investment of time and expense.

Interpretations

Stratigraphic Variability within Unit FS 10

We took advantage of the stratigraphic resolution and associated dates available for the Front Trench to look at the potential for variation and trends within the fishing economy over the past 2000 years. Accepting the potential for errors in the assignment of fauna to particular strata and taking into account the issue of the inverted dates for Field Strata 11 and 15, the overall patterns seem quite clear. Generally, the fauna from each stratum are consistent with respect to the main emphases of the site fisheries. Salmon predominate in all strata, but vary between 55 and 100% of the fish remains. The general pattern through time suggests that the decline of the salmon fishery, which began ca. 2000 BC and is attributed to periodic failure of the pink salmon fishery (Cannon and Yang 2006), continued through the first 1000 years of Period 6, following which the proportions of salmon rebounded to levels (92-97%) comparable to those observed in Periods 3 and 4 (97%). Further ancient DNA analysis is now underway to determine if this recovery in the salmon fishery is attributable specifically to the recovery of the pink salmon fishery. If so, further dating will be undertaken to refine the temporal resolution of the disruption and apparent recovery of the fishery.

The early strata in Unit FS 10 that show relatively low numbers of salmon remains also show relatively high numbers of ratfish. The clear inverse relationship between salmon and ratfish in this unit mirrors that documented in other parts of the site, and adds support to the conclusion that increased use of this marginal fish resource represents an effort to compensate for failures of the staple salmon fishery (Cannon 1995). A range of other fish are also abundant in strata lacking in salmon (see below), but the low food value of ratfish and its proportionately greater abundance in all deposits that lack salmon is the basis for describing this particular species as a marginal resource of last resort. Evidently, it was only appreciably valued at times when there was a need to compensate for a shortage of salmon.

The results of auger sampling in 1994 from the vicinity of the Front Trench show that small fish remains such as herring, greenling, and anchovy are under-represented in the fish recovered from the 1970 excavation (Cannon 2000). This is especially the case for herring (Table 2). Analysis of bulk samples in 1978 showed that this pattern of biased recovery against the bones of small fish occurred during the 1977-78 excavation (Fawcett 1991).

Within the framework of faunal recovery in 1970 and 1977-78, and apart from the major fluctuation in the numbers of salmon and ratfish over time, the fish from Unit FS 10 show remarkable consistency both between strata and overall, in relation to the fish recovered from other parts of the site. The one major exception is Field Stratum 11, dated to ca. AD 500-1000, which contained an exceptionally large number of cod, sablefish, greenling, and rockfish bones in addition to the large number of ratfish. In some respects, this diversity is a continuation of a pattern evident in Period 5 deposits, when salmon begin to show an overall decline, though this is difficult to verify on the basis of percentage figures given that the percentage representation of other fish would necessarily increase as the percentage of salmon declined. What is unusual about the Stratum FS 10.11 fish remains is the very large numbers of fish other than salmon and the completely unprecedented numbers of sablefish, which is never more than an occasionally occurring species at any other time. This stratum also contained an unusually large number of unidentified fish remains, which is probably a further indication of species diversity.

If the fish remains in Field Stratum 11 represent diversification of the fishing economy in response to failures in the salmon fishery, it is difficult to understand why the pattern was not sustained in subsequent periods when numbers of salmon remained relatively low. It may have been the observation of fish bones from this stratum that led Hester (1978:102) to suggest that this period saw the peak in the local fishing economy. We can only speculate that the diversity of fish from this stratum represents a short-lived response to periodic salmon failure, perhaps its worst period, but apparently this diversification of fishing was not sustained over the long term.

A Revised Assessment of the Period 6 Fisheries

Table 3 shows the revised NISP and percentage representation figures for the Namu fish fauna based on the materials recovered from excavations in various areas of the site in 1977-78 (Cannon 1991:18) and from Unit FS 10 in 1970. The total number of identified fish from Period 6 is now comparable to that for other periods from the last 7000 years of the site’s occupation.

The picture that emerges from the late period fisheries based on these revised figures is not radically different in most respects from patterns observed in other periods or that evident from the small numbers of fish remains recovered in 1977-78, although there are some important differences. The percentage of salmon in Period 6 is well below the peak levels exhibited in Periods 3 and 4, and is still the lowest overall percentage of any period, consistent with earlier interpretations that Periods 5 and 6 represented times of at least periodic shortfall in salmon production. The difference is that salmon only represented 67.0% of the 567 fish remains originally reported for this period. The revised percentage of 81.8% is a much more modest decline and is also consistent with the results of auger sampling that showed a less dramatic decline in salmon in the Period 6 deposits (Cannon 2000).

	Period 2		Period 3		Period 4		Period 5		Period 6		Period 6 +	
	5-4000BC		4-3000BC		3-2000BC		2000BC- AD1		AD1-Contact		Unit FS 10	
	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%
Rajidae	1	0.02	0	0.00	5	0.001	3	0.03	0	0.00	3	0.02
Squalus acanthias	74	1.15	37	0.21	49	0.08	73	0.65	17	3.00	165	1.35
Hydrolagus colliei	59	0.92	70	0.39	76	0.12	254	2.26	69	12.17	424	3.47
Clupea harengus pallasii	28	0.44	33	0.19	366	0.60	48	0.43	0	0.00	41	0.34
Oncorhynchus sp.	5720	89.17	17272	97.15	58940	96.82	9509	84.77	380	67.00	9994	81.82
Gadidae	81	1.26	54	0.30	296	0.49	86	0.77	45	7.93	496	4.06
Sebastes sp.	318	4.96	210	1.18	755	1.24	815	7.27	41	7.23	566	4.63
Anoplopoma fimbria	4	0.06	16	0.09	19	0.03	48	0.43	1	0.18	142	1.16
Hexagrammidae	79	1.23	28	0.16	172	0.28	215	1.92	5	0.88	320	2.62
Cottidae	3	0.05	1	0.01	15	0.02	19	0.17	0	0.00	0	0.00
Pleuronectidae	48	0.75	58	0.33	185	0.30	147	1.31	9	1.59	62	0.52
Unidentified	53		73		64		110		18		946	
Total Identified	**6417**		**17782**		**60882**		**11222**		**567**		**12214**	

Table 3: Representation of fish taxa as total NISP and percentage of identified fish by time period.

A larger sample would be expected to moderate extremes in variation, but the stratum by stratum comparison also allows us to determine that Period 6 includes deposits with the lowest numbers of salmon, possibly indicating the period of greatest crisis in the salmon fishery, and deposits with salmon in numbers comparable to their peak in earlier periods, suggesting overall recovery of the fishery by the latter half of Period 6. The small volume of Period 6 deposits excavated in 1977-78 and the small number of fish reported from those excavations were not sufficient to show this pattern.

The addition of data from Unit FS 10 also makes it possible to characterize fisheries other than salmon as generally comparable to those in place throughout the last 7000 years. The range and relative emphasis on different categories of fish are remarkably similar in all periods. The major exceptions in Period 6 are the numbers of ratfish, rockfish, and greenling, which are comparable to their high levels in Period 5, and the exceptionally large numbers of cod and sablefish, which can be attributed entirely to the unusually large numbers of their remains in Stratum FS 10.11. Herring, which is completely under-represented in the figures in Table 3, would have been numerically predominant in all periods of site occupation (Cannon 2000). Based on the results of auger sampling, it appears that the intensity of the herring fishery remained consistent throughout the past 7000 years.

It is difficult to find support in the fish fauna for any interpretation that would posit a shift in the pattern of site use during the last 1000 years. In contrast to observed distinctions in strata, features, artifacts, and mammalian faunal remains (Conover 1978:98), our data show consistency among most fisheries over the past 2000 years. Fisheries are also generally comparable with those from other periods, especially following the apparent recovery of the salmon fishery. It seems more likely that apparent distinctions in strata and features and in the density of fauna and artifacts are a function of the recent accumulation of the later site deposits. It is possible that greater compaction over time would have obscured the particular stratigraphic and feature characteristics observed in the upper portions of Unit FS 10 and resulted in a greater density of both fauna and artifacts.

Conclusions

The fish remains from Unit FS 10 have provided a larger and more representative sample of fish from the last 2000 years of the Namu site occupation, which is consistent with the diversity and emphasis of local fisheries throughout the last 7000 years. Although these included a wide range of taxa typical of Northwest Coast sites, the emphasis among larger fish was clearly on salmon in all periods. Herring, which were under-represented in the recovered remains, were numerically predominant in all periods. In comparison to herring and salmon, all other fish would have to be described as relatively minor components of the overall subsistence economy, though potentially of more or less importance at different times of year or in relation to periodic shortages of subsistence staples.

The larger sample of identified fish from Period 6 confirms the continued decline in salmon, but not to the extent suggested in earlier analysis. The revised data show continuing decline from Period 5 to the lowest percentages of salmon in any period in the lower strata of Unit FS 10, followed by recovery of the salmon fishery after ca. AD 1000 to the peak levels observed in Periods 3 and 4 (4-2000 BC). The fish remains from Period 6 also confirm consistent use of marginal resources such as ratfish to compensate for salmon shortages, and indicate efforts to diversify the local fishery by increasing emphasis on rockfish, cod, sablefish, and greenling, particularly during the period of the FS 10.11 deposits.

Despite problems in controlling for the recovery of fish remains in 1970 and concerns about the integrity of the samples in the decades since the excavation, the data we have been able to derive from this assemblage represent an additional dimension of information on the history of fisheries at the Namu site. These new data provide the first full picture of the last 2000 years as well as the basis for a more balanced overview of the 7000-year history of fishing at Namu.

Acknowledgments

Research for this paper was supported by a grant from the Social Sciences and Humanities Research Council of Canada. We thank Andrew Barton for providing access to the University of Colorado excavation materials and Roy Carlson for his continuing support of the analysis of the Namu faunal remains.

References Cited

Cannon, A.
1991 *The Economic Prehistory of Namu: Patterns in Vertebrate Fauna*. Burnaby, BC: Simon Fraser University, Department of Archaeology Publication 19.

Cannon, A.
1995 The Ratfish and Marine Resource Deficiencies on the Northwest Coast. *Canadian Journal of Archaeology* 19: 49-60.

Cannon, A.
2000 Assessing Variability in Northwest Coast Salmon and Herring Fisheries: Bucket-Auger Sampling of Shell Midden Sites on the Central Coast of British Columbia. *Journal of Archaeological Science* 27:725-737.

Cannon, A., and D. Y. Yang
2006 Early Storage and Sedentism on the Pacific Northwest Coast: Ancient DNA Analysis of Salmon Remains from Namu, British Columbia. *American Antiquity* 71:123-140.

Carlson, R. L.
1991 Appendix B: Namu Periodization and C-14 Chronology. In *The Economic Prehistory of Namu: Patterns in Vertebrate Fauna*, by A. Cannon, pp. 85-95. Burnaby, BC: Simon Fraser University, Department of Archaeology Publication 19.

Carlson, R. L.
1996 Early Namu. In *Early Human Occupation in British Columbia*, edited by R. L. Carlson and L. Dalla Bona, pp. 83-102. Vancouver: University of British Columbia Press.

Conover, K.
1978 Matrix Analyses. In *Studies in Bella Bella Prehistory*, edited by J. J. Hester and S. M. Nelson, pp. 67-99. Burnaby, BC: Simon Fraser University, Department of Archaeology Publication 5.

Fawcett, I.
1991 Appendix C: Faunal Analysis of Matrix *Samples*. In *The Economic Prehistory of Namu: Patterns in Vertebrate Fauna*, by A. Cannon, pp. 97-100. Burnaby, BC: Simon Fraser University, Department of Archaeology Publication 19.

Hester, J. J.
1978 Conclusions: Early Tool Traditions in Northwest North America. In *Studies in Bella Bella Prehistory*, edited by J. J. Hester and S. M. Nelson, pp. 101-112. Burnaby, BC: Simon Fraser University, Department of Archaeology, Publication 5.

Hester, J. J. and S. M. Nelson (editors)
1978 *Studies in Bella Bella Prehistory*. Burnaby, BC: Simon Fraser University, Department of Archaeology Publication 5.

Luebbers, R.
1978 Excavations: Stratigraphy and Artifacts. In *Studies in Bella Bella Prehistory*, edited by James J. Hester and Sarah M. Nelson, pp. 11-66. Burnaby, BC: Simon Fraser University, Department of Archaeology Publication 5.

A Preliminary Study of Methods for Identifying Archaeological Sea Urchin Remains in the Pacific Northwest

Greg Campbell
150 Essex Road, Southsea, Portsmouth, Hants, UK PO4 8DJ, g.v.campbell @btinternet.com

ABSTRACT

The remains of sea urchins are common at archaeological sites in the Pacific Northwest, providing valuable data for marine biologists and for archaeologists interested in the use of marine resources by early inhabitants of this region. However, archaeological urchin remains are typically fragmentary, limiting the applicability of traditional identification techniques. Methods have been developed recently to identify northeast Atlantic urchin remains to genus, to quantify the numbers harvested, to examine the manner in which they were prepared and to reconstruct their population structure. These methods are tested on three species of Pacific Northwest *Strongylocentrotus* urchins (the sole shallow-water echinoid genus) and are shown to be useful for species discrimination. Features on auricles and jaw elements, as well as the geometry of the jaws, may be characteristic of a particular species. In addition to permitting the identification of archaeological urchin remains, these distinguishing features may also shed some light on specialization and adaptation among these sea urchin species.

RÉSUMÉ

L'oursin est souvent présent dans les sites archéologiques du nord-est pacifique et représente donc une source importante de données sur les resources maritimes et leur utilisation dans le passé. Malheureusement, les restes d'oursin sont typiquemment mal conservés, ce qui restreint l'utilisation de techniques traditionnelles d'identification taxonomique pour cette classe. Des méthodes d'identification taxonomique pour les restes d'oursin ont été développées récemment dans le nord-est atlantique pour le calcul du nombre de restes, l'analyse des techniques de préparation et l'étude des structures de population. Dans cette étude, ces méthodes sont testées sur trois espèces du genre *Strongylocentrotus* de la côte du nord-est pacifique, démontrant leur utilité. Certains aspects des auricules et des éléments mandibulaires semblent caractériser les espèces et peuvent donc nous informer sur la spécialisation, l'adaptation et la spéciation des oursins.

CANADIAN ZOOARCHAEOLOGY/ZOOARCHÉOLOGIE CANADIENNE
NUMBER/NUMÉRO 25 (2008), 15-35.

Aliter echino: *solum mittes in aqua calida, coques, levas, in patella compones, addes folium, piper, mel, liquamen, olei modice, ova, et sic obligas in thermospodio coques, piper asparges et inferes.*

“another [thing to do with a] sea urchin: Drop one by one into boiling water, cook, lift out, and arrange on a platter; add [a sauce of] bay leaf, pepper, honey, fish sauce, a little oil, and eggs stirred together and cooked in a chafing dish; sprinkle with pepper and serve.”

- Apicius, *de re Coquinaria* IX, viii (compiled c. AD 500)

The consumption of sea urchins (marine invertebrates in the Class Echinoidea) is a common practice throughout the modern world (Lawrence 2001) which dates back to at least the Mesolithic (Menendez et al. 1986:286). Sea urchins are recovered regularly from coastal archaeological sites from around the world. In the Mediterranean, urchins have been found in Epipalaeolithic Cyprus (Reese 1999), Minoan Crete (Reese 1995) and Phoenician trading centres (Garcia and Moreno 1994, Reese 2003), and from Classical sites such as Pompeii (Ciaraldi 1997). Urchin remains have been found from sites all around the Pacific, including the Russian Pacific coast (e.g. Fitzhugh et al. 2007), Hawaii (Jones 2001), the Marshall Islands (Weisler 2001), Norfolk Island (Campbell and Schmidt 2001), and New Zealand (Best 1929), and in Chile (Jerardino et al. 1992) and Peru (LaVallee et al. 1999). Urchin remains are encountered regularly in archaeological excavations along the Pacific coast of North America, in Alaska (Dall 1877; Desautels et al. 1971), the Gulf of Georgia (Hanson 1995; Green 1999), the outer coast of Vancouver Island (Sumpter 1991, 2005) and the Channel Islands of California (Erlandson et al. 2005, Martz 2005).

Sea urchins are grazers of seaweed beds, sea-grass beds and stable surfaces such as rocky shores, from the low inter-tidal to depths of many metres. In well-lit levels of coastal waters, their grazing controls the balance between open space and seaweed cover and between different kinds of seaweed. They are the principal grazers of coastal kelp forests. The complex interaction between humans, sea otters and sea urchins seems to have controlled the rate and extent to which kelp forests were over-grazed into “urchin barrens” along this coast over the last few millennia (Erlandson et al. 2005:16). Reconstructing human impact on sea urchins in this and other coastal ecosystems may provide a useful line of evidence for interpreting human use of the coast over time.

Sea urchins are marine invertebrates in the phylum Echinodermata, along with the starfishes and sea-cucumbers. Those found outside tropical seas are usually in the Order Camarodonta. They are typically a flattened spherical shape studded with spines (Figure 1) with the anus centrally positioned at the top, the mouth centered at the base, and the surface bearing numerous prominent maneuverable spines and less obvious tube-feet. The solid part of the urchin (the *test*) is a hollow flattened sphere made up of *test plates*, arranged into five ambulacral zones (in which the plates have rows of paired pores for the tube feet and tubercles which serve as articulations for the spines) alternating with five interambulacral zones (in which the plates have tubercles only).

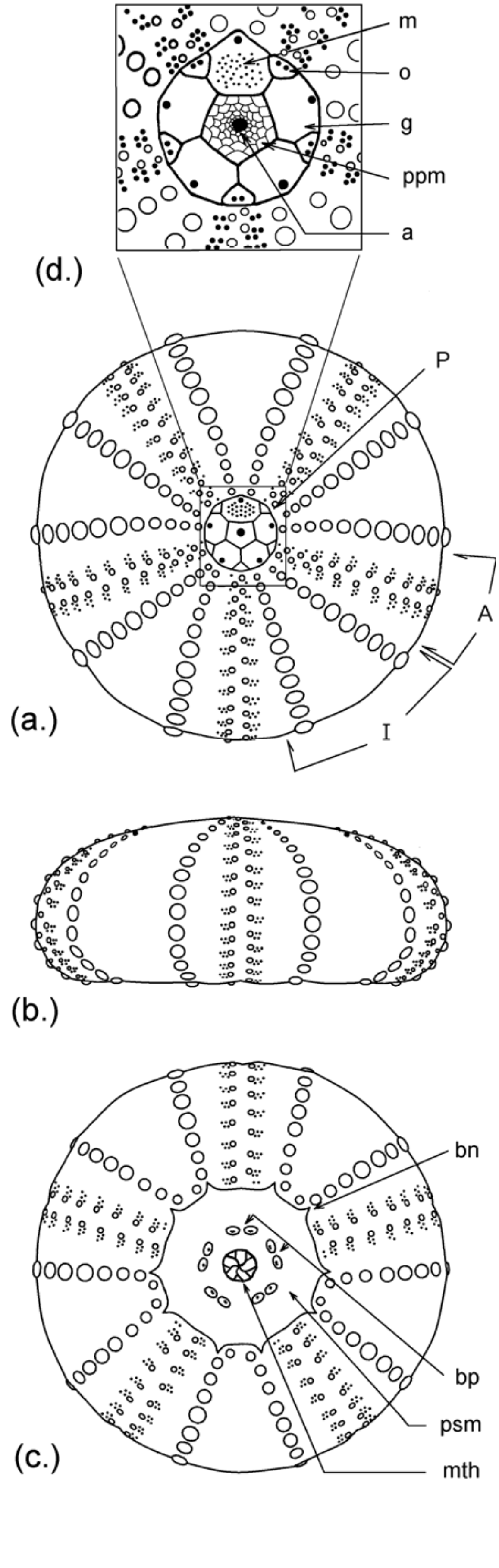

Figure 1: Diagram of a sea urchin (regular echinoid) test, with patterns of tubercles (circles) and pairs of pores (dots) much simplified. (a.): top view, with anus central. *P*, periproct with apical disk; *A*, one of the five ambulacral zones; *I*, one of the five interambulacral zones. (b.): side view, directly facing an ambulacral zone. (c.): base view, with peristome central. *mth*: mouth; *psm*: peristomal membrane; *bp*: buccal plate; *bn*: buccal notch, formerly called the "gill-slit." (d.): magnified view of periproct, showing apical disk of specialised plates. *a*: anus; *ppm*: periproctal membrane with closely-packed plates; *g*: one of the genital plates; *o*: one of the five ocular plates; *m*: madreporite. From Campbell (in press). No scale is provided in this figure and some of the figures to follow, as sizes vary greatly among urchins.

In the periproct on the top of the test are five *ocular plates* and five *genital plates*, one enlarged and perforate (the *madreporite*), arranged in rings around the periproctal membrane (Figures 1d and 2). This membrane bears numerous near-microscopic plates and surrounds the centrally placed anus. Around the mouth at the base of the animal is the tough peristomal membrane, sparsely packed with near-microscopic plates; in the camarodont urchins the only sizable ones are the five pairs of *buccal plates*. The test margin around the peristomal membrane is incised by five pairs of buccal notches, shallow in some urchin species and deep in others. Along the margin is an inward-pointing ridge, the perignathic girdle, which bears *auricles* (pairs of inward extensions for the muscles which align the jaws). Within the animal, just above the peristomal membrane, lies the urchin's jaw (known as "Aristotle's lantern"; Figures 2 and 3), a complex structure made up of five *teeth* (hard brittle structures of an open spiral shape), five pairs of *hemipyramids*, five pairs of *epiphyses*, five *rotuli* and five *compasses* ("T"-shaped in many urchins but "Y"-shaped in shallow-water *Strongylocentrotus* species on the Pacific coast of North America). A more detailed description of these parts and their relationships has been written with the archaeologist in mind (Campbell, in press). They are also described in many good biology and palaeontology texts (e.g., Melville and Durham 1966:244) and online (Smith 2005).

Urchins are useful in archaeology because they are found regularly in coastal excavations (sometimes in large quantities), enough to show that they were consumed regularly in the past. They are also good indicators of seasonality (the roe masses within the test bodies are large enough to eat for a limited part of the year), climate (each species is associated with a different optimum sea temperature range), and shore type (each species has a different tolerance range for salinity and for exposure to wave action, and the size and age distribution of a given species differs for different habitats).

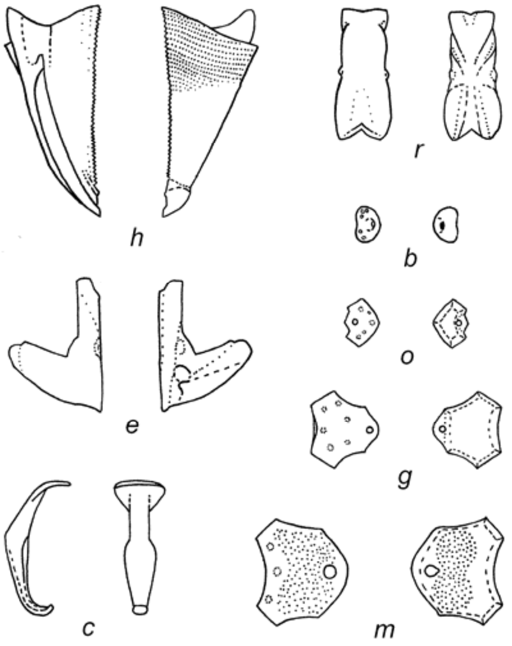

Figure 2: Sea urchin non-test elements often recovered from archaeological deposits. Elements from the jaw (Aristotle's lantern) include the hemipyramid (h), the epiphysis (e), the compass (c), and the rotula (r); buccal plates (b) from the membrane around the mouth, ocular plates (o), genital plates (g) and madreporites (m) from the periproct at the top of the test. After Campbell (in press).

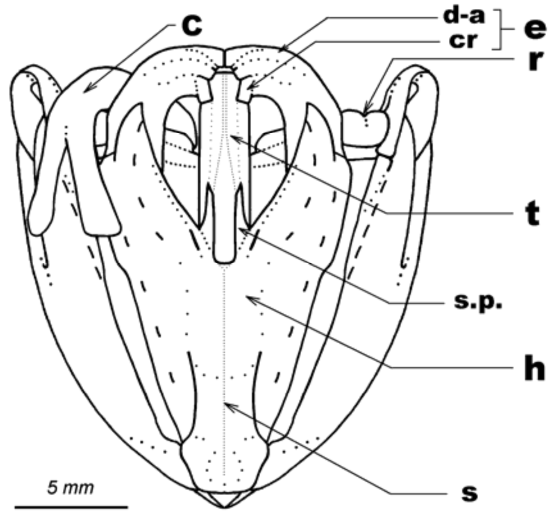

Figure 3: Abaxial (side view) of the jaw or lantern of a camarodont sea urchin (*S. fransiscanus*), orientated as in life. *c*: compass (removed from the right side of the figure); *e*: epiphysis; *d-a*: demi-arc; *cr*: crest; *r*: rotule; *t*: tooth, visible through the foramen magnum; *h*: hemipyramid; *s.p.*: styloid process; *s*: suture along which mirror-image pairs of hemipyramids are joined, surrounding lower part of tooth.

However, interpretations of urchin remains from archaeological deposits have been limited. A general problem for urchin remains is one of preservation: sea urchins are seldom found whole after death. Soft-tissue rot means that the spines, periproct and jaw come free of the test and the jaw falls apart, while the urchin test weakens and slowly falls apart along the joints between plates (Smith 1984:15-16). Dead or fossil animals are usually identified by the pattern of tubercles and especially by the number of pore-pairs on ambulacral plates (e.g., Smith 2005). However, surface sculpture and pore-pair counts vary within an animal. The count is low on plates near the mouth and high on plates near the top, and the difference in count due to position is greater than the difference in typical pore pair count between species. Therefore, it is not possible to tell from pore-pair counts on loose plates whether those plates came from different species of urchin or from different parts of the test in the same species of urchin. In some regions, some genera are indistinguishable on the basis of test sculpture and pore-pair count. The usual methods of identifying urchins to species or genus will not work on sea urchin remains in their typical state of preservation in archaeological deposits.

This typically poor preservation presents other problems for interpretation. As with other kinds of animal used for food, the numbers of urchins and their average sizes are required for estimation of intensity of exploitation and of their importance in the diet. A measure of the distribution of sizes, such as range or standard deviation, is required to compare urchin exploitation and use over time, both between deposits within a site and between sites or cultures. In addition, the size and age distribution for a particular species of urchin will vary with habitat; reconstructing these distributions therefore offers the potential to determine the past habitats that were being exploited. However, the typically poor preservation means that individual urchins can almost never be recognized, and the sizes of individual urchins can almost never be measured directly. Therefore, data on urchin numbers, their average size, and their size distribution (from which age distributions are derived) are usually not available.

Recent work on a European Atlantic sea urchin assemblage has drawn on previous work and pioneered some methods to begin to overcome some of these problems (Campbell 2007). The applicability of the methods devised to archaeological sea urchins in general is discussed elsewhere (Campbell, in press). Numbers of individuals can be reconstructed from counts of elements of the periproct, the auricles and the jaws, since each urchin has a known number of these elements. Differences between the numbers of elements from the top of the urchin (in the periproct) and from the base (the auricles and jaws) may represent evidence for processing prior to consumption. Such inferences can be examined by looking at differences in test fragmentation, since breaks in tests while fresh can be recognised because they propagate across test plates (Smith 1984:19). Because jaw size is roughly proportional to test size (although this may vary within a species depending on the availability and type of food [Ebert 2001]), the average size of an individual can be estimated from hemipyramid length. The distribution of sizes can be estimated from the distribution of hemipyramid lengths by using this proportional relationship. The age distribution can be estimated from the size distribution by a method applied commonly elsewhere in marine biology (Sparre and Venema 1998:63-94) for organisms including shelled marine invertebrates (Cerrato 1980:427).

The method devised to identify European Atlantic sea urchins was based on the observation by Mortensen (1943:167) that the most reliable way of discriminating between two genera with indistinguishable surface sculpture and pore-pair counts (*Paracentrotus* and *Strongylocentrotus*) is by the shape of the auricles. Differences in auricle form between genera had been recognized previously and a simple classificatory scheme had been devised (Hawkins 1934:621-2).

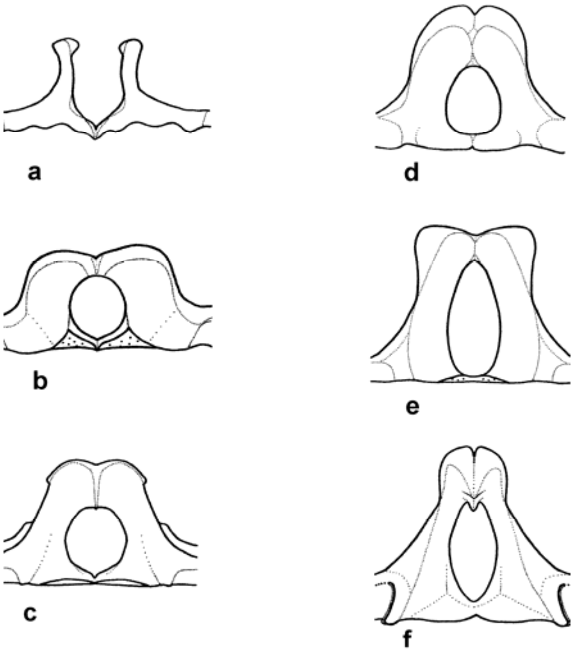

Figure 4: Diagram of auricles from North Atlantic shallow-water sea urchins. *a*: *Arbacia*; *b*: *Psammechinus*; *c*: *Echinus*; *d*: *Paracentrotus*; *e*: *Strongylocentrotus*; *f*: *Sphaerechinus*. From Campbell (2007).

A survey of the auricles for the North Atlantic genera showed that auricle shapes are different for different genera (Figure 4), ranging from simple upright shafts with enlarged heads, which are occasionally fused in larger animals, to increasingly complex and forms that are usually fused. The simplest auricle form occurs in that genus with the most basic anatomy (*Arbacia*), with auricle complexity increasing with anatomical complexity within the North Atlantic camarodont urchins. Therefore, there seems to be some adaptive advantage to changing the arrangement of how the auricle muscles work the jaws, which is preserved in auricle form.

A particular problem for the Pacific coast of North America is that the shallow-water urchins (those in water less than 200 m deep) are all in the same genus, *Strongylocentrotus* (Lambert 2007:1-2). While there are some features which distinguish between species (Jensen 1974), many are associated with elements that are typically lost through decay (Biermann et al. 2003:360). Usually, archaeological remains are reported as "*Strongylocentrotus* sp." In cases in which species designations are made, it is usually assumed that the species represented by the archaeological material is the same as the extant local species. In the few instances where more than one species of urchin has been recognized at a single site (Sumpter 2005), identification to species was based on test colour where preserved (Sumpter, pers. comm.). Changes in the ranges of the various urchin species over time along this coast are likely to be a topic of interest in its own right to marine biologists. Reconstructing the types of shore exploited by humans in the past as implied by the ecological requirements of the different urchin species is a topic of great interest to archaeologists. Reconstructing the direct and indirect effects of this human exploitation on coastal habitats (especially coastal kelp forest) is a topic of interest to both marine biologists and archaeologists. Therefore, developing a means of discriminating urchin species within a genus (in this case, *Strongylocentrotus*) would be useful to both marine biologists and archaeologists in the Pacific Northwest.

There are five *Strongylocentrotus* species common in the Pacific coast of North America, south of Alaska (Lambert 2007:2). The pink urchin, *S. fragilis* Jackson, 1912, is found in waters deep enough (below 50 m) to be a challenge to harvesting and therefore is unlikely to be found in archaeological assemblages. The white urchin, *S. pallidus* (Sars, 1871), is found only below 5 m in depth and would be expected to have been encountered by humans only occasionally in the past. The remaining three species, all found in shallow waters, have overlapping ranges. The red urchin, *S. fransiscanus* (Agassiz, 1863), the species which produces the world's largest urchins, is found throughout the northern Pacific; the purple urchin, *S. purpuratus* (Stimpson, 1857), occurs from southern Alaska to Baja California; and the green urchin, *S. droebachiensis* (Müller, 1776), found from Puget Sound northwards, has a circum-Arctic distribution (Jensen 1974). Jensen (1974:142) observed that green urchins have tubercles with undercut necks while red and purple urchins both have tubercles with squat plug-like tops. Jensen (1974:140) also observed that there were species differences in the features on the epiphyses.

Material

Material was kindly supplied from four areas along the west coast of North America:

- In September 2005, seven purple urchins and eight red urchins from 7 m depth, from Coal Oil Point, California (34°24'N, 119° 52.5'W).
- In April 2006, 24 purple urchins from Cape Blanco, Oregon (42°50'N, 124°34'W): six from pits and six from bare rock at 0.15 m above mean low water (MLT), and six from pits and six from bare rock at 0.3 m below MLT.
- In winter 2005, green urchins from subtidal waters and white urchins from below 50 m in the San Juan Channel, Washington (48°31'N, 122°57'W), and purple urchins originally from Slip Point, Clallam Bay, Washington (48°16'N, 124°18'W), held in subtidal cages in the San Juan Channel.
- In June 2006, 11 red urchins from 7 m depth, and eight red urchins and eight green urchins from 5 m depth, from the vicinity of Nanaimo, British Columbia (49°N, 123°W).

The urchins provided from each location ranged in size from small (22-25 mm diameter) to large (45-60 mm for most species, and 95-145 mm for red urchins). From around the San Juan Channel, only larger urchins (over 35 mm) without lanterns were provided.

Methods

The smaller tests had their spines removed and the jaws (lanterns) extracted and disarticulated by overnight suspension in a dilute sodium hypochlorite solution (domestic bleach). They were rinsed and air-dried, either by the author or by the contributors prior to shipping. The larger urchins (the more mature red urchins), shipped dry, had their jaws dissected out and disarticulated by overnight soaking in dilute hypochlorite, and were rinsed and air-dried. The maximum diameter (D) and height (H) of each air-dried test was measured to the nearest millimetre. The auricles and lantern elements were examined visually, in some cases under low-power magnification, to see if there were any attributes of these elements which might distinguish between species.

Differences in jaw element attributes raised the possibility that there might be differences in lantern shape between species. Any difference in lantern shape will be reflected in differing shapes of the hemipyramid, so, to test this possibility, the following dimensions were taken of a hemipyramid or two from each urchin, to the nearest 0.1 mm (Figure 5):

> *Length* (L): Maximum overall dimension, from the oral tip of the broad flat plate to the dorsal tip of the projecting process. This measure was used in preference to the usual measurement for hemipyramid length, the maximum dimension of the broad flat plate (Lawrence et al. 1995: 244), since the corners of the

plate are fragile and are frequently broken off on small fresh hemipyramids and in archaeological material.

-

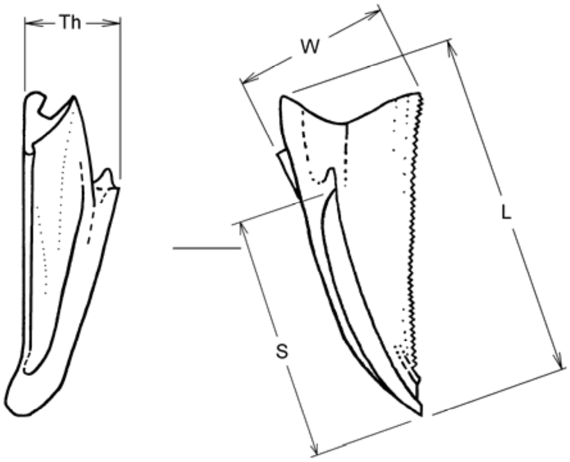

Figure 5: Sea urchin hemipyramid, showing measurements employed.

- *Thickness* (Th): Dimension from the broad flat surface of the plate to the articular suture with that hemipyramid's pair, at the base of the foramen magnum.
- *Width* (W): Maximum dimension across the plate. This is a bit tricky to measure consistently even in fresh material, and it is not well preserved in archaeological contexts, due to the breakage of plate corners.
- *Suture length* (S): Distance from the oral tip of the broad flat plate to the aboral end of the articular suture with the hemipyramid's pair, at the base of the foramen magnum.

A simple way to remove size as a factor when comparing shapes is to calculate ratios, expressing one dimension as a proportion of another. Comparing shapes via the means and standard deviations of these ratios is a traditional method in interpreting shape in archaeological invertebrates (e.g., Kent 1992:25-27). Ratios of width/length, thickness/length, thickness/width and suture/length were calculated for each hemipyramid.

Archaeologists face different sampling challenges from ecologists and palaeontologists: archaeological samples are small, biased due to selection during harvesting (size ranges are often restricted, and distributions are often positively skewed because young small prey were ignored) and likely to have come from a range of habitats. Harvesters probably exploited more than one habitat for a single consumption event, and single deposits can consist of waste from several consumption events.

Results

Auricles

About 20% of the smaller urchins (<30 mm) had unfused auricles, normally one (rarely two) in a particular urchin. There were some subtle differences in auricle shape between larger animals of the three *Strongylocentrotus* species (Figure 6).

In purple urchins (*S. purpuratus*) the auricles were thin shafts, angled away from the lantern; only the upper third of the shaft was flattened. In green urchins (*S. droebachiensis*) the shafts were thicker, with the upper half flattened. Red urchins (*S. fransiscanus*) had even thicker shafts, wider towards the top with the upper half flattened. White urchins (*S. pallidus*) had short, thick shafts; the top edge of the auricle was rolled forward and curved to form a gutter. In the other three types, the top of the auricle bears a small flange which meets the flat face at a sharp angle. This deeper-water near-shore species has auricles similar to the deeper-water near-shore North Atlantic species *Echinus esculentus* (Figure 4c), so auricles facing similar forces due to similar living conditions may take similar forms.

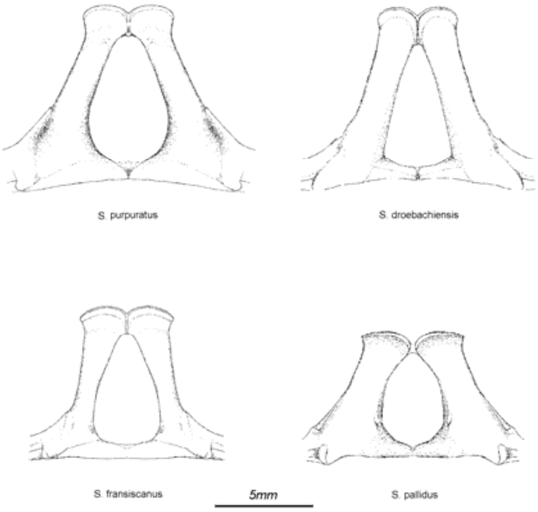

Figure 6: Diagram of the abaxial (inner) face of the auricles in mature specimens of the shallow-water Pacific North American sea urchins (*Strongylocentrotus* sp.). Clockwise from top left: *S. purpuratus, S. droebachiensis, S. pallidus* and *S. fransiscanus*.

Auricles may have some other uses. Three of the purple urchins from Cape Blanco had misshaped auricles, bent over and fused oddly (Figure 7). This form of auricle was restricted to pit-dwelling urchins. It may therefore result from these urchins being struck with enough force to break the auricles against the jaws, but surviving and repairing the damage because they were safe in their pits. As a result, these structures may have the potential to discern the life history of individuals, as well as the shore type of their habitat.

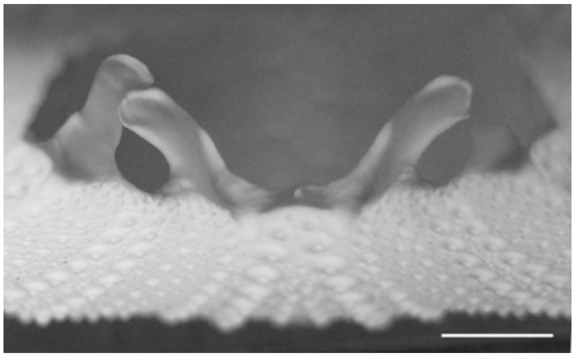

Figure 7: View of the abaxial (inner) face of the perignathic girdle of a pit-dwelling purple urchin (*S. purpuratus*) from Cape Blanco, Oregon (test diameter of 44 mm), showing two anomalous auricles. On the left, the upper part of right shaft has been displaced downwards toward centre of auricle and has fused with the inner face of the left shaft. On the right, the upper part of the left shaft has been displaced centrally, and the upper part of the right shaft has been resorbed. Other auricles were of typical form (cf: Figure 6). Scale bar = 5mm.

However, differences in auricle shape between species are small, and auricles vary with test size within a species. In a blind test on identified *Stronglyocentrotus* specimens from the collection at the Natural History Museum, London, *S. pallidus* was usually recognized by its auricles, but the other species could not be distinguished.

Jaw features

Each epiphysis bears a long thin arm, which articulates with the top of the broad flat plate of the hemipyramid, and a shorter stouter curved arm, the demi-arc. In camarodont urchins, the demiarcs span the space between the tops of the joined pairs of hemipyramids (Figure 3). The abaxial (inside) face of the demi-arc bears a crest, a small extension which supports the upper part of the tooth (Figures 3 and 8). The material studied here was consistent with the observation of Jensen (1974:140) that these crests were small buds in small individuals across all *Strongylocentrotus* species (Figure 8a), but were different in larger individuals (Figure 8b-d). In purple urchins (*S. purpuratus*) the crests are thin and project both upwards and down from the demi-arc (Figure 8b). In green urchins (*S. droebachiensis*) the crests are broader and project only upwards from the demi-arc (Figure 8c). In red urchins (*S. fransiscanus*) the crests are broad and stocky, and project only slightly (Figure 8d).

Each hemipyramid has a styloid process (Figure 3), a spur-like upward extension which supports the middle part of the tooth. In the material studied, the styloid processes were all quite small and stubby in small animals (Figure 9a), but in mature purple urchins (*S. purpuratus*) they were short and blunt (Figure 9b), in green urchins (*S. droebachiensis*) they were longer and pointed (Figure 9c), and in red urchins (*S. fransiscanus*) they were very long and thin (Figure 9d), fragile, and often broken even in fresh material.

Jaw morphology

The three different species of urchin appeared to have a different arrangement of crests and styloid processes to support the tooth. This raised the possibility that each species had a characteristic lantern shape. Any such lantern shape differences would be reflected in the relative shape of the hemipyramids: short broad lanterns would be made up of comparatively short broad hemipyramids. Therefore, if the lantern shape is really different between species, the ratios of the hemipyramid dimensions should be significantly different between species.

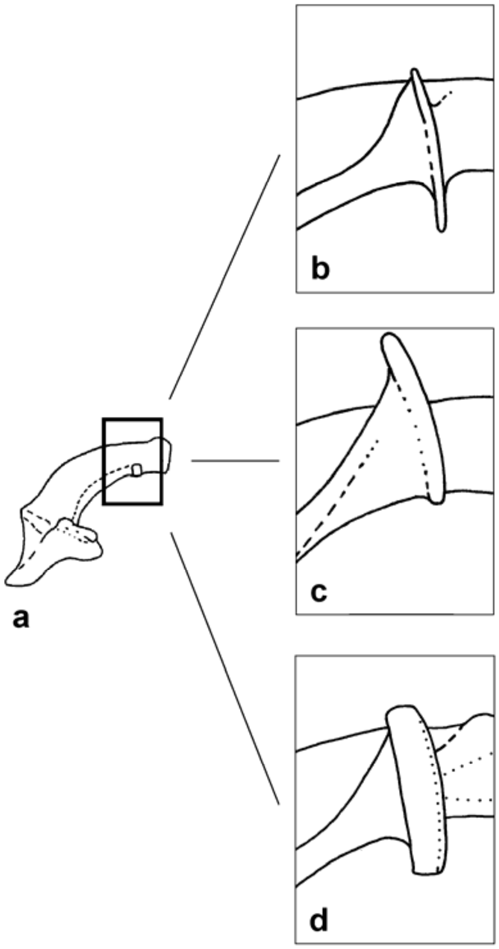

Figure 8: (a): Adaxial (outer) view of epiphysis showing the crest typical of smaller *Strongylocentrotus*. Crests of larger individuals: (b) *S. purpuratus*, (c) *S. droebachiensis*, (d) *S. fransiscanus*.

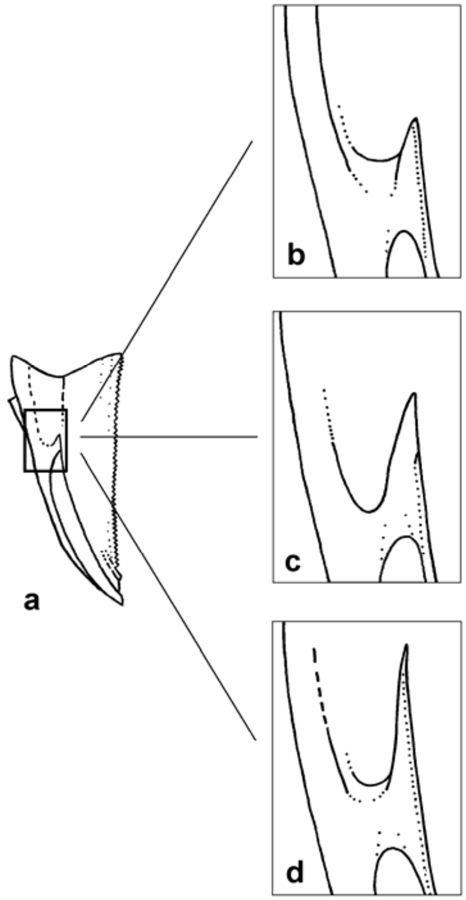

Figure 9: (a): View of the internal face of a hemipyramid, showing the location of the styloid process typical of smaller *Strongylocentrotus*. Processes of larger individuals: (b) *S. purpuratus*, (c) *S. droebachiensis*, (d) *S. fransiscanus*.

The relationship of test diameter to jaw length (the jaw-test allometry) and of thickness to jaw length (the jaw length-thickness allometry) for the three species is shown in Figure 10. There were clear differences in test size distribution within species from different locations.

The jaw-test allometry was only roughly linear and was clearly different within species from different locations. The jaw-test allometry and jaw length-thickness allometry formulae for the various samples are presented in Table 1, although it may not be justifiable to compare jaw-test allometry on such small samples.

However, there seems to be no difference within species in the relation of hemipyramid thickness to jaw length from different locations (Figure 10). The relationship appeared reasonably linear (the slopes, β, of the jaw length-thickness allometry formulae in Table 1 are all near to 1.0), and the jaw length-thickness allometry seemed quite different between species.

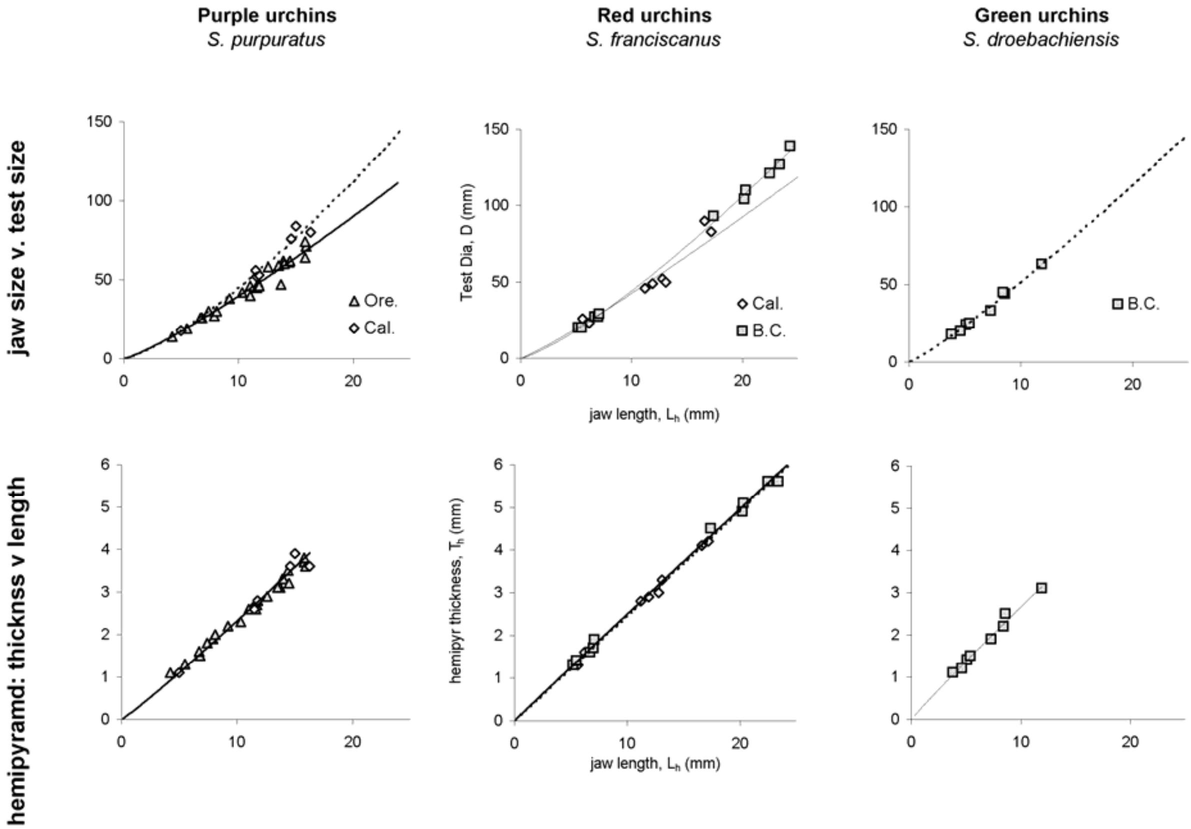

Figure 10: Test diameter (D) and hemipyramid thickness (Th) as a function of jaw size (L) for three species of *Strongylocentrotus.*

Table 1: Allometry of test diameter (D) and hemipyramid thickness (Th) with jaw size (L) for the three species of *Strongylocentrotu*s

species	site		$D = \alpha (L)^{\beta}$			$Th = \alpha (L)^{\beta}$		
		No.	slope (α)	exp (β)	r^2	slope (α)	exp (β)	r^2
S. purpuratus	Cape Blanco, OR	24	2.59	1.185	0.974	0.265	0.949	0.990
	Coal Oil Pt., CA	7	2.12	1.325	0.988	0.195	1.076	0.985
S. fransiscanus	Vancouver Isl., BC	11	2.39	1.267	0.999	0.255	0.991	0.997
	Coal Oil Pt., CA	8	3.22	1.120	0.939	0.242	1.005	0.993
S. droebachiensis	Nanaimo, BC	8	3.66	1.148	0.987	0.296	0.954	0.986

The statistics for the various hemipyramid ratios are presented in Table 2. While the Cape Blanco, Oregon, purple urchins came from four different habitats, these four samples were not significantly different in terms of their ratio of hemipyramid Th/W (anova: $F_{[3,20]}$ =1.146, *P* =0.355), W/L

($F_{[3,20]}$=0.114, P=0.950), S/L ($F_{[3,20]}$ =0.317, P=0.813), or Th/L ($F_{[3,20]}$ =0.679, P=0.575). When the purple urchins from Coal Oil Point, California, were included, there was still no significant difference in the ratios (anova: Th/W: $F_{[4,26]}$=0.699, P=0.60; W/L: $F_{[4,26]}$=0.119, P=0.97; S/L: $F_{[4,26]}$ =0.220, P=0.93; Th/L: $F_{[4,26]}$=0.364, P=0.83). While the red sea urchins came from three different locations, the three samples were also not significantly different in terms of their hemipyramid ratios (Th/W: $F_{[2,24]}$=0.339, P=0.72; W/L: $F_{[2,24]}$=1.020, P=0.38; S/L: $F_{[2,24]}$ =0.256, P=0.78; Th/L: $F_{[2,24]}$=0.672, P=0.52). The hemipyramid ratios appear to be similar within a given species, whether collected in different parts of the same locality or from different localities.

The Nanaimo red urchins came in two size ranges, one small (20-33 mm diameter), the other very big (93-148 mm). The two size ranges had different hemipyramid ratios (Table 2). The difference was not significant for Th/L ($t_{[17]}$=1.46, P=0.16), but in large red urchins, Th/W was significantly larger ($t_{[17]}$=2.58, P=0.019), S/L was significantly smaller ($t_{[17]}$=3.31, P= 0.0041), and W/L was significantly smaller ($t_{[17]}$=3.70, P=0.0018). The Coal Oil Point red urchins seemed to exhibit the same trends between big and small, with the larger urchins (>35 mm across) being similar to big red urchins from Nanaimo (Table 2). The smaller purple urchins from Cape Blanco also seemed to have different ratios from those over 35 mm across (Table 2): this difference was not significant for Th/W ($t_{[22]}$ =0.277, P=0.78) or for S/L ($t_{[22]}$=0.480, P=0.64), but Th/L was significantly smaller in big purple urchins ($t_{[22]}$=2.27, P=0.033) and W/L was significantly smaller in big purple urchins ($t_{[22]}$=2.82, P=0.010). The purple urchins from Coal Oil Point seemed to exhibit the same trends between big and small, with the larger purple urchins similar to the big purple urchins at Cape Blanco (Table 2). The three larger green urchins from Nanaimo (>35 mm) had hemipyramid ratios virtually identical to those of the smaller ones. There may be some alterations of jaw morphology with age and size under certain conditions.

When the three hemipyramid ratios were pooled by species, there was a significant difference between species for each ratio except S/L (Table 3). When the species pooling was restricted to larger urchins (>35 mm) to minimize the effects of size, there was still a significant difference between species in two of the ratios, but not in Th/W or S/L. The middle of the three average values of Th/L ratio was for the larger red urchins; this was significantly different from that for both the larger purple urchins ($t_{[38]}$=4.45, P<0.001) and the larger green urchins ($t_{[18]}$=4.49, P<0.001). The middle of the three W/L ratio averages, also from the larger red urchins, was also significantly different from the average W/L ratio of larger purple urchins ($t_{[38]}$=2.06, P=0.046) and that for the larger green urchins ($t_{[18]}$ =5.80, P<0.001).

Table 2: Hemipyramid ratios for the three species of urchin

species	locality	category		Th / W		W / L		Th / L		S / L	
			No	avg	s.d.	avg	s.d.	avg	s.d.	avg	s.d.
S. purpuratus	Cape Blanco, OR	low, bare	6	0.535	0.017	0.435	0.020	0.233	0.009	0.595	0.040
		low, pits	6	0.556	0.028	0.431	0.018	0.240	0.012	0.594	0.038
		v low, bare	6	0.536	0.019	0.437	0.031	0.234	0.008	0.579	0.040
		v low, pits	6	0.534	0.030	0.439	0.021	0.234	0.007	0.579	0.036
		all	24	0.540	0.025	0.436	0.022	0.235	0.009	0.587	0.037
		large	17	0.543	0.022	0.429	0.018	0.232	0.007	0.577	0.035
		small	7	0.533	0.031	0.453	0.021	0.241	0.012	0.611	0.032
	Coal Oil Pt, CA	all	7	0.544	0.036	0.432	0.019	0.235	0.015	0.585	0.045
		large	6	0.551		0.431		0.237		0.579	
		small	1	0.500		0.440		0.220		0.620	
S. fransiscanus	Nanaimo, BC	5 m	8	0.553	0.028	0.453	0.033	0.250	0.010	0.584	0.026
		7 m	11	0.544	0.032	0.460	0.027	0.250	0.009	0.592	0.033
		all	19	0.548	0.030	0.457	0.029	0.250	0.009	0.589	0.030
		large	11	0.561	0.019	0.441	0.013	0.247	0.008	0.573	0.016
		small	8	0.530	0.033	0.479	0.031	0.253	0.010	0.610	0.032
	Coal Oil Pt, CA	all	8	0.554	0.024	0.443	0.012	0.245	0.009	0.584	0.021
		large	6	0.561		0.437		0.245		0.584	
		small	2	0.536		0.458		0.245		0.583	
S. droebachiensis		all	8	0.570	0.032	0.478	0.014	0.272	0.013	0.608	0.040
	Nanaimo, BC	large	3	0.568		0.477		0.271		0.609	
		small	5	0.571		0.478		0.273		0.607	

Table 3: Hemipyramid ratios from sea urchins pooled by species, and *anova* results

common name	purple urchin		red urchin		green urchin			
species	*S. purpuratus*		*S. fransiscanus*		*S. droebachiensis.*		*anova*	
			Urchins of all sizes					
No.	31		27		8		$F_{[2,63]}$	*P* of F
	avg	s.d.	avg	s.d.	avg	s.d.		
Th / W	0.541	0.027	0.550	0.028	0.570	0.032	3.45	0.038
W / L	0.435	0.021	0.453	0.026	0.478	0.014	12.8	0.000022
Th / L	0.235	0.010	0.248	0.009	0.272	0.013	44.2	1.0×10^{-12}
S / L	0.586	0.038	0.587	0.027	0.608	0.040	1.39	0.258
			large urchins (D > 35mm)					
No.	23		17		3		$F_{[2,40]}$	*P* of F
	avg	s.d.	avg	s.d.	avg	s.d.		
Th / W	0.547	0.025	0.561	0.016	0.568	0.036	2.51	0.094
W / L	0.429	0.018	0.440	0.011	0.477	0.001	13.6	0.000031
Th / L	0.234	0.009	0.246	0.007	0.271	0.017	26.3	5.2×10^{-8}
S / L	0.577	0.035	0.577	0.017	0.609	0.017	1.66	0.203
			small urchins (D < 35mm)					
No.	8		10		5			
	avg		avg		avg			
Th / W	0.529		0.531		0.571			
W / L	0.451		0.475		0.478			
Th / L	0.239		0.252		0.273			

There were significant differences between species in hemipyramid thickness as a proportion of length and width as a proportion of length. Comparing Th/L ratios with W/L ratios (Figure 11) showed quite clear clusters for each species, although there is some overlap. It appears there are significant differences in jaw geometry between species of *Strongylocentrotus*.

Discussion

This is a preliminary study, based on a small number of samples, with small numbers of individuals within a sample. This is especially notable for green urchins, which were represented by a sample of eight individuals from only one location. However, it can no longer be assumed that there are no differences in the solid anatomy within the test of the shallow-water *Strongylocentrotus* species of the central Pacific coast of North America. There do seem to be significant differences in the development of several features with age or size: the crests on the epiphyses, the styloid processes on the hemipyramids, and the shape of the lantern (as measured by hemipyramid thickness/-length and width/length ratios) and, to a lesser extent, the shape of the auricles.

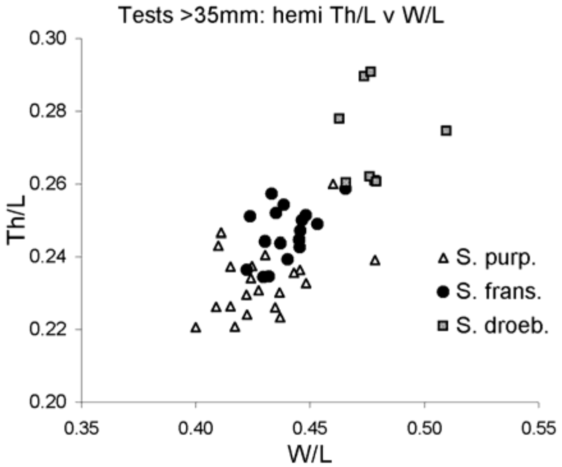

Figure 11: Distribution of hemipyramid thickness-length ratios vs width-length ratios for all of the green urchins (*S. droebachiensis*) and the larger tests (>35 mm) of red urchins *(S. fransiscanus*) and purple urchins (*S. purpuratus*).

What are the causes of these differences? In the material studied here, the differences in these structures are best explained as differences between species, rather than differences within a species at different locations. The hemipyramids of red urchins tend to be relatively wider and thicker than purple urchins, with those of green urchins the widest and thickest of the three. Since the point of maximum thickness occurs at about the same distance up the hemipyramid in all three species (S/L ratios not being significantly different), purple urchins tend to have the most sharply pointed lantern of the three, with those of green urchins being the most broad and blunt.

If the features noted are different between species, they can therefore be used to identify urchin species. Identifying the urchin species present at archaeological sites will help both biologists and archaeologists to reconstruct near-shore conditions such as sea temperature or sea-weed cover, and to look for potential succession of dominant forms along this coastline over time. Population structures are different for different shores, and the relationship between jaw size and test size for these different populations has been researched for other purposes (e.g., Ebert et al. 1999:203). As a result, reconstructing population structures from hemipyramid length distributions (in the manner of Campbell 2007:34-38) would allow the reconstruction of former shore conditions with some accuracy. For archaeological material this has the potential to reconstruct exploitation strategies (types of shores and populations of urchins exploited), and compare such strategies over time and between sites and cultures. It may also help elucidate the phylogenetic relationships within each genus.

If there are no real differences in these anatomical structures between species, the differences observed in this study may be the result of adaptation to environmental conditions such as food type, food availability or substrate (Ebert et al. 1999:194). As a result, we can still use the structures directly to reconstruct type of shore and its change over time, even if we do not know the species of *Strongylocentrotus* urchin present.

It is also possible that these structures are neither species-specific nor closely adaptive, but simply reflect the genetic makeup of a population. Since changes in these structures would therefore reflect changes in this genetic makeup, tracing changes in these structures still provides an opportunity to follow genotype proportions over time. This provides the potential to estimate rates of change in urchin populations and whether change in the nature of the coast was abrupt or gradual.

For the variation of the features of the auricles and lantern to be fully understood and its potential fully employed, it needs to be studied within a given species, on different shore types (given variables such as wave exposure, tidal cover and seaweed cover) at a given latitude, and with a particular shore type across a range of latitudes. Only then can any variation be seen to be due to species, habitat or genetics. The urchin *S. polyacanthus* should be included to see if variation in auricles and lantern can discriminate species along the Alaskan coast. Such a study may seem dauntingly large in scope, but a small army of researchers is already deployed in collecting archaeological urchin remains from across this coast and in assessing modern populations of *Stronglyocentrotus* urchins as part of fish stock assessments, ecological surveys, and experiments in embryology and aquaculture. All that is required is continued cooperation between archaeologists and marine biologists.

Acknowledgments

Many people showed a sustained interest in this project, often over several years: Debbie Corbett at the U.S. Fish and Wildlife Service in Alaska, Rebecca Wigen at the University of Victoria, Chris Pearce at Fisheries Canada Pacific Biological Station in Nanaimo, Richard Strathmann at the Friday Harbor Lab of the University of Washington, Mike Etnier at the Anthropology Department of the University of Washington, Prof. Jon Erlandson at the Anthropology Department of the University of Oregon, Bruce Bourque (Chief Archaeologist at the Maine State Museum), Dr. Andrew Smith in the Palaeontology Department of the Natural History Museum, London, and especially Ben Grupe (now M.Sc.) at the Oregon Institute of Marine Biology, Charleston, and Prof. Tom Ebert of the Biology Department of San Diego State University. Ian Sumpter at Parks Canada’s Gwaii Haanas National Park provided information on species of archaeological urchins in the Pacific Northwest. Ben Grupe, Sean Williams at Fisheries Canada Pacific Biological Station, George von Dassow at Friday Harbor Lab and Shane Anderson at the Life Sciences Department of the University of California, Santa Barbara, went through the wet and smelly process of collecting urchins for this study. Comments by Professor Ebert, Dr. Smith and an anonymous reviewer improved the text.

References Cited

Best, E.
1929 *Fishing Methods and Devices of the Maori.* Dominion Museum Bulletin No. 12. Wellington: New Zealand Government Printer.

Biermann, C. H., B. D. Kessing, and S. R. Palumbi
2003 Phylogeny and development of marine model species: strongylocentrotid sea urchins. *Evolution and Development* 5:360-371.

Campbell, C. R. and L. Schmidt
2001 Molluscs and echinoderms from the Emily Bay settlement site, Norfolk Island. In *The Prehistoric Archaeology of Norfolk Island, Southwest Pacific*, edited by A. Anderson and P. White, pp. 109–114. Sydney: Australian Museum.

Campbell, G.
2007 Appendix G: The marine invertebrate remains. In *Les Fouilles du Yaudet en Ploulec'h, Cotes d'Armor* 3, edited by P. Galliou and B. Cunliffe. (http://www.arch.ox.ac.uk/research/research_projects/le_yaudet/appendices).

Campbell, G.
(in press) Sorry, Wrong Phylum: A neophyte archaeomalacologist's experiences in analyzing a European Atlantic sea urchin assemblage. In *Proceedings of the Inaugural Meeting of the ICAZ Archaeomalacology Working Group, University of Florida, Gainesville, 2005*, edited by K. Szabo and I. Quitmeyer. *Archaeofauna.*

Cerrato, R. M.
1980 Demographic analysis of bivalve populations. In *Skeletal Growth of Aquatic Organisms: Biological Records of Environmental Change,* edited by D. C. Rhoads and R. A. Lutz, pp. 417-465. London: Plenum Press.

Ciaraldi, M.
1997 Plant remains. In *Anglo-American Pompeii Project 1996*, edited by S. Bon, R. Jones, B. Kurchin, and D. Robinson, pp. 17-23. Bradford University Archaeological Sciences Research **3**.

Dall, W. H.
1877 On succession in the shell-heaps of the Aleutian Islands. In *Tribes of the Extreme Northwest; the Aleutians and Adjacent Territories,* by W. H. Dall, pp. 41-91. Contributions to North American Ethnology 1. Washington, DC: Government Printing Office.

Desautels, R. J., A. J. McCurdy, J. D. Flynn, and R. R. Ellis
1971 Echinoderms. In *Archaeological Report: Amchitka Island, Alaska 1969-1970.* U.S. Atomic Energy Commission Report TID-25481, pp. 324-336. Archaeological Research, Inc.

Ebert, T. A.
2001 Growth and survival of post-settlement sea urchins. In *Edible Sea Urchins: Biology and Ecology,* edited by J. M. Lawrence, pp. 79-102. Amsterdam: Elsevier.

Ebert, T. A., J. D. Dixon, S. C. Schroeter, P. E. Kalvass, N. T. Richmond, W. A. Bradbury, and D. A. Woodby
1999 Growth and mortality of red sea urchins *Strongylocentrotus fransiscanus* across a latitudinal gradient. *Marine Ecology Progress Series* 190:189-209.

Erlandson, J. M., T. C. Rick, M. H. Estes, M. H. Graham, T. J. Braje, and R. L. Vellanoweth
2005 Sea otters, shellfish and humans: 10,000 years of ecological interaction on San Miguel Island, California. In *Proceedings of the Sixth California Islands Symposium, 2005,* edited by D. K. Garcelon and C. A. Schwemm, pp. 9-21. Arcata, CA: National Park Service Technical Publication CHIS-05-01.

Fitzhugh, B., M. Etnier, B. MacInnnes, S. C. Phillips, and J. Taylor
2007 *Kuril Biocomplexity Project: Report of Archaeological Field Research in 2006, including Geological Descriptions of Archaeological Locales.* Unpublished report, University of Washington.

Garcia Flores, J. A., and R. Moreno Nuño
1994 The echinoderms. In *Castillo de Doña Blanca: Archaeoenvironmental investigations in the Bay of Cádiz, Spain (750-500 B.C.)*, edited by E. Rosello and A. Morales, pp. 183-184. British Archaeological Reports (International Series) 593.

Green, J.
1999 Shellfish analysis of the 1996 investigations. In *Houses and Households in the Gulf of Georgia: Archaeological Investigations of Shingle Point (DgRv 2), Veldes Island, British Columbia,* by R. G. Matson, J. Green and E. McLay, pp. 120-192. Victoria, BC: Report to Archaeology Branch.

Hanson, D. K.
1995 Subsistence during the late prehistoric occupation of Pender Canal, British Columbia (DtRt-1). *Canadian Journal of Archaeology* 19:29-48.

Hawkins, H. L.
1934 The lantern and girdle of some Recent and fossil Echinoidea. *Philosophical Transactions of the Royal Society of London, Series B,* 223:617-649.

Jensen, M.
1974 The Strongylocentrotidae (Echinoidea): a morphologic and systematic study. *Sarsia* 57:113-148.

Jerardino, A., J. C. Castilla, J. M. Ramírez, and N. Hermosilla
1992 Early coastal subsistence patterns in central Chile: a systematic study of the marine-invertebrate fauna from the site of Curaumilla-1. *Latin American Antiquity* 3:43-62.

Jones O'Day, S.
2001 Excavations at the Kipapa Rockshelter, Kahikinui, Maui, Hawai'i. *Asian Perspectives* 40:279-304

Kent, B.
1992 *Making Dead Oysters Talk: Techniques for Analyzing Oysters from Archaeological Sites.* Crownsville, MD: Maryland Historical Trust.

Lambert, P.
2007 *Checklist of the Echinoderms of British Columbia* (Victoria, BC: Royal British Columbia Museum) (http://www.geog.ubc.ca/biodiversity/efauna/documents/EchinodermsofBCChecklist.pdf).

LaVallee, D., M. Julien, P. Bearez, P. Usselmann, M. Fontugne, and A. Bolanos
1999 Pescadores-recolectores arcaicos del extremo sur Peruano: excavaciones en la Quebrada de los Burros (Tacna, Peru): primeros resultados 1995-1997. *Bulletin d'Institute Français d'Etudes Andines* 28:13-52.

Lawrence, J. M.
2001 Sea urchin roe cuisine. In *Edible Sea Urchins: Biology and Ecology,* edited by J. M. Lawrence, pp. 415-416. Amsterdam: Elsevier.

Lawrence, J. M., B. D. Robbins, and S. S. Bell
1995 Scaling of the pieces of the Aristotle's lantern in five species of *Strongylocentrotus* (Echinodermata: Echinoidea). *Journal of Natural History* 29:243-247.

Martz, P. C.
2005 Prehistoric settlement on San Nicolas Island, California. In *Proceedings of the 6th California Islands Symposium, 2005,* edited by D. K. Garcelon, and C. A. Schwemm, pp. 65-82. Arcata, CA: National Park Service Technical Publication CHIS-05-01.

Melville, R. V. and J. W. Durham
1966 Skeletal morphology. In *Treatise on Invertebrate Palaeontology,* Part U. *Echinodermata* 3, edited by R. C. Moore, pp. 220-251. Lawrence, KS: University of Kansas Press.

Menendez de la Hoz, M., L. G. Straus, and G. A. Clark
1986 The ichthyology of La Riera Cave. In *La Riera Cave: Stone Age Hunter-Gatherer Adaptations in Northern Spain,* edited by L. G. Straus and G. A. Clark, pp. 285-313. Tempe, AZ: Arizona State University Anthropological Research Papers 36.

Mortensen, T.
1943 *A Monograph of the Echinoidea* III.3: *Camarodonta* II: *Echinidae, Strongylocentrotidae, Parasaleniidae, Echinometridae.* Copenhagen: Reitzel.

Reese, D. S.
1995 The marine invertebrates. In *Kommos I: The Kommos Region, Ecology and Minoan Industries*, by J. W. Shaw and M. C. Shaw, pp. 240-278. Princeton: Princeton University Press.

Reese, D. S.
1999 Marine invertebrates. In *Faunal Extinction in an Island Society: Pygmy Hippopotamus Hunters of Cyprus*, by A. H. Simmons, pp. 188-191. New York: Kluwer.

Reese, D. S.
2003 The shells, astragali and fish. In *Excavations at Kition VI: the Phoenician and Later Levels*, by V. Karageorghis, pp. 413-428. Nicosia: Department of Antiquities.

Smith, A. B.
1984 *Echinoid Palaeobiology.* London: George Allen & Unwin.

Smith, A. B.
2005 *The Echinoid Directory.* London: Natural History Museum online publication. (http://www.nhm.ac.uk/research-curation/projects/echinoid-directory).

Sparre, P. and S. C. Venema
1998 *Introduction to Tropical Fish Stock Assessment, Part I: Manual.* Rome: FAO Fisheries Technical Paper 306/1. (http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/w5449e/w5449e00.htm)

Sumpter, I.
1991 *Archaeological Investigations at Little Beach Site, Ucluelet, B.C.* Interim report by Arcas Consulting Archaeologists Ltd. Victoria, BC: Unpublished manuscript, Ministry of Sustainable Resource Management.

Sumpter, I.
2005 Three Shellfish Assemblages from Ts'ishaa, Site DfSi-16 (204T), Benson Island, Pacific Rim Naitonal Park Reserve of Canada. In *Ts'ishaa: Archaeology and Ethnography of a Nuu-chah-nulth Origin Site in Barkley Sound*, edited by A. D. McMillan and D. E. St. Claire, Appendix C, pp. 136-172. Burnaby, BC: Archaeology Press, Simon Fraser University.

Weisler, M.
2001 *On the Margins of Sustainability: Prehistoric Settlement of Utrok Atoll Northern Marshall Islands.* British Archaeological Reports (International Series) 967.

The Dienje Kenyon Fellowship

A fellowship in honor of the late Dienje M. E. Kenyon is offered to support the research of women archaeologists in the early stages of their graduate training. An award of $500 will be made to a student pursuing research in zooarchaeology, which was Kenyon's specialty. To qualify for the award, applicants must be enrolled in a graduate degree program focusing on archaeology with the intention of receiving either the M.A. or Ph.D. on a topic related to zooarchaeology and must be in the first two years of graduate studies. Strong preference will be given to students working with faculty members with zooarchaeological expertise.

Special Requirements:

- A statement of proposed research related to zooarchaeology, toward the conduct of which the award would be applied, of no more than 1500 words, including a brief statement indicating how the award would be spent in support of that research.
- A curriculum vitae.
- Two letters of reference from individuals familiar with the work and research potential of the applicant. One of these letters must be from the student's primary advisor, and must indicate the year in which the applicant began graduate studies.

Deadline:
The statement and curriculum vitae should be sent as an e-mail attachment in Microsoft Word. Letters of reference should be e-mailed separately by the people providing them. Applications are due no later than December 1, 2008.

Contact:
Dr. Ariane Burke
Département d’anthropologie
Université de Montréal
C.P. 6128, succursale Centre-Ville
Montréal, QC, Canada H3C 3J7
Email: a.burke@umontreal.ca

Canadian Zooarchaeology
Zooarchéologie canadienne

Number/Numéro 25 • 2008

Published by the University of Victoria