PREHISTORIC SUBSISTENCE STRATEGIES ON THE PECHO COAST:

AN EXPERIMENTAL COLLECTION OF CALIFORNIA MUSSELS AND TURBAN SNAILS

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Introduction

Shellfish exploitation by ancient Indigenous people can be observed in archaeological assemblages from shellfish middens throughout California (Erlandson 1988; Glassow 1992; Kennett 2005; Kennedy 2005; Whitaker 2008). Indigenous Californians relied upon the resources from open rocky coast ecosystems as early as 9,000 years BP, yet archaeological researchers continue to debate the actual dietary value of and energy required for procurement of such shellfish (Erlandson 1988; Jones 2003; Jones and Richman 1995). In order to discern the costs and benefits associated with shellfish exploitation, researchers have conducted archaeological experiments to try to replicate prehistoric shellfish foraging. The empirical data produced from experimental archaeology yields predictive models for the optimal diet of foragers, which can then be compared to data acquired from archaeological excavations to predict past ecological and social circumstances (Jones 2003; Kennett 2005; Whitaker 2008). For this project, I conducted a shellfish collection experiment at the Diablo Canyon Nuclear Power Plant harbor in San Luis Obispo to determine the energetics involved in the exploitation of California mussels, *Mytilus californianus*, and turban snails, *Tegula funebralis*.

The conclusions derived from experimental archaeology are based upon optimal foraging theory, which states that humans will choose subsistence strategies that maximize foraging efficiency (Jones and Richman 1995; Whitaker 2008). Optimal foraging theory predicts that in order to forage most efficiently, humans will exploit the highest ranking resource possible from the most resource abundant environment available to them (Kennedy 2005). As ecological or social conditions shift, foragers may be forced to exploit lower ranked resources as higher ranked resources become less abundant due to decreased ecological productivity or increased human population pressures (Whitaker 2008). Optimal foraging theory provides the basis for understanding how changing ecological and social conditions can result in the emergence of different subsistence patterns observed in the archaeological record.

Results From Richman's Experiments

Richman and Jones conducted four shellfish harvesting experiments between 1992 and 1993 with the intention of better understanding the differences in stripping and plucking strategies (Jones and Richman 1995). Two collections were undertaken at protected mussel beds in Big Sur, one of which followed a plucking strategy and the other a stripping strategy. A total of 1553 mussels were collected in 20 minutes by following a stripping strategy, while only 424 mussels were collected in 20 minutes using a plucking strategy (Table 1). The mussels were then boiled and the meat was extracted by hand and weighed to calculate the net caloric yield of the entire process. Despite gathering far more mussels by stripping, the plucking strategy yielded 338.4 kcal/hr compared to the stripping strategy's 133.4 kcal/hr due to how much larger the mussels were when collected by plucking (Jones and Richman 1995) (Table 1). Richman and Jones undertook an additional two collections at open mussel beds in Davenport following the same experimental design. A similar pattern emerged where the plucking strategy yielded fewer mussels than the stripping strategy, only 746 mussels compared to stripping's 1478 mussels. However, the plucking strategy yielded 357.7 kcal/hr while the stripping strategy yielded only 277.8 kcal/hr (Jones and Richman 1995) (Table 1).

Table 1: Results from Richman's Experiments

Location	**Date**	**Status**	**Collection strategy**	**Collection time (min.)**	**Meat Weight (g)**	**N Mussels**	**Processing time (min.)**	**Kcal/Hour with processing time (Kcal/hr)**
Big Sur	Sept. 1992	Protected	Plucking	20	470.7	424	40.0	338.4
Big Sur	Sept. 1992	Protected	Stripping	20	343.5	1553	90.9	133.4
Davenport	Dec. 1992	Open	Plucking	20	564.0	746	48.0	357.7
Davenport	Dec. 1992	Open	Stripping	20	750.2	1478	116.6	277.8

Results From Kennedy's Experiments

Within open rocky coast environments, the numerous shellfish species provide varying amounts of meat and involve varying amounts of harvesting and processing labor. The energy required for shellfish procurement and the calories those resources provide can be calculated to determine the net return rate in kilocalories obtained per hour for each shellfish species (Jones and Richman 1995). The expected net return rates for each resource have been used in the creation of prey rank models by researchers including Kennedy (2005), who conducted a series of 56 experiments in Northern California's Bodega Bay pertaining to the economics of shellfish foraging (Kennedy 2005). Kennedy's experiments included the two species of shellfish discussed in this paper, California mussels and turban snails. Kennedy found that mussels consistently yielded between 392 and 593 kcal/hr (Table 2). He concluded that the collection of California mussels results in dependably high caloric earnings because, despite mussels' considerable processing time, they regularly produce large harvests. Turban snails were found to yield return rates from 40-153 kcal/hr, rates so low that, according to Kennedy, the energy input required for their procurement is not offset by consumption (Table 2).

Kennedy similarly ranked the three different ecological niches, or patches, represented in Northern Californian archaeological middens based on their productivity and the availability of resources (Kennedy 2005). His patch rank model asserts that terrestrial patches are the most desirable environments to exploit due to their resource abundance, followed by the inner coastal environments of protected bays and estuaries. Outer coastal patches, which includes open rocky coasts, were ranked last by Kennedy due to the perceived difficulty of navigating California's cold, turbulent shoreline. However, California's outer coastal patches have been continually exploited by Indigenous peoples despite their supposed inconvenience, as evidenced by marine shellfish assemblages dating to as early as 12,000 BP (Erlandson 1988). California mussels specifically have played a vital role in prehistoric subsistence, as demonstrated by their overwhelming abundance in coastal archaeological sites throughout central California (Jones and Richman 1995).

Table 2: Results from Kennedy's Experiments

Location	**Date**	**Collection time (min.)**	**Meat Weight (g)**	**N Mussels**	**Processing time (min.)**	**Kcal/Hour with processing time (Kcal/hr)**	**Reference**
Coleman Beach	1999/2000	20	1012.6	743	127.2	296.7	Kennedy (2005)
Coleman Beach	1999/2000	20	2855.9	1279	254.9	448.2	Kennedy (2005)
Carmet Beach	1999/2000	10	950.0	1125	173.1	303.2	Kennedy (2005)

Shellfish Harvesting Strategies

A study conducted by White (1989), which focused on discerning possible mussel procurement strategies, compared the mussel size frequencies from archaeological assemblages to hypothetical mussel size profiles produced by two possible collection methods: plucking and stripping (White 1989). Plucking involves focusing efforts on obtaining the largest specimens possible, while stripping involves harvesting an entire section of mussel bed, irrelevant to the size of specimen collected (Whitaker 2008; White 1989). Previous archaeological experiments have found a plucking strategy to be consistently more efficient than a stripping strategy, though routinely collecting mussels from the same bed results in a less pronounced difference over time in the mussel size frequencies produced by either strategy (Jones and Richman 1995). The consistent exploitation of mussel beds prohibits mussels from growing to a substantial size, which eventually diminishes the overall productivity of beds subject to regular harvest irrelevant to the collections strategy utilized (Jones 1996).

Results from Previous Cal Poly Experiments

Previous Cal Poly experiments were conducted at the Diablo Canyon Nuclear Power Plant harbor with a primary focus on the difference in caloric yields of stripping versus plucking collection strategies. Two experiments by Cook in 2016 found that a stripping strategy resulted in 357.9 and 493.1 kcal/hr, while a plucking strategy resulted in yields of 380.9 to 457.9 kcal/hr (Cook 2016) (Table 3). A similar series of California mussel collection experiments was conducted by Noet between 2017 and 2018. Noet’s findings from two stripping collections resulted in caloric yields of 226.8 and 166.8 kcal/hr (Table 3). Noet conducted four mussel collections following a plucking strategy, resulting in yields of 383.0, 532.3, 576.8, and 647.5

kcal/hr (Table 3). Noet's experiments clearly showed that plucking is a more efficient harvesting method, however Cook's mussel experiments did not produce the same results. Tatlow's experiments undertaken in 2019 followed a modified stripping strategy, resulting in caloric yields of 257.4 and 826.5 kcal/hr (Table 3). Tatlow's second experiment resulted in the highest overall caloric yield of all previous experiments. In all of the experiments outlined above, mussels were processed raw by cracking the shells open with a pitted stone, which is a highly labor intensive and challenging endeavor that likely prevented researchers from recording even higher net return rates.

Table 3: Results from Previous Cal Poly Experiments

Location	**Date**	**Collection strategy**	**Collection time (min.)**	**Meat Weight (g)**	**N Mussels**	**Processing time (min.)**	**Kcal/Hour with processing time (Kcal/hr)**	**Reference**
Diablo	Feb. 2016	Stripping	10	470.7	950.0	104.5	357.9	Cook (2016)
Diablo	Feb. 2016	Plucking	10	343.5	629.5	61.3	380.9	Cook (2016)
Diablo	Mar. 2016	Stripping	5	564.0	457.2	35.0	493.1	Cook (2016)
Diablo	Mar. 2016	Plucking	5	750.2	372.5	30.1	457.9	Cook (2016)
Diablo	Dec. 2017	Plucking	10	1456	-	154	383.0	Noet
Diablo	Dec. 2017	Stripping	10	836	-	149	226.8	Noet
Diablo	May 2018	Plucking	10	1900	97	144	532.3	Noet
Diablo	May 2018	Stripping	10	1150	281	287.4	166.8	Tatlow (collecting) Noet (processing)

Diablo	Aug. 2018	Plucking	5	1522	65	96.4	647.5	Noet
Diablo	Nov. 2018	Plucking	5	916	40	63.5	576.8	Noet
Diablo	Oct. 2019	Stripping (modified)	5	1760	209	290	257.4	Tatlow
Diablo	Apr. 2020	Stripping (modified)	2.5	1500	72	75.8	826.4	Tatlow

Methods

Mussel Collection Method

Previous research conducted by Cal Poly shows that it is not realistic to exclusively follow a stripping or plucking strategy (Tatlow 2019). Mussels attach themselves to the surrounding substrate with strong byssal threads, and the tightly packed nature of mussel beds results in individual mussels connecting themselves to each other in large groups. Plucking one large mussel specimen from a bed therefore often results in the bycatch of other mussels attached through a web of byssal threads (Binford 1978; Lyman 1994) (Figure 1). Additionally, previous research undertaken by Tatlow shows that a modified stripping technique is more efficient than plucking or stripping (Tatlow 2019). The current experiment was focused on further evaluating the modified stripping technique which involved focusing on collecting larger mussel specimens as opposed to completely stripping a bed. The mussels were collected on April 1, 2022 at the Diablo Nuclear Power Plant harbor by Claire Tatlow, who has prior experience collecting mussels for research purposes through the Cal Poly Experimental Program. Tatlow collected mussels by hand into a bucket while Dr. Jones timed the collection. Tatlow collected a total 140 mussels after collecting for two and a half minutes.

Figure 1: A grouping of California mussels collected by Claire Tatlow

Mussel Processing Method

The collected mussels were brought back to the Cal Poly Archaeology Lab for processing. The mussels were cooked by boiling, which caused the mussel shells to open on their own as mussel shells open up on their own when heated. I extracted the meat from the mussel shells by hand while Dr. T. Jones timed and supervised the process. The extracted meat was collected in a bowl and weighed to determine the net weight of meat collected. The total processing time, which includes boiling and meat extraction, was 21 minutes. The total weight of meat for all 140 mussels was 851 grams.

Turban Snail Collection Method

Turban snails were collected on April 1, 2022 from the same Diablo Canyon Nuclear Power Plant harbor after the mussel collection was undertaken. I collected the turban snails by hand into a bucket while Dr. T. Jones timed the collection. A total of 128 turban snails were collected after 30 seconds of harvesting.

Turban Snail Processing Method

The collected turban snails were brought back to the Cal Poly Archaeology Laboratory for processing. Half of the turban snails were boiled and the other half were left raw prior to being processed. All turban snails were crushed using a pitted stone and a hammer stone, then the broken shell fragments were separated by hand from the meat. The process was timed and supervised by Dr. T. Jones. The boiled turban snails were processed in 11 minutes and 45 seconds, while the raw turban snails were processed in 16 minutes. I noted that processing cooked turban snails felt easier than processing raw snails, because raw snails seemed to coil themselves tightly around the shell when crushed, while cooked snails fell away from the shell.

Results

Experimental Results

The current mussel collection experiment produced a net caloric yield of 1562.2 kcal/hr, close to three times higher than the return rates reported by Kennedy (Table 4). This result was achieved in part due to the fact that the collector had participated in a multitude of prior mussel collection experiments and had honed her skills and collection method over time to become more efficient. Additionally, the mussel bed is highly protected which allows its shellfish populations to boom in an environment unimpacted by human predation.

The turban snail collection experiment produced net caloric yields of 262.5 kcal/hr when the snails were processed raw and 344.5 kcal/hr when the snails were cooked prior to being processed (Table 5). These results not only dwarf Kennedy's return rates of 40-153 kcal/hr, but exceed some of the caloric yields produced from prior mussel collection experiments conducted by the Cal Poly Experimental Program.

Table 4: California Mussel Collection

Location	**Date**	**Collection strategy**	**Collection time (min.)**	**Meat Weight (g)**	**N Mussels**	**Processing time (min.)**	**Kcal/Hour with processing time (Kcal/hr)**
Diablo	Apr. 2022	Stripping (modified)	2.5	851.0	140	21	1562.2

Table 5: Turban Snail Collection

Location	**Date**	**Collection time (min.)**	**Meat Weight (g)**	**N Snails**	**Processing method**	**Processing time (min.)**	**Kcal/Hour with processing time (Kcal/hr)**
Diablo	Apr. 2022	0.25	60	64	Raw crushing	16	262.5
Diablo	Apr. 2022	0.25	58	64	Cooked crushing	11.75	344.5

Conclusion

The findings from this experiment are comparable to those of previous Cal Poly experiments, however based on the results from Tatlow's previous experiment and the current experiment a modified stripping collection strategy produces higher net caloric yields. This experiment also corroborated the findings from previous Cal Poly experiments that suggest that boiling mussels prior to extracting the meat is a more efficient processing strategy than the method of crushing the shells with pitted stones. The findings from our turban snail collection experiment were surprisingly high due to the ease with which large quantities of snails can be collected when found in a group. This seems to explain why turban snails are found in abundance alongside mussel shells in the archaeological record of the Pecho Coast despite their minimal size and the substantial processing effort required for consumption.

The results drawn from this shellfish collection experiment contradict the findings of previous research that minimize the importance of marine shellfish as a staple in the diet of prehistoric humans in California. The substantial amount of calories generated from this collection of California mussels and turban snails helps explain their prominence in the archaeological record of coastal California. The high caloric yields generated through the experiment I conducted with Tatlow demonstrates the value of open rocky coast ecosystems. Indigenous Californian foragers collecting shellfish were able to rely upon knowledge accumulated over thousands of years of occupation of open rocky coast ecosystems. Indigenous consumption practices were presumably far more efficient than experimental research can replicate, due to the sheer difference in hours spent practicing the skills required for shellfish collection.

Works Cited

Bell, Arran M.

2009 On the Validity of Archaeological Shellfish Metrics in Coastal California. Master's thesis, Department of Anthropology, California State University, Chico.

Binford, L.R.

1978 Nunamiut Ethnoarchaeology. *Academic Press, New York.*

Campbell, Breana, and Braje, Todd J.

2015 Estimating California mussel (*Mytilus californianus*) from Hinge Fragments: a Methodological Application in Historical Ecology. *Journal of Archaeological Science* 58:167-174.

Erlandson, Jon M.

1988 The Role of Shellfish in Prehistoric Economies: A Protein Perspective. *American Antiquity* 53:102-109.

Glassow, Michael A.

1992 The Relative Dietary Importance of Marine Foods Through Time in Western Santa Barbara County. In: Jones, T.L. (Ed.), Essays on the Prehistory of Maritime California. Center for Archaeological Research at Davis 10:115-128

Glassow, Michael A.

2017 Issues in the Identification of Umbos in California mussel Shell Assemblages. *Quaternary International* 427:31-35.

Glassow, Michael A., Sutton, Elizabeth A., Fernandez, Carola Flores, and Thakar, Heather B.

2016 Proxy Measurements on California Mussel Valve Length. *Advances in Archaeological Practice* 4(1):31-40.

Jones, Terry L. and Richman, Jennifer, R.

1995 On Mussels: *Mytilus californianus* as a Prehistoric Resource. *North American Archaeologist* 16:33-58.

Jones, Terry L.

1996 Mortars, Pestles, and Division of Labor in Prehistoric California: A View from Big Sur. *American Antiquity* 61:243-264.

Jones, Terry L.

2003 Prehistoric Human Ecology of the Big Sur Coast, California. *Contributions of the University of California Archaeological Society, San Luis Obispo, CA.*

Kennedy, Micheal

2005 An Investigation of Hunter-Gatherer Shellfish Foraging Practices: Archaeological and Geochemical Evidence from Bodega Bay. PhD dissertation, Department of Anthropology, University of California, Davis.

Kennett, Douglas J.

2005 The Island Chumash: Behavioral Ecology of a Maritime Society. *University of California Press, Berkeley.*

Lyman, R.L.

1994 Vertebrate Taphonomy. *Cambridge University Press, Cambridge.*

Whitaker, Adrian R.

2008 Incipient Aquaculture in Prehistoric California?: Long-term Productivity and Sustainability vs. Immediate Returns for the Harvest of Marine Invertebrates. *Journal of Archaeological Science* 35:1114-1123.

White, Greg

1989 A Report of Archaeological Investigations at Eleven Native American Coastal Sites, MacKerricher State Park, Mendocino County, California. Submitted to California Department of Parks and Recreation, Cultural Heritage Resource Protection Division.