

WAPATO FOR THE PEOPLE:
AN ECOLOGICAL APPROACH TO UNDERSTANDING THE NATIVE AMERICAN
USE OF *SAGITTARIA LATIFOLIA* ON THE LOWER COLUMBIA RIVER

by

Melissa Cole Darby

A thesis submitted in partial fulfillment of the requirements for the degree of
Master of Arts
in
Anthropology

Portland State University
1996

Table of Contents

FIGURES	ii
TABLES	iii
ACKNOWLEDGMENTS	iv
CHAPTER ONE : INTRODUCTION.....	1
ORGANIZATION OF THE STUDY.....	1
BACKGROUND.....	4
<i>Geography</i>	4
<i>Biota</i>	5
<i>Fauna</i>	7
THE PEOPLE.....	7
<i>Introduction</i>	7
<i>Language</i>	8
<i>Occupations</i>	9
<i>Settlement</i>	10
<i>Trade</i>	10
<i>Population</i>	12
THEORETICAL FRAMEWORK.....	14
<i>Research Parameters</i>	14
<i>Ecological Theories: The Ecosystem Approach</i>	15
INTENSIFICATION.....	19
<i>Intensification and Social Complexity in the Northwest</i>	20
<i>The Emergence of Intensification and Plant Domestication</i>	21
<i>Food Processing Technologies</i>	23
CHAPTER TWO :ASPECTS OF THE ECOLOGY OF SAGITTARIA SPECIES.....	26
BOTANICAL FEATURES.....	26
<i>Population Structure: The Monoecious and Dioecious Condition</i>	31
WAPATO IN THE FOOD WEB: PROFITABLE PREY.....	32
<i>Waterfowl Predation</i>	32
<i>Muskrat Predation</i>	34
<i>Summary Prehistoric Predation</i>	37
MODERN PREDATION.....	38
<i>Summary</i>	41
CHAPTER THREE : ETHNOGRAPHIC, ETHNOHISTORIC & ARCHAEOLOGICAL ACCOUNTS	42
<i>Ethnographic Accounts From East Asia</i>	43
<i>Ethnographic Accounts from the Eastern United States</i>	44
<i>Ethnographic Accounts from the Midwest</i>	45
<i>Ethnographic Accounts from the Far West</i>	47
<i>Accounts from the Northwest Coast Area</i>	48
ETHNOHISTORIC ACCOUNTS: THE GREATER LOWER COLUMBIA.....	50
<i>Men of the Sea</i>	50
<i>Lewis and Clark Journals</i>	52
<i>Accounts from the Fur Trade Era</i>	57
<i>Settler Era 1850-1870</i>	60

ETHNOGRAPHIC ACCOUNTS: THE GREATER LOWER COLUMBIA.....	61
<i>The Tualatin</i>	62
<i>Chinook</i>	64
<i>Wishram Chinook</i>	65
ARCHAEOLOGICAL CONTEXTS.....	65
<i>Great Basin</i>	66
<i>Northwest Coast</i>	67
SUMMARY AND DISCUSSION.....	67
<i>Harvest</i>	68
<i>Cooking</i>	68
<i>Storage</i>	69
<i>Seasonality</i>	70
CHAPTER FOUR :DIET AND SUBSISTENCE	72
SOME MAJOR SUBSISTENCE RESOURCES	72
SUBSISTENCE DEPENDENCE	74
DISCUSSION AND CONCLUSIONS	78
CHAPTER FIVE : WAPATO PRODUCTION ON SAUVIE ISLAND.....	79
THE SETTING: SAUVIE ISLAND	80
QUANTIFYING SURFACE AREA OF SAUVIE ISLAND	88
<i>Method</i>	88
<i>Available Harvest</i>	90
<i>Population</i>	92
<i>Cost/Benefit Analysis</i>	94
<i>Discussion and Conclusions</i>	100
CHAPTER SIX : ADDRESSING THOMS MODEL OF ROOT-FOOD INTENSIFICATION.....	102
RESEARCH DESIGN AND METHODS	102
<i>Discussion and Conclusions</i>	110
CHAPTER SEVEN : CONCLUSIONS.....	111
CHAPTER EIGHT :BIBLIOGRAPHY.....	117

Figures

Figure 1-1. Wapato Valley and the Greater Lower Columbia. _____	6
Figure 1-2. Clark's drawing of a shovelnose canoe. _____	10
Figure 1-3 Extensive wapato patch at Crane Lake, Sauvie Island _____	18
Figure 2-1 <i>Sagittaria latifolia</i> , reprinted with the permission of the Missouri Botanical Garden. (Rept. Mo. Bot. Gard., Vol. 6) _____	Error! Bookmark not defined.
Figure 2-2. Female Flower _____	28
Figure 2-3. Plant showing rhizomes and tubers. _____	30
Figure 2-4. Tubers. _____	30
Figure 5-1. Central Wapato Valley Population by Town Circa 1805. _____	82
Figure 5-2. Coast and Geodetic Survey Chart: Sauvie Island _____	89

Tables

<i>Table 2-1. Number of Identified Specimens (NISP) of remains of three small mammals at the Meier Site (35CO5). Church and Lyman, Ames et al 1995. Total NISP = 6421.</i>	36
<i>Table 4-1. Classification of wild foods mentioned in ethnographic literature from the region.</i>	73
<i>Table 4-2. Nutrient composition of selected root foods.</i>	77
<i>Table 5-1. Sauvie Island Village populations in the two versions of Lewis and Clark's "Estimate of the Western Indians" (Boyd and Hajda, 1987, Table 1)</i>	83
<i>Table 5-2. Productivity experiments by date and location.</i>	97
<i>Table 5-3. Cost/Benefit ratios of selected wild roots</i>	99

Acknowledgments

I wish to offer my heartfelt thanks to Ken Ames for his inspiration and guidance during this endeavor. I shall be forever grateful to John Kallas for his advice and support. I will always remember the professional camaraderie we shared in pursuit of the wild wapato. I would like to particularly acknowledge the assistance of Bill Kinyoun and Terry Dufour of the Oregon Fish and Wildlife Department for their support, and for giving me access to the wapato patches. I especially want to thank Bill for that great ride down the Gilbert River. I would like to thank the members of my committee for their suggestions and clarifications, particularly to Yvonne Hajda, Carol Carter and Virginia Butler. Tadayoshi Tanimoto's assistance with productivity data was invaluable, and I thank him for his help. Finally I would like to thank Denny, my husband, for his support and patience. This is dedicated to my daughter, Kathleen Rose Louise Darby.

ABSTRACT

An abstract of the thesis of Melissa Cole Darby for Master of Arts in Anthropology presented May 28, 1996.

Title: WAPATO FOR THE PEOPLE: An ecological approach to understanding the Native American use of *Sagittaria latifolia* on the Lower Columbia River.

Sagittaria latifolia Willd. was an important root food and trade commodity for the Indians who lived along the Lower Columbia River in early historic times. This plant was prolific in the extensive wetlands of the Lower Columbia from about the great Cascades to the Kalama River. The tubers of this plant were called 'wapato' in Chinook Jargon, the local trade language. The wetlands, and this plant that grew there, occupied a vast extent of the Lower Columbia territory; so much so that this valley was named 'Wapato Valley' by Lewis and Clark in 1805. This thesis will provide pertinent information on botanical characteristics, habitat, productivity, and traditional harvesting and preparation techniques of this species. Nutritional analyses show that wapato could have provided meaningful quantities of energy (carbohydrates), fiber, and trace elements.

Ecological data pertaining to this species, and ethnographic and archaeological data from North America and especially the Lower Columbia, are used to address the following research question: Was wapato intensively exploited by the Indians of the Greater

Lower Columbia River (Hajda 1984) in early prehistoric times? A test of root food intensification using ecological and ethnohistoric data demonstrated: 1) that wapato was a cost effective food to harvest; 2) that the annual productivity of this root food in Wapato Valley could have fed a larger population than was estimated to exist in the valley at contact; 3) that root-food intensification may not always be indicated by the presence of large earth ovens and ground stone tools. In this study I conclude that wapato was sufficiently productive and predictable to be intensively exploited and to function as a staple food resource. This assessment illustrates the need to reconsider some commonly accepted ideas about the intensification of root foods and the archaeological characteristics of root processing sites.

Chapter One : INTRODUCTION

Sagittaria latifolia Willd. is a wetland plant that produces starchy tubers that were once an important root food for the Indians of the Lower Columbia River. Early ethnohistoric accounts describe wapato as an essential food staple and trade commodity of the Chinookan peoples. It was also noted for its resemblance in taste and texture to a white potato, though it is typically smaller, averaging between 35 and 55 mm in length, and weighing about 7.5 grams when fully ripened.

The word 'wapato' refers to both the plant and the edible root. In historic accounts it is variously spelled: wappatoe, wapattoo, wap'tu, 'pota, and papato among others. French (cited in Zenk 1976) suggested that since some dialects of Chinook and Kalapuyan languages share the -ptu portion of the word ('wa-ptu'), that 'wapato' is actually the Chinook feminine singular form of the word (French, personal communication in Zenk 1976:85).

ORGANIZATION OF THE STUDY

This chapter (Chapter one) begins with an introduction to the subject , and geographic and environmental descriptions of the region. The next major section is a description of the people who lived along and adjacent to the lower part of the Columbia River in early historic times. The last major section of this chapter outlines the theoretical framework of this thesis, including the research parameters. This section explains why the study of the intensification of a root food in the Lower Columbia region is important. Intensification is defined as the net increase in annual food production per capita, or as an increase in the

efficiency of food production (Bender 1978). Ecological theories that are relevant to the subject are reviewed.

Ethnographic, ethnohistoric, archaeological and ecological data are employed in this thesis to address the question of whether wapato was an intensifiable and intensified food source on the Lower Columbia. The intensifiability of wapato will be assessed using five criteria under which the intensive and sustained exploitation of roots would be expected (Thoms 1989:81). Following Thoms, intensifiable roots must have the following: (1) carbohydrate-rich bulbs, corms or tubers, etc., (2) reproductive systems well-adapted to regularly churned soils; (3) extensive abundance in accessible settings; (4) readily available (relative ease of digging) and (5) resilience to environmental fluctuations (Thoms 1989:175).

In light of these criteria, Chapter Two has two main purposes. The first is to provide ecological data about *Sagittaria* species, principally relating to botanical features, reproduction and population structure. The second section is a description of wapato's place in the trophic schema, and its decline-- due in part to introduced predators. The third chapter is an overview of archaeological, ethnohistoric and ethnographic accounts describing the use of this plant in North America and Asia. This chapter contains information pertinent to root food intensification relating to seasonality, harvesting, cooking, and storage techniques employed by aboriginal populations specifically for this species. One purpose of this chapter is to describe the cosmopolitan use of the roots of this plant. There is specific emphasis on ethnohistoric accounts of wapato from the Greater

Lower Columbia region. These data will be used to address the question of intensification on the Lower Columbia.

Chapter Four will discuss subsistence on the Lower Columbia. The nutritional composition of wapato, and its place within the diet of the people of the Lower Columbia will be considered.

In order to address the questions of abundance and productivity, an ecological model of annual wapato production on Sauvie Island is presented in Chapter Five. Five aboriginal villages were located on the island in 1804. Sauvie Island was chosen for this model because a large human population was juxtaposed with a high concentration of wapato patches. In addition the island has definable boundaries, and there are good maps of the lakes and ponds and wetlands that existed in early historic times. This chapter is divided into three parts. In part one, productivity of wapato patches on the island will be calculated by hectare. Part two is a cost/benefit analysis of wapato compared to other important root foods in the Northwest. The second part of this chapter discusses human population estimates for the Lower Columbia River at contact, and in late prehistoric (pre-epidemic) times. In Chapter Six the significance of this species to the people of the Lower Columbia will be analyzed within the theoretical context of Thoms' ecological model for geophyte intensification (Thoms 1989). Chapter Seven contains a brief summary, conclusions and identifies subjects for further study.

BACKGROUND

Geography

The lower Columbia River, from The Dalles to the sea, including the area from Willamette Falls to Multnomah Channel, and from the mouth of the river north to Willapa Bay, and south to Tillamook Bay was, in early historic times inhabited chiefly by Chinookan-speaking Indians (see Figure 1-1). This area as well as the lower Willamette River region (occupied by Kalapuyan speakers from Willamette Falls south) is referred to here as the Greater Lower Columbia, following Hajda (1984). *Sagittaria latifolia* was prolific in the broadest part of the river's estuarine zone, referred to here as Wapato Valley, following Lewis and Clark. Wapato Valley begins at about the Sandy River where the Columbia River Gorge opens into a fertile basin that is surrounded on the east by the lower foothills of the Cascade Mountains. This basin extends westward to about the Cowlitz River and to Willamette Falls on the south. This region has also been referred to as the Portland Basin (Saleeby 1983, Clarke 1975).

The principal watersheds that discharge into the Columbia in the region are the Willamette, Sandy, Kalama, Lewis, and the Washougal Rivers (Clarke 1975:3). At Longview (just down river from Wapato Valley) the main channel of the Lower Columbia is approximately 0.75 miles wide, and the mean annual flow is approximately 220,000 cfs (Clarke 1975:7). The river's large discharge and minimal gradient have resulted in the development of extensive meander floodplain features including lakes, islands, and sloughs. Saltwater intrusion from the Pacific Ocean can reach as far as Longview in the summer (Terry Link, personal communication). Daily tidal fluctuations are experienced throughout

most of Wapato Valley. At St. Helens, near the northern point of Sauvie Island, the mean diurnal range is 2.5 feet, and the high water interval is 4 hours, 40 minutes (US Coast and Geodetic Survey 1930).

Lewis and Clark named this valley 'Wappato Valley' in 1805 because the plant grew "Spontaneously {sic} in this valley only" (Clark in Thwaites 1959, 3:202). Wapato stands grew dense and lush in slackwater bays, on low marshy islands in the channel, and in myriad ponds, lakes and sloughs. It was especially prolific in the many lakes and ponds of Sauvie Island, centered in Wapato Valley, at the confluence of the Columbia and Willamette Rivers. Accordingly, Lewis and Clark named this island 'Wapato Island'.

Biota

Vegetation is made up of plant communities within the Franklin and Dryness' Interior Valley Zone of western Oregon and Washington (1973:124-126). In pre-contact times much of the low land was prairie, maintained by the native peoples with the use of fire [This was done in order to preserve and fertilize important sources of wild food (Norton 1979:175-179)]. The valley floor is flat or gently undulating, and was composed of a complicated mosaic of wetland, prairie, oak savanna (*Quercus garryana*, *Salix scoulerurana*), pine-wood coppice (*Pinus ponderosa*, *Pinus contorta*), with riparian communities of cottonwood and willow along shorelines (*Populus spp.*, *Salix scouleurana*). Coniferous forests with Douglas fir (*Pseudotsuga menziesii*), Western red cedar (*Thuja*

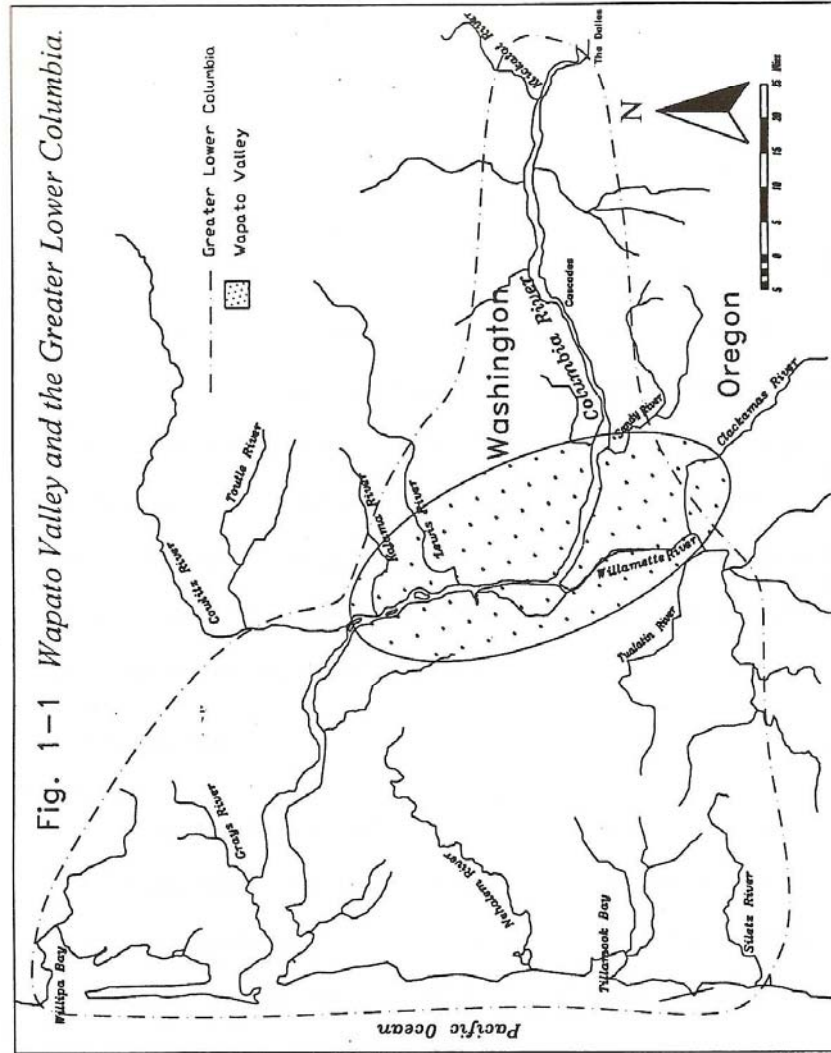


Fig. 1-1 Wapato Valley and the Greater Lower Columbia.

Figure Chapter One -1. Wapato Valley and the Greater Lower Columbia.

plicata) and many broad-leaved trees were abundant on the low foothills and slopes of the Coast Range and the Cascades, and in patches on the valley floor.

Fauna

The area supported abundant fish, bird, and mammal populations, the former two groups including significant numbers of both migratory and resident taxa. Some of the larger mammals found in this area include the Roosevelt elk (*Cervus canadensis*), Columbian black-tailed deer (*Odocoileus hemionus*), Oregon white-tailed deer (*O. vancouverianus*) and the black bear (*Ursus americanus*). Sea mammals, principally the harbor seal (*Phoca vitulina*) and sea lions can be found in the Columbia and Willamette Rivers, typically during fish runs. The principal fish are salmon (*Oncorhynchus* sp.), smelt (*Thaleichthys pacificus*), and sturgeon (*Acipenser transmontanus*). Important migratory bird species include Canadian geese (*Branta* sp.), swans (*Cygnus* sp.), sandhill cranes (*Crus canadensis*) and several species of ducks (*Anas* sp.).

THE PEOPLE

Introduction

Culturally, the people who lived along the Greater Lower Columbia occupied a portion of the southern coast of the Northwest Coast cultural area (Ames 1994). The Northwest Coast people shared some basic traits: salmon were a dietary staple; resource areas were controlled; and the people were sedentary or semi-sedentary depending on resource predictability and productivity (Ames 1994). The basic social division was between free and slave, and rank was determined by wealth and inherited status (Boyd and Hajda 1986:310).

Language

Although the Chinookan language family has no close affiliates, it has been grouped into the Penutian phylum along with Kalapuyan and Takelman (Hajda, personal communication 1996). The Chinookan language family is composed of two main languages; Lower Chinook and Upper Chinook. Upper Chinook is divided further into several dialects, though the exact number is not known. These include Kathlamet, “Multnomah”, Hood River, Wasco, Wishram and Clackamas. Lower Chinook was spoken at the mouth of the Columbia, and Upper Chinook from Kathlamet to The Dalles.

Chinook was not the only language family on the river. The Greater Lower Columbia was occupied by groups speaking languages from many linguistic stocks:

The ribbon of Chinookan peoples from the Dalles to the mouth of the Columbia was interrupted by pockets of natives bearing other family designations--the Cowlitz, a Salish people on the north bank from just east of Oak Point (Washington) to the Cowlitz River, and the Klatskanies, an Athabaskan people across the Columbia from the Salish at a point about fifty miles from its mouth (Ruby and Brown 1976:5).

Using historical records, ethnohistoric accounts and genealogies, Hajda studied regional unity and subdivision among the groups in the Greater Lower Columbia. She found that these groups were connected by links which she categorized as follows: marriage, visiting, conflict, resource collecting and trade (Hajda 1984:123). “Numerous unrelated languages were spoken, so most villages, and many individuals, were multilingual, a situation resulting from the marriage and slavery patterns,” (Boyd and Hajda 1987:310).

Occupations

The chief occupations of the people of the Greater Lower Columbia were fishing and trading. They built several types of canoes, each specialized for a specific purpose. According to Ray (1938) the finer canoes were painted red, and had inlaid shells. He describes hunting and sealing canoes, and their various paddle styles (1938). The Chinook canoe was typically twenty to thirty-five feet long with a flat bottom and a high prow well adapted for riding high waves. This style was widespread in coastal Washington and Oregon. Lewis and Clark noted that some canoes were fifty feet long. The cutwater canoe was thirty to thirty-five feet long and could carry a considerable amount of cargo. This canoe had a lower prow and an undercut stern. The double cutwater canoe was usually thirty-five feet or longer and was distinctive because it had carved figures mounted on both the prow and the stern.

Another type of canoe was the small shovelnose canoe, used for short distance forays, principally by women. Clark drew a picture of a typical shovelnose canoe from the examples he saw near the village of Neerchokioo, (Fig. 1-2) and described it as follows:

I observed small canoes which the women make use of to gather wappato & roots in the Slashes. those canoes are from 10 to 14 feet long and from 18 to 23 inches wide in the widest part tapering from the center to both ends in this form and about 9 inches deep and so light that a woman may with one hand handle them with ease, and they are sufficient to carry a woman an[d] some loading. I think 100 of these canoes were piled up and scattered in different directions in the woods in the vicinity of this house (Clark in Thwaites Vol. 4:237, spelling as in original).

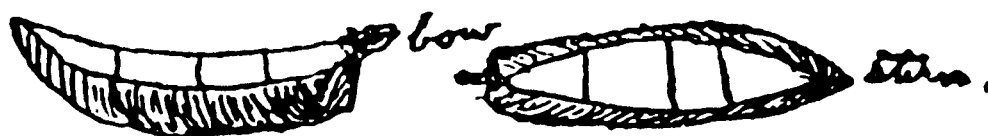


Figure Chapter One -2. Clark's drawing of a shovelnose canoe.

Settlement

Throughout the Greater Lower Columbia aboriginal settlements were in the form of either villages, containing several houses, or hamlets with only one or two permanent houses. These villages and hamlets in Wapato Valley swelled with visiting friends and relatives during resource collecting times. People came in the fall for the elk and wapato seasons, and again in the spring for fish resources (Hajda 1984:175).

Food was collected in areas controlled by people with whom the collectors had immediate consanguineal ties (Hajda 1984). Some reciprocity may have been assumed or expected. Some of these ties were created by marriages, which “were undertaken to strengthen commercial relations’---presumably, to promote trade with groups among whom one found wives,” (Hajda 1984:130).

Trade

“A thorough-going occupation with commerce dominated Chinook life,” (Ray 1938:99). They had both a currency (dentailia shells) and a trade language--Chinook Jargon. Hajda suggests that dentailia were not a currency for all goods, only for valuables in normal circumstances (Hajda, personal communication 1996). Raw materials and subsistence goods (like wapato) were exchanged for other raw materials or subsistence goods, rather than purchased with dentailia shells Trading conditions were ideal due to the juxtaposition

of a rich habitat which supplied a surplus of goods, and waterways which facilitated transportation (Ray 1938).

Wapato may have been an important attraction for foreigners during the typical time of food shortages; late winter, and early spring. In early April on their return journey Lewis and Clark reported meeting migrants from upriver that were nearly starving, and had come into the valley “in search of subsistence which they find easy to procure in this...valley,” (Thwaites 4:228,230).

A variety of goods and services were available in the region. There were three centers of trade: The Dalles, Willamette Falls on the Willamette River, and the mouth of the Columbia. Ray summarized the trade practices as follows:

From Willapa Bay to the mouth of the river steadily flowed large quantities of dried shell-fish. These were arranged on sticks of salmonberry wood, each about two feet long. From the Kwalhiokwa the Willapa Bay people received furs of the larger animals and dried meat packed in tule bags. The bay people furnished the Kwalhiokwa with shell-fish likewise; and again, with goods received from the Columbia. Home products of the Columbia, which were distributed in all directions, included dried salmon, pulverized salmon, dried smelt, dried seal meat, blubber and canoes....Some (of these products) especially blubber and canoes, were almost exclusively exports. The upriver groups brought, above all, wapato and camas to the coastal people. These foods were highly prized on the coast and were imported in great quantities (Ray 1938:99).

There was a standardization of products, as the above passage suggests for dried shellfish and dried meat. Alexander Ross mentions that dried smoked ulichans are prepared for “distant market” by stringing them head to tail, and selling them by the fathom (Ross 1966). Skarsten’s (1964) narrative of George Drouillard service as a hunter and interpreter for Lewis and Clark has a passage describing dried salmon being sold by the crate at The Dalles: “The crates were the size and shape of an apple crate and would hold from ninety to

one hundred pounds of fish...In one village Clark counted one hundred seven stacks of these crates, twelve baskets per stack amounting, possible to ten thousand pounds,” (Skarsten 1964:154). Lewis and Clark refer to procuring “parcels” and “basquits” of wapato, as well as “bushels”. There may have been a standard weight or basket size for wapato but it was not recorded.

Referring to the people of Wapato Valley, Meriwether Lewis wrote that wapato was the “principal article of traffic” traded from the people of the valley to people at the mouth of the river in exchange for “beeds, cloath and various articles. The natives of the sea coast and lower part of this river will dispose of their most valuable articles to obtain this root,” (Lewis in Thwaites 1969 4:222, spelling as in original).

Population

Prior to contact with whites, the region had one of the densest populations in America north of Mexico (Hajda 1984:67). By 1805 the people of the Greater Lower Columbia had suffered through two epidemics. These were probably smallpox epidemics, which occurred in 1775 and again in 1801. Boyd estimates that the mortality rate for the 1775 epidemic was minimally 33%, and suspects that the mortality rate in 1801 was slightly less because some individuals had developed an immunity in the previous epidemic (Boyd 1985).

Lewis and Clark estimated the population from the mouth of the Columbia to The Dalles in 1805-6 to be 27,000 or 18,040 depending on which of their estimates is used (Hajda 1984:70). These figures are derived from two sources: Clark’s “Estimate of the Western Indians (Thwaites 1969 6:113-120) and an unpublished estimate of Clark’s based

on figures obtained upon arrival in the region in the fall of 1805. Boyd and Hajda suggest both estimates are correct, and reflect seasonal fluctuations in population (Boyd and Hajda 1987).

The people of the Greater Lower Columbia were felled in great numbers by subsequent epidemics. In sequential order these were: probably smallpox or measles 1824-1825; malaria 1830-1832; dysentery 1844; measles 1848; and smallpox 1853 (Boyd 1985:270). The malaria epidemic in the 1830's was incredibly devastating, depopulating whole villages. Between 1805 and 1840 over 86% of the total native population was lost to disease.

Summary

This brief overview of the people of the Greater Lower Columbia made the following points: 1) The Greater Lower Columbia valley was occupied by several linguistically diverse groups; 2) Outside groups had access to food resources in Wapato Valley; 3) These groups typically had blood or marriage ties to the local permanent population; 4) resource areas were controlled; 5) Trade was formalized with a trade language, a currency, and standardization of products; 5) in late prehistoric and early historic times this region had a dense population which was subsequently reduced by epidemics.

THEORETICAL FRAMEWORK

Research Parameters

The study of subsistence practices on the Northwest Coast is of theoretical interest , for the following two reasons identified by Suttles:

First, their rich, maritime, temperate-zone habitat is a type in which few food-gathering peoples survived until historic times, partly because this very type of habitat elsewhere saw the growth of more advanced forms of subsistence. Second, the Northwest coast peoples seem to have attained the highest known levels of cultural complexity achieved on a food-gathering base and among the highest known levels of population density (Suttles 1969:56).

“Changing subsistence practices, including the relative roles of salmon and other resources in the diet, are major issues in Northwest archaeology,” (Ames et al. 1995:104). Evidence of wapato use in both time and space is necessary to address change in subsistence practices. Due to poor preservation of plant tissues in archaeological contexts, evidence of wapato use before white contact is scant. This thesis addresses whether wapato was an intensifiable resource within a specific time period and place: the Greater Lower Columbia at contact and in early historic times, circa 1790-1840.

Intensification is defined as the net increase in annual food production per capita, or as an increase in the efficiency of food production (Bender 1978:205-206). Resource intensification is a process by which the total productivity per areal unit of land is increased. The intensification potential of a resource is assessed by resource abundance, predictability, stability, and distribution over the landscape. Abundance has been described in qualitative terms such as “bountiful” runs of salmon and “vast quantities” of roots (Saleeby 1983:154). What is needed is a more quantitative approach to determine abundance.

This paper analyzes primary production of wapato roots using the “human ecosystem approach” as defined by Butzer (1990) to elucidate the role of wapato as an intensifiable food source exploited by Indians of the Lower Columbia region. This approach analyzes ecological data, archaeological data, and information from historical sources within a theoretical framework of ecology and systems theory.

I begin this section with a general overview of ecological theory. The next section is a discussion of intensification and the increased complexity of hunter-gatherer groups, including groups in the Northwest. Next, is an overview of general theories and models addressing the transition of groups from complex hunter-gatherers to agriculturists. Included in this section is discussion of tools as indicators (in archaeological sites) for plant food intensification.

Ecological Theories: The Ecosystem Approach

This paper uses Butzer’s ‘human ecosystem’ approach to the research and evaluation of wapato on the Lower Columbia. Butzer (1990) emphasizes an interdisciplinary methodology. He demonstrated the value of using contemporaneous written records and other historical data, combined with archaeological data, in order to elucidate how economic structures functioned, and to answer research questions. Written records had, of course, been used by archaeologists in North America, Europe, the Middle East and elsewhere. What Butzer proposed was collecting and setting up the data so it could be analyzed within an ecological theoretical framework. This way, written records can be used to test human ecological models through time and space, and on various scales (Butzer 1990).

Written records of explorers, traders, missionaries and settlers, and ethnographic accounts are used in this study of *Sagittaria latifolia* use on the Lower Columbia.

Descriptions of vast patches of wapato on the Lower Columbia in many of the accounts led to field investigations which located isolated large stands of wapato (Fig 1-3). Ecological data was collected from the field, and analyzed within an ecological theoretical framework.

Information found in historical records and accounts is applied to questions of intensification, seasonality, and artifact and features types. Ethnohistoric descriptions of harvesting assisted this worker in reconstructing harvest methods, which led to estimates of harvest time and production.

Butzer's ecosystem approach had its roots in previous work. In 1953 the modern concept of the 'ecosystem' crystallized in Eugene Odums's *Fundamentals of Ecology*. He defined the ecosystem as an organizing principle emphasizing obligatory and causal relationships that maintain an equilibrium (Moran 1990:5). This work influenced a whole generation of biologists. Ecosystem research required the study of complex interactions, often in large scale units such as the polar region and the rainforest, but also within ecosystems as small as a pond. Studies of trophic levels and energy flow required quantitative techniques to measure energy flow through a system. Biologists developed ways of measuring and analyzing energy flow through trophic levels, and began modeling ecosystems.

Geertz (1963) was one of the first to apply the ecosystem approach to anthropology. He argued that "the ecosystem approach attempts to achieve a more exact specification of the relations between selected human activities, biological transactions and physical

processes by including them within a single analytical system, an *ecosystem*,” (Geertz 1963:3, Geertz’s emphasis). Environmental, geographical and cultural deterministic approaches in anthropology that had previously been popular, were questioned in light of the holistic emphasis of systems theory that the ecosystem approach necessitated.

Ecosystem models measure energy flow and materials through a generalized ecosystem, and provide a way of testing hypotheses about the role subsistence plays in population dynamics (Belovsky 1988:330). Optimal foraging models, intensification models, predictive settlement and subsistence models, economic models, and others, became devices to explain the human condition in the past.

The use of the ecosystem approach as applied to human behavior was rooted in organic analogy (Moran 1990:6). As Winterhalder points out, the ecosystem approach was attractive to anthropologists for a number of reasons, including that “It was elaborated in terms of structure, function, and equilibrium that suggested the possibility of common

Figure 1-3 Extensive wapato patch at Crane Lake, Sauvie Island



Figure 1-3 Extensive wapato patch at Crane Lake, Sauvie Island

Figure Chapter One -3 Extensive wapato patch at Crane Lake, Sauvie Island

principles in biology and anthropology” (Winterhalder 1984:302). Ecological models are dynamic, and their predictive power for explaining developments through time and space was compelling. However, models based on organic analogy often failed to predict human behavior. Human behavior, always the wild card, proved difficult to model even when the ‘optimal solution’ seemed clear (for example see Reidhead 1980). Butzer argues that the use of the ecosystem approach in anthropology requires the use of some restrictions because human ecosystems differ from biological ecosystems, in kind as well as degree (Butzer 1990:93).

INTENSIFICATION

Introduction

The study of the intensification process in various settings and with various plants helps us understand the function and evolution of past agricultural systems, increased complexity of hunter-gatherer groups, sedentism, advances in storage techniques, food processing technology, and the development of agriculture. The study of wapato intensification on the Lower Columbia by the Chinook is relevant to the above questions. The following section introduces several theories about how social complexity developed in the Northwest.

Intensification and Social Complexity in the Northwest

The relationship between the development of social complexity and intensification of resource use on the Northwest Coast has recently been a major topic of theoretical interest. Several authors have proposed models to explain the development of social complexity of Northwest Coast hunter-gatherer societies. A brief review of their models is presented below. The intensification of salmon is a component in each of these models.

Fladmark argued that complexity on the coast resulted from the exploitation (intensification) of regular, large salmon runs which began on the coast ca 5000 B.P., when post-glacial sea levels and river drainage stabilized (Fladmark 1975:vi). Schalk argues that salmon storage and preservation technology was the cause of complexity (Schalk 1977). Arnold has recently proposed that advances in water transportation technology affected the degree in which prehistoric peoples became maritime oriented and hierarchically organized (Arnold:1995). She uses the Northwest Coast as an example. She argues that the ramifications of “advanced water transport technology” (i.e. good canoes) include political, symbolic and practical impacts. Among the practical impacts she explores are the opportunities availed for intensifying subsistence, communication, networks of exchange, and hierarchy through advanced boat technology.

Burley’s model of the development of complexity is based on his study of the Marpole culture, a culture history unit described for the Gulf of Georgia area, coastal B.C. He suggests that complexity occurred along streams, in part because salmon exploitation was easier in streams, particularly the Fraser River, rather than on the coast proper (Burley

1980:74). Matson suggests that intensification, sedentism, and ownership of patches evolved when resources were sufficiently abundant, predictable, and limited geographically and temporally (Matson 1983:142). Since not all groups had access to the same resources, inequalities would occur between groups and individuals within a group. This would result in a ranked society.

Ames (1994) has proposed a multivariate and dynamic model explaining complexity as an interplay among the following variables: circumscription, specialization in salmon and other resource-collection methods, population growth, sedentism, and ritual promotion (Ames 1994:212).

The Emergence of Intensification and Plant Domestication

Intensification requires an ecosystem where flora and fauna flourish. According to a model put forward by Harris (1977), the dynamics of an emergent stable agricultural system would include a generalized ecosystem with high species and pattern diversity, crop ecology that lends itself to intensification, and the intensive management of the resources within the ecosystem. Abundance and predictability are key variables necessary for intensification of plant foods.

Binford (1983) postulated that hunter-gatherer groups were in equilibrium systems homeostatically regulated below the carrying capacity of the local food supply. He inquired if there was no adaptive pressure to increase the food supply, what was the stimulus? According to Binford there could be only two sets of conditions that lead to increased productivity: 1) A change in the physical environment which brings about a reduction in the

biotic mass of the region, which would stimulate the population to intensify their efforts at food procurement; 2) Change in the demographic structure of a region which brings about the impingement of one group on the territory of another (Binford 1964:328). Binford postulated that agriculture would arise at the boundaries (tension zones) where the lands of less sedentary groups were in the process of being occupied by other groups from more sedentary populations.

Binford's observations of the change from mobility to sedentism among the Nunamiut led him to postulate that demographic consequences led to plant intensification, and eventually agriculture. He saw a worldwide pattern of a reduction in mobility as being an integral part of the change from subsistence based on wild foods to one based on domesticated foods (Binford 1983). Binford's work influenced David Harris who postulated a 'stress model' of the transition from hunter-gatherers to agriculturists (Harris 1977:189).

Rindos suggests that there is a co-evolved relationship between plants and primates (Rindos 1984:127), and that several centers of agricultural origin independently emerged. Therefore, according to Rindos, there must be some aspect inherent to agriculture that is the factor responsible for the elaboration of developed agricultural systems. Plowing, weeding, harvesting, storage and planting are farming techniques that affect the environment in which a cultivated plant grows. According to Rindos, the origin of agriculture is due in part to the origin and development of these techniques. Clearing the land and weeding removes competing plants, increasing the plant's dependence on human protection. Planting introduces uniform germination, but also reduces variation. The result of some or all of

these techniques was that there was a growing specialization in diet, and society gradually became dependent on agriculture (Rindos 1984:267).

Chang discusses environmental change on the macro scale to explain changes in intensification patterns. He argues that after the last glacial period in Asia, a hypisthermal was reached between about 8,000 to 4,000 B.P. which resulted in a moist environment with thicker vegetation, and a greater abundance of faunal and floral resources than had been found during the previous glacial advance (Chang 1979:176).

One of the great theorists who addressed the advent of agriculture was Carl Sauer, who proposed the earliest cradle of agriculture to be Southeastern Asia (Indochina and India) (Sauer 1952). His model described the first farmers as fisherfolk who lived in a wooded and organically diverse environment on freshwater streams. These people grew crops vegetatively, rather than by planting seed. He reasoned that since plant cuttings are identical to the parent, selection of traits was easy: one just planted part of the parent to produce a clone. Over time this led to plants that lost their capacity to bear viable seeds.

Food Processing Technologies

The development of food processing technologies is of theoretical interest in the context of the development of plant intensification. Meat from big game species was a major dietary staple for people during the Pleistocene period while the human population was small in relation to the biomass of available fauna (Eaton and Konner 1985:284). By the end of the upper Paleolithic, plants were being intensified, as evidenced by the tools found in sites from this period. In the new world, root foods are believed to have not been a dietary staple for humans until 7,000 to 8,000 years ago (Cohen 1977). The change from a

meat-based diet to one that included more vegetables is attributed to population growth and circumspection, overhunting, and climatic change (Eaton and Konner 1985:284).

In archaeological sites where root foods were exploited, Thoms argues that tools for mashing fresh roots and tools for grinding dried food or grains would likely be present (Thoms 1989:87). The tool types he describes that are commonly associated with plant exploitation include grinding stones, mortars, pestles, manos and tools for their manufacturing and maintenance. Also in the stone tool assemblage would be components for digging sticks such as stone tips and weights, and worked bone and antler handles. A variety of simple chipped stone knives and scrapers for slicing, peeling and trimming of vegetables would also be indicators.

In addition to artifactual correlates, Thoms proposes that certain features also are correlates of root food intensification:

Bulk processing of lily family and other geophytes tends to entail the use of substantial storage facilities as well as large earth ovens, the use of which should result in the massive accumulation of byproducts, always charcoal and commonly fire-cracked rock. Processing sites tend to be located either near procurement sites or well-removed from residential structures (Thoms 1989:120)

These correlates are part of Thoms' general model of geophyte intensification.

Thoms states that the utility of his model is subject to assessment using data for any wild edible geophyte that grows in northern settings. Thoms model is assessed using ethnohistoric and ethnographic data relating how *Sagittaria latifolia* was processed, what tools were necessary, and if procurement sites were away from residential structures.

My research demonstrates that wapato does not require processing with grinding or mashing tools, or tools for cutting or trimming. Nor did wapato require large earth ovens,

or masses of fire cracked rock. Ethnohistoric evidence presented in Chapter 3 demonstrate that wapato was most often baked, and eaten whole. This leads to the conclusion that the intensification of roots may not always be indicated by the presence of large earth ovens, and ground stone tools.

Chapter Two :ASPECTS OF THE ECOLOGY OF SAGITTARIA SPECIES.

Botanical Features

For botanical nomenclature and taxonomic classification I referred to Hitchcock and Cronquist (1994), Gilkey and Dennis (1980) and Smith's "A Revision of the North American Species of *Sagittaria* and *Lophotocarpus*," (1894). Some of the following observations are my own. I have studied two taxa of *Sagittaria* species on the Lower Columbia River: *Sagittaria latifolia* and *Sagittaria cuneta* Sheld. The former is a larger plant, and more prolific than the later, which tends to grow in sandy substrates, from about the Cascades to The Dalles. The tubers of both species were used by the Indians of the Lower Columbia. This study focuses on the more common taxa, *S. latifolia*. (Figure 2-1, 2-2).

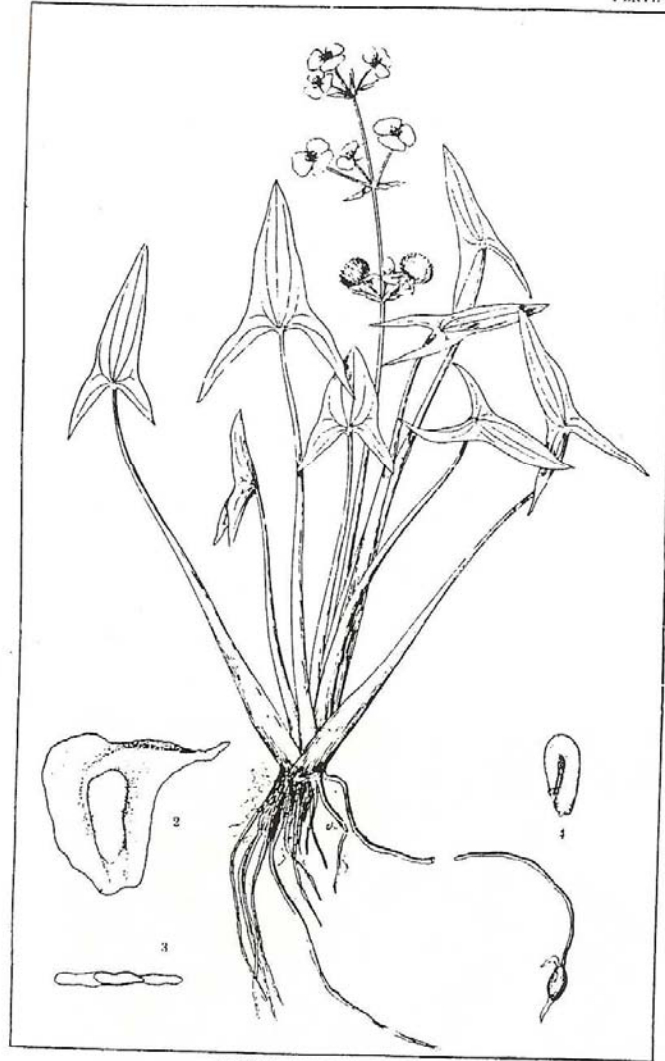
Sagittaria latifolia is a species of water plant of the water plantain family, Alismataceae. This genus is widely distributed across North America, from Newfoundland to Mexico (Smith 1894). Wild populations of *Sagittaria latifolia* are not abundant in many parts of its former range in the Northwest, though it was considered common on the Lower Fraser River and the Lower Columbia River prior to the 1880's.

The Army Corps of Engineers conducted a survey of aquatic macrophytes of the Columbia and Snake River Drainage. Their descriptions of the occurrence of this plant are

Figure 2-1. *Sagittaria latifolia*, reprinted with permission of the Missouri Botanical Garden

REPT. MO. BOT. GARD., VOL. 6.

PLATE 5.



SAGITTARIA LATIFOLIA, c.

Figure 2-1. *Sagittaria latifolia*, reprinted with permission of the Missouri Botanical Garden

a measure of the abundance of this water plant in several locations. They referred to *Sagattaria* spp. as a “nuisance” species in at least one lake or waterway in each of the following counties: Harney County, Oregon, Elko County, Nevada, Kootenai, Adams, Valley Counties in Idaho, and Flathead County, Montana. A “nuisance occurrence” of this taxon was when growths were “aesthetically offensive”, impeded water flow in channels, clogged water intakes, hindered boating or swimming (Falter et al 1974).

Some of *S. latifolia*'s common names include tule potato, duck potato, arrowhead (after the arrow shaped leaf blades) and swan potato. It grows in shallow water (up to four feet in depth), and on the margins of lakes between seasonal high and low water lines, as well as in slow streams and perennial wetlands. It ranges from sea level to timberline.



Figure Chapter Two -4. Female Flower

It is a perennial herb with an erect growth habit. The leaves are sessile, and long-petioled, meaning that they emerge from a single base (a thickened rootstock) at ground level, and have long leaf stalks that do not branch. The leaves are sheathing, and glabrous; smooth and without hair or glands. Though all the leaf forms are three-lobed and sagittate, there is some variation in form and size. “As in most aquatics, the leaves vary through wide limits in the same species, and characters founded on leaf differences, at least among the *Sagittifoliae*, are of little value,” (Smith 1894:29). The plants can grow to 150 centimeters tall, but are typically a meter or less. Leaves of *S. latifolia* can be as long as 25 cm., and almost that broad (Smith 1894, Hitchcock and Cronquist 1994). The flowers are white, in whorls of three petals, on a simple leafless raceme (Fig. 2-2). The flower stem can have as many as ten whorls. There are generally between 25-40 stamens on male flowers. The fruiting heads grow to 25 mm in diameter. The fruit is an achene.

The overwintering part of this plant is a tuber [Thoms 1988: 47, as adapted from Craighead, Craighead, and Davis (1963 xxvii-xxvi)]. In *Sagittaria spp.*, tubers are formed on the ends of rhizomes, which are horizontally creeping stems (Figure 2-3). These slender white rhizomes can be as long as four feet, but are typically less than three feet. If a rhizome is broken into several fragments, each fragment is capable of producing shoots above and roots below. The rhizomes have a pointed tip at the distal end which eventually forms into a tuber. This rhizome also assists the plant to spread. During the spring and mid-summer, these tubers (still attached to the mother plant through the rhizome) produce

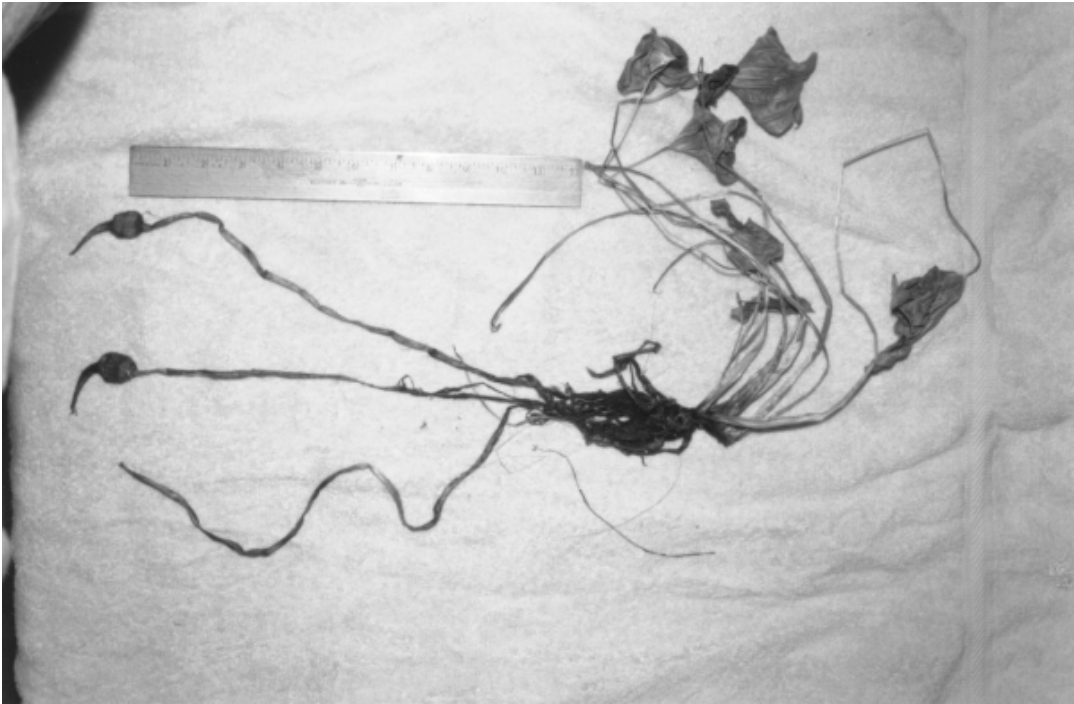


Figure Chapter Two -5. Plant showing rhizomes and tubers.

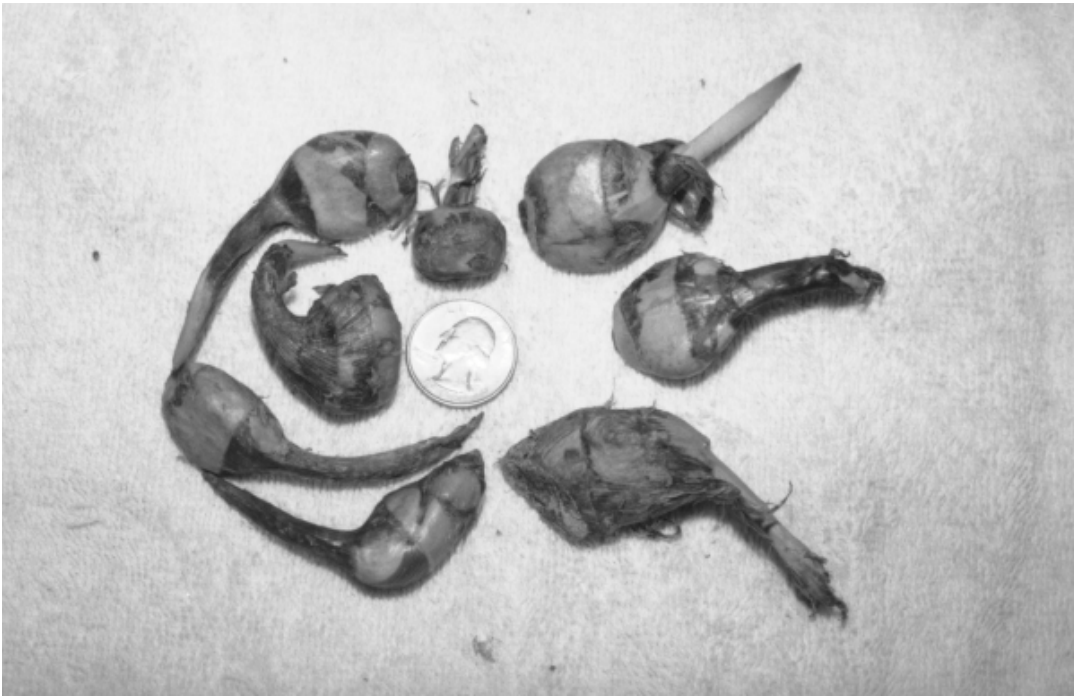


Figure Chapter Two -6. Tubers.

other plants. By late August on the Lower Columbia, these tubers cease to send up shoots, rather they thicken and develop into the starchy overwintering organ (Fig. 2-4). In the fall and spring, these enlarged tubers have the ability to float. Not all tubers are buoyant at any one time. This may be dependent on where the tuber is in its maturation process, or whether it is growing on a lake margin or submerged (some of the tubers that were harvested in November and December (1994) from hydric soils on the margin of Steelman Lake did not float).

Population Structure: The Monoecious and Dioecious Condition

A usual part of the specific description of this species is to note the prevalence of dioecious populations. This species is typically dioecious (meaning that individual plants are a single gender, not both) in the Northwest, and parts of its northern range, from Prince Edward Island to British Columbia and southward to New York, Kentucky and Nebraska (Smith 1894:38). There is some overlap in range between the monoecious and dioecious varieties. In its southern range, from Massachusetts west to Colorado, and south to Florida and Louisiana, it is typically monoecious, (having male and female flowers on the same plant).

Since plants are either male or female, the structure of the population in an ecosystem is divided by sex. At Steelman Lake and Crane Lake on Sauvie Island, the population structure is ordered in a mosaic pattern, with patches of male plants adjacent to patches of female plants. The patches vary in size generally from ten to twenty meters in diameter. The edges of the patches are distinct, the sexes do not intermix. Wooten studied a dioecious *S. latifolia* population in a pond that was composed of approximately 500

female plants on one side of the pond, a population of about 1000 *Sagittaria cuneta* plants in the middle of the pond, and 300 male *S. latifolia* plants on the other side of the pond. In their study of the plant, Muenchow and Delesalle observed that a patch several meters wide and consisting of more than a hundred ramets (clones) can be a single genet. They noted that single gender patches are often that large (Muenchow and Delesalle 1992).

From her experiments on *Sagittaria latifolia*, Wooten concluded that dioecious populations of this species produce seeds that do not readily germinate, and that the plants reproduce vegetatively, and spread clonally (Wooten 1971).

WAPATO IN THE FOOD WEB: PROFITABLE PREY

The following section discusses wapato predation by waterfowl, muskrats, pigs, cattle, and carp. Understanding wapato's place in the trophic schema is important to understanding the historic environment of Wapato Valley and the current status of this plant. *Sagittaria spp.* are r-strategists, that is, they produce many more offspring than survive to reproduce, thus providing an abundance of food for their predators. This section illustrates that this abundance of wapato supported other predators besides humans. The estimated impact of waterfowl predation on below-ground biomass calculated in this section will be applied to the model of available wapato productivity presented in Chapter 5. Also in this web was the muskrat. Muskrats favor the roots and rhizomes of marsh plants, and were once a common animal in the Lower Columbia estuarine zone.

Waterfowl Predation

In fall and spring as many as one million ducks, geese, and swans arrive on the Lower Columbia. Modern aerial waterfowl surveys count as many as 100,000 ducks, geese

and swans present on any day in November and December on Sauvie Island during peak migration (Oregon Fish and Wildlife Statistics 1994).

Wapato is an important food for several waterfowl species. Hunters noticed that when wapato became all but extinct (as discussed later) on the Lower Columbia in the 1890's, canvasback ducks also all but disappeared (Anonymous, Oregonian 1898). Lewis and Clark noted that swans particularly favor wapato. Wildlife managers on Sauvie Island have reported that swans are commonly found grazing in wapato patches. They have also been observed grazing in agricultural fields where potatoes are growing (Terry Dufour, personal communication).

Water fowl and *Sagittaria spp.* have co-evolved in a mutually beneficial relationship. Waterfowl grubbing breaks up rhizomes which float away and produce new plants. This activity also releases tubers from the substrate. Those that are not eaten reestablish themselves. Waterfowl also assist in dispersing the seeds, which stick to the skin on their feet and legs.

Several studies have estimated the impact of herbivores on net below-ground primary production of various wetland plant species. These studies found that even though large amounts of plant material are removed by waterfowl in tidal and freshwater marshes, marsh vegetation is resilient and the effect of waterfowl grazing on the primary production of biomass is minimal.

Smith and Odum estimated that snow geese removed an average of 58% below-ground biomass in coastal salt marshes of the Atlantic Coast (1981 as quoted in Giroux and Bedard 1987). In a study of food habits of wintering canvasbacks in Louisiana, Hohman et

al. (1989) found that dry mass of *Sagittaria latifolia* tubers and American bulrush rhizomes in sites ungrazed by ducks was four times as high as the disturbed sites. Hohman and his colleagues found that canvasbacks have minimal effect on reducing the density of plant foods because duck herbivory was patchy; the area of mud flats remaining undisturbed was greater than the disturbed area (Hohman, Woolington and Devries 1989).

Giroux and Bedard (1987) conducted an experiment to estimate grazing damage from waterfowl use on the wetland plant *Scirpus americanus*. Using an equation relating above-and below-ground biomass, Giroux and Bedard estimated that after two years of goose exclusion, the below-ground biomass in grazed plots of *Scirpus americanus* was 252 dry grams per square meter per year. The ungrazed plots yielded 661 dry grams. Geese had removed approximately 62% of the below-ground biomass. Even in the most intensively grazed plots, Giroux and Bedard found that there was no gradual decrease in net above-ground primary production. It was fairly constant per square meter per year over three years. They concluded that the system was a low level steady-state, even with a 62% reduction of below-ground biomass.

Muskrat Predation

Musk rats (*Ondatra* spp.) were once common in *Sagittaria* habitat on the Lower Columbia. This habitat was extensive, so it follows that muskrats were numerous. This section looks at the importance (previously undescribed) of muskrats to the peoples of the Lower Columbia. Musk rats may have been an important winter food source, as well as a good source of pelts. Blankets made of muskrat pelts are reported in the ethnographic

literature, where they are described as items traded out from Wapato Valley to peoples on the coast (Clark in Thwaites Vol 3).

Muskrats live in marshy environments, and make their low, conical lodges from the stems of marsh plants. They can produce as many as fourteen offspring per litter. Muskrats gather *Sagittaria spp.* roots and store them for the winter. Ethnographic accounts from the Midwest recorded that muskrats and beaver store large covered caches of the root, which the Indians recognized and appropriated, which saved them the trouble of collecting it themselves (Smith 1923:254).

The effect of furbearer predation on *Sagittaria latifolia* production in Wapato Valley is unknown. According to Clark and Kroeker, “muskrats are the most significant resident vertebrate consumer of emergent vegetation in many North American wetlands, and their feeding activities may play an important role in vegetation decomposition” (Clark and Kroeker 1993:1620). At times, muskrats can exceed the carrying capacity of a marsh resulting in ‘eat outs’ of emergent vegetation (Clark and Kroeker 1993:1621).

In their description of the clothing of the Indians at the mouth of the Columbia, Lewis and Clark mention “they procure a roabe from the nativs above [in Wapato Valley], which is made of Skins of a Small animal about the Size of a cat, which is light and durable and highly prized by those people,” (Clark in Thwaites Vol. 3:242, my brackets, spelling as in original). Paul Kane describes the clothing of the Chinook men as consisting of “a muskrat skin robe, the size of our ordinary blanket, thrown over the sholder, without any breechcloth, moccasins, or leggings,” (Kane 1968). Women, he noted, wear the blanket in very severe weather.

Blankets made from woodchuck or groundhog pelts are mentioned in several stories taken down by Boas (*Chinook Texts* pp. 220, 231, and *Kathlamet Texts* pp. 51).

Woodchucks and groundhogs are not found in Chinook territory, and Ray suggests that these robes and blankets were most likely made from the pelts of mountain beaver (*Aplodontia*) or wood rat (*Neotoma*) (Ray 1938:45).

Table Chapter Two -1. Number of Identified Specimens (NISP) of remains of three small mammals at the Meier Site (35CO5). Church and Lyman, Ames et al 1995. Total NISP = 6421.

GENUS	COMMON NAME	NISP	Frequency
Alplodontia	mountain beaver	7	.001
Neotoma	wood rat	1	.000
Ondatra	muskrat	374	.058

Archaeological evidence from the Meier Site (35CO5) excavations in 1973 and 1987-1991 clearly indicates that the muskrat was taken in larger quantities than either the mountain beaver or the wood rat (see Table 2-1). In addition, muskrat is the third most frequently recovered mammalian taxa, after deer (*Odocoileus*) and elk (*Cervus*) with NISP values of 3,780 and 935 respectively (Ames 1995, Table 3)

A population density study of muskrats at Delta Marsh in Manitoba, Canada found that the average density was .4/ha in May and 21.3/ha in October (Clark and Kroeker 1993:1625). This study also found that adult muskrats (living in a stable environment) did not lose mass over a typical winter, and juveniles gained weight.

The density of muskrats and their eating habits on the Lower Columbia have not been studied. The above data from Manitoba may not be directly applicable, but raises some questions about the importance of this animal to the people of the Lower Columbia.

If the above densities and animal biomass data are applicable to the Lower Columbia, muskrats could have provided fresh meat--rich in fat--during the winter months when fish were scarce, and large game animals were lean. To what extent the Indians used muskrat meat remains unclear, and is a subject for further study. Clearly the Indians utilized muskrats, and muskrats were common in *Sagittaria* habitat.

Summary Prehistoric Predation

In ecological terms wapato is a 'producer' and an r-strategist. Wapato provided an abundance of food for its predators. Although annual waterfowl predation was significant, early historic accounts from the Lower Columbia and ecological data suggest that a sustained yield situation (for wapato) had been maintained.

Annual waterfowl herbivory reduced the annual net below-ground biomass of *Sagittaria latifolia* by a factor of approximately 60%. This estimate will be used in the model of productivity presented in Chapter 5. Given the lack of study of muskrat feeding habits, the annual biomass loss due to muskrat predation in *Sagittaria latifolia* habitat on the Lower Columbia is difficult to assess. For the purpose of this study, their effects are assumed to be negligible. However, I wanted the reader to be aware of the presence of muskrat in the trophic schema.

MODERN PREDATION

No discussion of *Sagittaria latifolia* would be complete without a discussion of why wild populations of wapato are presently not abundant in many parts of its former range. This is due to wetland abatement practices, introduction of domestic animals, and infestation of the Lower Columbia waters by carp (*Cyprinus carpio*).

Domestic hogs were in the region as early as 1811 when the Pacific Fur Company established a trading post at Fort George. They brought with them 50 hogs (Franchere 1967:44). This company merged with the Hudson's Bay Company. In the 1830's the HBC established a farm on Wapato Island, (later named Sauvie Island) and set a few hogs loose on it. Thomas J. Farnham traveled through the Oregon country in 1839. This is how he described the island: "The Hudson Bay Company, some years ago, placed a few hogs upon it, which have subsisted entirely upon roots [probably camas and wapato], acorns, &c. (sic) and increased to many hundreds" (Farnham 1906:14). On a boat trip from Fort Vancouver to Cowlitz, his group stopped on the island for lunch. "Having eaten our cold lunch, we left Wappatoo Island to the dominion of its wild hogs, and took again to our boats" (Farnham 1906:67).

Swedish botanist Peter Kalm observed a similar situation on travels in Pennsylvania and New Jersey in 1770. He described how the Iroquois harvested the tubers of *Sagittaria latifolia*, and noted that these roots used by the Iroquois "were said to have been almost destroyed by hogs, which were exceedingly greedy for them. The cattle are very fond of their leaves" (Benson 1770:259).

It has been my observation that a typical lake margin in *Sagittaria spp.* habitat where cattle are present has a band several meters wide where the plants grow sparingly, and those that do grow are cropped off to the ground. Plants that had spread into this band of the lake margin during high-water are at risk as the water recedes. If the substrate is firm, cattle will wade in to graze. If the substrate is unconsolidated (such as in silted-up lakes), cattle avoid it. The leaves of *Sagittaria spp.* are nutritious forage for cattle and are grown in China principally for forage (Hu 1992:265).

The predator that probably had the most disastrous effect on wapato was the carp, which lives largely on a vegetable diet. The German carp was imported by Captain John Harlow. He was the founder of Troutdale, situated where the Sandy River discharges into the Columbia. The town was named Troutdale after the ponds he stocked for the local fish markets. In 1880 he imported thirty-five carp from San Francisco. This fish was hailed as the “most toothsome table fish of them all” (Lampman 1946:11). A flood in May of 1881 washed 3000 newly hatched fry into the Columbia River. The fecund fish proved to be an ecological disaster. They destroyed much of the wapato and permanently muddied the waters.

A dozen years later *The Oregonian* reported that commercial fishermen were offering to supply carp as fertilizer in any quantity to farmers at \$5.00 a ton. Then all the lowland waters were silted by the ceaseless grubbing of the carp--never again to be clear (Lampman 1946:14).

Thomas Howell, a botanist whose family home was on Sauvie Island, noted in his book *A Flora of Northwest America* (1903) that “this species [*Sagittaria latifolia*] was very abundant along the Lower Columbia river, but is now almost exterminated by the Carp,”

(1901:679). In 1898 *The Oregonian* reported that wapato was making a limited comeback, and theorized the loss of the wapato was due in part due to a heavy silt load deposited in the great floods of the 1890's.

Sportsmen will remember that several years since the wapatoes which grew so luxuriantly in many ponds, lakes and sloughs on Sauvie's Island and in other places along the Columbia and which were the favorite food of the canvas-back duck totally disappeared. Their loss was mourned by all sportsmen, as with the wapatoes disappeared almost entirely the flight of canvas-backs they used to attract (anonymous in *The Oregonian*, OHS Scrapbook 35:43).

Carp had caused ecological disaster in other waters as well. In 1891 Lake Merced (one of the reservoirs of San Francisco) was so "roiled by carp as well nigh to be useless," (Lampman 1946:24). That year, 19 sea lions were placed in the lake.

So epic was the slaughter for the sea lions played and rioted among the carp, that men then were hired to patrol the lake and its shores, picking up the many fragments of fish that endangered the purity of the water. In 1895 the lake was seined, but no fish of any sort were found--and the sea lions had become emaciated (Lampman 1946:24).

Summary

In early historic times, domestic livestock had a deleterious effect on wapato patches. The grubbing of the carp eliminated *Sagittaria latifolia* from open water areas of its former range, such as bays, lakes, ponds and sloughs (Lampman 1946). It has been my observation that *Sagittaria latifolia* continues to flourish in silt-filled lakes and wet areas that drain to the extent that the carp are unable to reach the plants. Cattle prefer wapato foliage to grass, and will wade into ponds and on the margins of silt-filled lakes to graze.

Chapter Three : ETHNOGRAPHIC, ETHNOHISTORIC & ARCHAEOLOGICAL ACCOUNTS

Introduction

The following are descriptions of the use of *Sagittaria spp.* in East Asia, the American East, the American Midwest, the American West, and the Greater Lower Columbia. These accounts were selected because they describe traditional harvesting, preparation and storage techniques used by Native Americans and Asians for this species.

Notes on the use of this plant were from several sources. This is not intended to be an exhaustive collection of every citation of this plant in the literature, but rather a general overview of how this plant was used over a broad geographic area. Many of the references from the Midwest and the East were found in *Food Plants of the North American Indians*, published by the U.S. Department of Agriculture in 1928, and reprinted in *The North American Indian* (Thomas 1986). The preparers of this publication searched ethnographies, articles, books, and journals for references to plant foods. This publication is an excellent index that lists the resulting reference material for each plant by author, title and page. Twenty eight titles contained information on the native use of *Sagittaria spp.* The *Handbook of Indian Foods and Fibers of Arid America* provided ethnographic information on how this plant was used in California and Colorado (Ebeling 1986). *Sagittaria spp.* grow well in the South, especially Florida and Louisiana, but I was unable to obtain information on the aboriginal use of this species in these areas. Ethnohistoric accounts from the Northwest, and especially the Greater Lower Columbia region contributed detailed

descriptions of wapato harvesting, cooking techniques and trade practices. The best descriptions of wapato are from the journals of Lewis and Clark in 1805 and 1806. In the index of the Thwaites' *Lewis and Clark Journals* 'wapato' (and versions of the word) are cited over ninety times.

Ethnographic Accounts From East Asia

Sagittaria sagittifolia and *Sagittaria trifolia* are cultivated crops of China, Japan and Korea. *Sagittaria* spp. have largely been displaced by the white potato, which was introduced into China primarily by French Catholic missionaries in the eighteenth and nineteenth centuries (Anderson 1988:122). The tubers of *Sagittaria* spp. are often mentioned as being similar in taste and texture to the potato. As noted above, it is still cultivated in China principally for the use of the leaves as forage. "The use of water surfaces and wet land to produce forage in China is common, and results in good productivity," (Hu 1992:265).

Sagittaria trifolia var. *edulis* (Sieb.) Ohwi is grown in Japan and referred to as Chinese Arrowhead. The common name is 'Kuwai'. It is an important ingredient of traditional dishes for the New Year in Japan (Tanimoto 1989:345). It is typically steamed on wooden skewers, and dipped in a soy-based sauce. It is eaten by squeezing the pulp out of the skin into one's mouth, and discarding the skin.

There are three cultivars of this plant in Japan; Aokuwai, Shirokuwai, and Suitakuwai. The first two varieties originated in China. One was brought to Japan in the late 10th century by a Chinese delegate to the emperor's court (personal communication

Tanimoto 1995). The third is thought to be a domesticated variety derived from a paddy field weed, *S. trifolia* (L).

The Chinese variety, Aokuwai, is the most popular in Japan because it exhibits ‘good quality in tuber shape and color’ (Tanimoto 1993:623). However it is slightly bitter, and not as productive as the ‘paddy weed’ variety Suitakuwai, which produces small, though better tasting tubers.

The use of wild *Sagittaria spp.* in Japan in prehistoric times is poorly understood, in part because the taphonomy of root crops in general is poor. However, several Jomon sites southeast of Hida in Japan yielded the charred remains of starchy cakes made from a finely ground meal. Their outer surfaces were charred, and bore the imprints of leaves in which the cakes had been wrapped. These cakes were found adjacent to a milling stone. Researchers tried to duplicate the process. They ground and combined several plant materials, and formed them into cakes. The only cake that held together and resembled the prehistoric cakes was one made from portions of “sticky, potato-like roots” and rice and wheat grains (Aikens and Higuchi 1982:182). This “potato-like root” was unfortunately not identified in the article.

Ethnographic Accounts from the Eastern United States

The Iroquois boiled the tubers, and according to Parker, they were sometimes eaten raw “but in this state the bitter milky juice made them repugnant to anyone but a starving person” (Parker 1910:105). Peter Kalm, a Swedish botanist who traveled to North America in 1770, spent some time with the Swedish settlers in Pennsylvania and New Jersey. “Some of the old Swedes were yet alive who in their younger years had intercourse with the Indians

and had thoroughly observed their manners” (Benson 1770:258). He described the Native Americans that had formerly occupied the vicinity as farmers who cultivated corn, beans and squash, but principally relied on wild foods such as fish and game. The Iroquois name for *Sagittaria spp.* was “Katniss.” At the time Kalm visited, the Swedes still referred to the species by that name.

“The root is long, commonly an inch and a half long, and one inch and a quarter broad in the middle; but some of the roots are as big as a man’s fist. The Indians either boiled this root or roasted it in hot ashes. Some of the Swedes ate it with much relish at the time when the Indians were so near the coast; but at present none of them make any use of the roots. Nils Gustafson told me that he had often eaten these roots when he was a boy...He added that the Indians, especially the women, travelled to some islands, at about Whitsuntide, dug out the roots...while they had them they desired no other food” (Benson 1770:259).

Ethnographic Accounts from the Midwest

The Meskwaki and the Menomini people refer to the plant as wapasi’piniak, also known as ‘white potato’, and wild goose or swan potato.

This is one of their valued potatoes. The round corms are attached by a slender rootlet to the main cluster of fibrous roots, and in digging for a specimen one is very apt to detach them from their rootlets. The muskrats gather these corms for their winter store of food, and along a stream where these grow one can often find a cache of them. When the Indians find them it saves the trouble of digging them. These white potatoes are boiled, then sliced and strung on a piece of basswood string and hung in the rafters for the winter supply (Huron Smith 1923a:254).

The Ojibwe call this plant wabasi’pin which means white potato. They too would often gather these from muskrat nests or beaver dens, but they would dig for them if they

could not be more easily obtained (Smith 1932:327). These tubers were also known as a remedy for indigestion among the Pillager Ojibwe.

The Dakota called this tuber 'pshitola'; the Omaha-Ponca referred to it simply as "Si". In the Omaha myths, "Ishtinike and the Four Creators" and "How the Big Turtle Went to War" Si is mentioned. The Winnebago called it Si-poro, and the Pawnee called it Kirit (Gilmore 1919:65). These tribes, according to Gilmore, used the tuber in much the same way. It was prepared by boiling or roasting. "The Pawnee must have some other use for the plant because an old medicine-man showed excited interest when he saw a specimen in my collection, but he did not communicate to me what the use is," (Gilmore 1919:65). The Chippewa have names for *Sagittaria latifolia* and *Sagittaria arifolia* (Nutt.). These names share the same root-word which means "heron-leg" (Gilmore in Thomas 1986:125).

The Cocopa occupied the Lower Colorado river basin where *Sagittaria latifolia* grew abundantly. "They were never stored, but were gathered only for immediate consumption. This fact, plus the considerable labor involved in digging them, made the tubers the only food product valuable enough to use in gambling games," (Ebeling 1984:414).

Ethnographic Accounts from the Far West

In the *Handbook of Indian Foods and Fibers of Arid America* (Ebeling 1986), wapato is referred to as tule potato. It was “much used” for food by the Indians. This species grew “abundantly” on islands on the lower Sacramento and San Joaquin rivers. They were harvested in late summer by women pushing canoes. They were cooked whole on the embers of a fire, and skinned. This source says that the Chinese immigrants recognizing this plant, began to cultivate it for the roots (Ebeling 1986).

The Klamath of Northern California and Southern Oregon referred to the tuber as *cho-a'*. “From the fact that the tubers bear a general resemblance to those of the cultivated potato the name cho-a' was at once applied to that plant when it first became known to the Klamaths,” (Coville 1897:90). The Chewaucan River (wapato river) empties into a large marsh known as Chewaucan (place of wapato) that drains into the Lake Abert Basin in Southeast Oregon. The marsh was a traditional place to collect wapato. When Captain Fremont explored this region in mid-December 1843, he described the scene as follows:

The rapid stream of pure water [Chewaucan River] roaring along between banks overhung with aspens and willows, was a refreshing and unexpected sight; and we followed down the course of the stream, which brought us soon into a marsh, or dry lake, formed by the expanding waters of the stream... Large patches of ground had been torn up by the squaws in digging for the roots, as if a farmer had been preparing the land for grain” (Fremont 1849:593).

He noted ‘frequent trails’ and fresh tracks of Indians. He tried to see what they had been digging but was unable to find any roots.

The Modoc of Northern California were neighbors of the Klamath people. Marcella Rawe in a letter dated September 7, 1974 to author Harriet Smith, writes about how a Modoc woman dried wapato:

The wapato was about the size of a pullet's egg and almost tasteless. It was baked in its jacket and wrinkled and dark on the outside. Mrs. Moses (informant-Modoc) said that she did not think they had dried or parched that batch enough. It takes steady drying for several weeks. In a typical Indian style they had piled a couple of bushels on the sunny side of the shed, and they would turn the tubers every few days with a pitch fork. The only trouble was that it rained a lot that year and those on the bottom did not dry out (Harriet Smith 1982:3).

Accounts from the Northwest Coast Area

The Katzie of the Lower Fraser River lived in an ecosystem similar to the Lower Columbia, one very favorable to the *Sagittaria spp.*: "...the unusual extent of low, seasonally flooded lands in Katzie territory gave them an unusual abundance of several bog and marsh plants. The two most important of these were the cranberry and the wapato" (Suttles 1951:26).

The Katzie wapato harvest was in October and November. The tubers were gathered by "wading and treading on the plants, 'dancing' until they came floating up" (Suttles 1951:27). They were taken home raw and unwashed, and would keep for several months. They were baked in hot ashes as they were needed.

Some patches belonged to the Katzie tribe, while others belonged to families. Suttles informant could name nine patches that belonged to his father's family. There was also a large public patch. Families could seasonally claim parts of it by clearing tracts

several hundred feet long along the shore so the plants could be collected more easily (Suttles 1951:27).

Katzie territory was famous for cranberries and wapato, and “in the fall outsiders came from a number of other tribes to gather them” (Suttles 1951:27). Suttles’ informant said that permission was not refused to outsiders to harvest the cranberries, nor did they exact any tribute. Suttles inferred that “ownership of ...a rich cranberry bog was its own reward in that it permitted the owners to play the role of hosts. A host at one time and place is potentially a guest at another,” (Suttles 1951:27).

Haerberlin, an ethnologist, worked on the Tulalip Reservation in 1916-1917, principally with members of the Snohomish and Snoqualmi tribes of the Puget Sound lowlands of Western Washington. His manuscript and notes were edited and published by Gunther in 1930. His informants described wapato as an important and widespread food which grew in shallow lakes and streams, and further that “this plant can be easily grown and transplanted” (Gunther 1930). Gunther, in her footnote, said that “this reference is the only reference of any kind to cultivation. In 1854 the Sound Indians are supposed to have raised 11,000 bushels of potatoes. The species is not stated. These may have been ordinary potatoes, Indian potatoes or wappato,” (Gunther 1930:21, citing Gibbs).

ETHNOHISTORIC ACCOUNTS: THE GREATER LOWER COLUMBIA

Men of the Sea

The Northwest Coast was not charted until the voyages of the Spanish explorers Perez, Heceta, Bodega, and Arteaga in the years 1774 to 1779 (Darby 1991:174). In 1778, Captain Cook explored the coast for the British, purchasing sea otter skins at Nootka Sound, and sold them in China at high prices. Thus began the fur trade by sea. It was not long before both British and American vessels came to exploit this trade (Hussey 1949:3).

The first ship to enter the Columbia River was *Columbia Rediviva* in May of 1792, which was commanded by Captain Robert Gray. John Boit's log of that voyage describes a 'ground nut' that grows on the banks of the river. This reference is probably describing wapato. On May 18, Boit described the scene as follows:

The river abounds with excellent salmon and most other river fish, and the woods with moose and deer, the skins of which were brought to us in great plenty. The banks produce a ground nut, which is an excellent substitute for bread and potatoes (Johansen 1960:)

The next historical account of *Sagittaria spp.* along the Columbia River was made that same year by Lieutenant W.R. Broughton of the brig *Chatham*, which was one of the ships of the exploring squadron under the command of Captain George Vancouver. Broughton and his men rowed up the river for several days, reaching about 100 miles upstream of the mouth. On the last week of October, 1792, Lieutenant Broughton mentioned that his crew ate a "bulbous root about the size and not unlike the crocus, that ate

much like a mealy potatoe,” (Broughton 1792:39). Like Boit, he doesn’t mention a name for this root, however he was on the river during peak harvest time for wapato.

Thomas Manby, the master of the *Chatham*, also made note of this root. On November 4, 1792 while they were waiting in Bakers Bay for calm water to cross the Columbia River Bar, Manby decided to hunt water fowl in a “swamp” four miles from the cove near the mouths of the Chinook and Wallacut Rivers. He met with a small party of Indians who supplied him with salmon and “a basket of roots not much unlike small potatoes and a little inferior to them in taste” (Howay and Elliot 1942:325).

The *Ruby* crossed the Columbia River bar the first week of June, 1795. Captain Charles Bishop wrote an account of this voyage. He described their purpose as chiefly a trading episode, though during the stay “the ship was ballasted, the hold restowed, and wood and water for three months put on board” (Howay 1927:14). The captain planned to winter at the mouth of the Columbia, and had the crew plant beans, potatoes, peas and sowed mustard, cress, celery and radishes on a small island. Though there was considerable trade between the crew and the Indians, no mention was made of wapato in Bishop’s log until they returned in October for the winter. Captain Bishop’s description of wapato is as follows:

As none of us are acquainted with Bottoney, I can offer nothing on that head, but what is discribed in the account of Nootkan Productions, in Cooks voyage we found here, except the Wild Potatoe called by the natives “Wappatoe” which we have seen nowhere else, they in general are of the size of a Pidgeons Egg, and appear to grow like an onion or Turnip, above the surface of the Earth are found in swampy grounds, and when boiled or roasted, eat not unlike potatoes, but it is observed that if they continue

boiling longer than necessary they harden in the room of desolving to a flour or paste (Elliot 1927:274, spelling as in original).

The garden they had planted in the summer produced a good crop of potatoes, and a few beans. However, the crew that winter subsisted chiefly on salmon, cranberries, wapato and wild game supplied by the natives.

Lewis and Clark Journals

It is notable that though many of the explorers, travelers and adventurers that came to the Lower Columbia had considerable experience with other Native American groups, only one man, Wilson Price Hunt, a commander of the overland Astoria fur party expedition in 1811-1812, mentioned seeing wapato being used by a Native American group other than the people on the Columbia. Certainly Sacajawea of the Lewis and Clark party was familiar with this root, because when the vote was taken on where to camp for the winter, she voted to be near the wapato grounds: “Janey [Sacajawea?-ed] in favor of a place where there is plenty of Pota [sic],” (Thwaites Vol. 3: 247).

Lewis and Clark’s first encounter with wapato occurred on November 4, 1805. In Clark’s first draft he describes eating a “round root near the size of a hens egg” at a village past the mouth of what is now known as the Sandy River. The roots were roasted in the embers until they became soft (Thwaites Vol. 3:194). In his second draft describing the same day, he noted that the Chinese cultivate this plant in great quantity and it is called the common arrowhead or *Saggiti folia* [sic], and mentioned that it had “an agreeable taste and answered well in place of bread”. They purchased four bushels and divided it among their party (Thwaites Vol. 3:196-197).

They noted that it grew in great profusion on an island farther downstream. Lewis described the island as “about 20 miles long and from 5 to 10 in width; the land is high and extremely fertile and intersected in many parts with ponds which produce great quantities of the sagittaria Sagitifolia (sic), the bulb of which the natives call wappetoe, (Lewis in Thwaites Vol.3. pg 218). They named this island Wappato Island, and they named this part of the Lower Columbia Valley “Wap-pa-too Valley from that root or plants growing Spontaneously [sic] in this valley only “ (Clark, Thwaites Vol.3 pg. 202).

On November 7, two days after their original encounter with wapato, they met some Indians who took them to their village which was “Situating on the Stard. side behind a cluster of Marshey Islands, on a narrow chan. of the river,” (Clark in Thwaites Vol 3:208). Clark described the four houses that made up the village. These were described as being entirely above the ground, with eaves about five feet from the ground to the eave-line (suggesting a gabled roof) and with doors on the side of the house. Americans in New England and the South placed doors on the roof-slope side of a house rather than the gable-end, so this description probably suggests that the door was on the gable-end side. Clark also noted that the door was in a ‘corner’, i.e. not centrally located on the facade as was typical of American houses of this era. This would give the natives more unbroken length to use for storage space. Clark noted that their beds were along the walls, about four feet above ground level. This would give only one foot of head space at the wall, along the slope side of the building, but provided more storage space than if the beds were lower. Clark noted baskets of dried fish, berries and wapato were stored under bed platforms.

The party purchased some wapato roots, three dogs and two otter skins for some fish hooks. They stayed at this village one and a half hours before continuing to the main channel of the river. While they were en route, near what is now known as Tenasillihee Island, several “canoes came along Side with Skins, roots fish &c. to Sell, and had a temporey residence on this Island,” (Clark Nov. 7 1805, in Thwaites Vol. 3:209). The party landed at another village fourteen miles below the previous village, where for the second time in the same day they purchased wapato roots and a dog. Between November 7 and November 14, all the wapato and dogs had been eaten, and there was nothing to eat but pounded fish (Clark in Thwaites Vol. 3:221).

Near the mouth of the Columbia the corps traded again for wapato and other roots. Clark noted that in this region “the Wapto root is scerce, and highly valued by these people, this root they roste in hot ashes like a potato and the outer skin peals off, tho this is a trouble they seldom perform,” (Thwaites Vol. 3:240).

On November 26, Clark described the Cat-tar-bets (Cathlahma) people occupying a village of nine houses. “They live on fish & Elk and Wapto roots, of which we bought a few at a high prices,” (Thwaites Vol. 3:250).

The Lewis and Clark party wintered at Fort Clatsop on the Pacific Ocean. They occasionally were able to trade for wapato, which was a welcome addition to their diet. On December 31, they purchased one and a half bushels of wapato, for which they were grateful since they had been living on spoiled elk, which was “disagreeable to the smel. as well as the taste” (Clark in Thwaites Vol 3: 294).

On Saturday, January 4 Lewis wrote, “The hunters were all sent in different directions, and we are now becoming more anxious for their success since our store of wappatoo is all exhausted,” (Allen 1914, Vol 2:105). They record one other episode that winter when they were able to obtain wapato. On January 10 they were presented with “a basquit of woppetoe” from a chief of the Cathlamet people.

In March of 1806 they began their return journey. In Wapato Valley they stopped at a village (Cathlapohtle) near the mouth of the Lewis River, and noted an abundance of sturgeon and wapato. They camped near a pond about a mile above the village. The following description is probably from an interview.

...in this pond the natives inform us they collect great quantities of p[w]appato, which the women collect by getting into the water, sometimes to their necks holding by a small canoe and with their feet loosen the wappato or bulb of the root from the bottom from the Fibers, and it imedeately rises to the top of the water. they collect & throw them into the canoe, those deep roots are the largest and best roots (Clark in Thwaites: March 29, 1806: Vol. 4: 217, spelling as in original).

The Biddle version of this passage written in 1814, perhaps with further clarification by Clark, records that the roots were collected “chiefly by the women” who would remain in the water for several hours even in the “depth of winter,” (Allen 1914:225).

Lewis wrote that wapato is taken in great quantities from the ponds around Cahtlapohtle. It was the “principal article of traffic with those Tribes which they despose of to the nativs below in exchange for beeds, cloath, and various articles” (Lewis in Thwaites 4:222). They purchased “a considerable quantity of wappetoes, 12 dogs, and 2 Sea otter skins of these people,’ (Thwaites Vol. 4:215). On Monday, March 31 the party had reached a small hamlet belonging to the Shah-ha-la Nation (Cascades people) which they had visited

the November before. On their first visit, there were 24 straw houses and one wooden house. Lewis remarked that all these houses are destroyed.

The inhabitants [of these houses] as the indians inform us have returned to the great rapids of this river which is their permanent residence; the house which remains is inhabited; soon after we landed two canoes came over from this house with 4 men and a woman. they informed us that their relations who were with them last fall usually visit them at that season for the purpose of hunting deer and Elk and collecting wappetoe....These indians frequently visit this valley at every season of the year for the purpose of collecting wappetoe which is abundant and appears never to be out of season at any time of the year. (Thwaites Vol. 4: 223).

The above quote was from Lewis' first draft. In the second draft he states that the people who live in this house "inform us that their relations also visit them frequently in the spring to collect this root which is in great quantities on either side of the Columbia," (Thwaites Vol 4:226). The second draft mentioned that it was harvested in the spring, as well as the fall, and this information is consistent with my field observations of this plant.

Clark observed about 100 small canoes which were piled up and scattered in different directions in the woods, on the river bank and in the vicinity of the house. Clark went into the house and offered several articles to the people in exchange for wapato, but they were not inclined to trade. So he performed a trick for them. He had a one inch length of 'port fire match' which he put into the fire creating a bright colorful fire which lasted awhile and alarmed the natives. Clark also took out his magnet and ran it around his compass so the needle turned with the magnet. The natives, very alarmed, immediately placed several parcels of wapato at his feet and asked him to leave. The women and children were cowering in their beds, and an old blind man was 'imploring his god'. Clark gave them some 'smoke' and something in trade for the roots (Thwaites Vol. 4:237).

On April 7, 1806 Sergeant Gass and Collins and Windsor returned from a hunting party without the female bear they were hunting, but brought three bear cubs instead. The Indians who visited the party that day wanted the cubs and traded some wapato for them. The last mention of wapato in the journals was on April 9, 1806 when they purchased five dogs and some wapato from people who lived near Beacon Rock, on what is now the Washington side of the Columbia River.

Accounts from the Fur Trade Era

Trade goods were introduced in large quantities after 1810 when the inland fur trade began with the establishment of a small post by traders from Boston at the mouth of the Columbia River. This post lasted less than a year (Hajda 1984:39). In 1811 Fort Astoria was constructed at the mouth of the Columbia by John Jacob Astor's Pacific Fur Company. This was taken over by the Northwest Company in 1812, which dominated the fur trade on the Columbia River until 1821 when it merged with the Hudson's Bay company (Hussey 1949).

Several members of the Astorian expedition published personal narratives about their adventures on the Columbia River, including Gabriel Franchere, Ross Cox and Alexander Ross who mentioned wapato. Alexander Ross described wapato as "a perennial root, of the size, shape, and taste of the common potato, is a favourite article of food at all times of the year" (Ross in Thwaites, Vol. 7: 109). Ross Cox described the root as excellent, "In size they resemble a small potatoe, for which it is a good substitute when roasted or boiled; it has a very slight tinge of bitterness, and is highly esteemed by the natives, who collect vast quantities of it for their own use and for barter" (Cox 1957:79).

Franchere found the wapato root to be a “good substitute for potatoes,” and procured a quantity for the staff at Fort George during an upriver trade excursion in the first week of October, 1812 (Franchere 1904:278).

Wilson Price Hunt commanded the Astoria party of fur trappers who traveled overland from the Arikara villages near the present site of Pierre, South Dakota to Fort Astoria. They arrived at Fort Astoria in the winter of 1812. Hunt described a trading episode with the Native Americans of the Lower Columbia where wapato, dogs, beaver pelts, and dried salmon were received in a trade. In his journal he noted that this root is called ‘ouapasippin’ on the Mississippi (Franchere 1973).

Fort Vancouver was the headquarters of the Hudson’s Bay Company’s Columbia Department. Established in 1825, one hundred miles upstream from the mouth of the Columbia River, it was situated on the north side of the river, in the center of Wapato Valley. The river was navigable, and Fort Vancouver became an important land and sea trading center. Trade goods were imported from Great Britain, New York, and Canton via the Sandwich Islands (Ross 1979:21), and distributed to over 30 satellite posts within the HBC Columbia Department, which embraced present-day British Columbia, Washington, Oregon, and Idaho.

Five years after the establishment of Fort Vancouver, a malaria epidemic struck the region (Boyd 1985). Mortality was high, perhaps as much as 75% along parts of the lower Columbia. Sauvie Island had no villages left after 1836 (Hajda 1984:44).

On the heels of the fur traders were missionaries, botanists and government officials. Wapato occasionally received a passing note in the journals that these men kept.

Slacum was sent to the Oregon territory by President Jackson in 1835 to obtain information about the native inhabitants. He reported "...the ease with which they procure food, fish, and fowl, with the delicious vegetables the "Wapspitoo" and "Kamass" engenders the most indolent habits among these people," (Scott 1912:200).

Catholic missionary Father Blanchet mentioned that on March 11, 1841 he visited Wapato Lake "where the Indians of the Clackamas tribe were assembled to dig the wapato root on the right shore of the Willamette" (Bagley, 1932:99). The botanist, David Douglas, mentions eating wapato during an episode when he was stormbound at Cape Shoalwater (the outer coast of Washington) in October (Harvey 1947:63).

Dr. White, and his wife were missionaries to the Oregon country from 1837 to 1847. The following is a story they related in their journal about their travels. The missionaries arrived at the mouth of the river in May, and proceeded upriver in a canoe with a crew and a pilot. They decided to stop for the night. On the shore they noticed an Indian man and woman near a large fire. The Indians were so intent on what they were cooking that they didn't notice the intruders until the canoe landed. Upon seeing them, the woman fled into the forest, and the man momentarily hid behind a tree and pointed a gun at the canoe. The crew walked to the fire, and stood for a few moments. After awhile, the Indian man joined them, apparently "convinced of their inoffensiveness." The missionaries and their group settled around the fire, and the Indian woman came out of the woods and joined them. The woman served them some roasted wapatoes, which the missionaries found to be not as good as potatoes, but "as their appetites were sharpened, tasted well" (Allen 1850:59).

The Reverend Samuel Parker visited the Oregon Territory in the 1830's. In describing the geography, he mentioned Wapato Island "so called for a nutritive root found in the small lakes in the interior, which is much sought for by Indians as an article of food [Parker (1838) 1967:141].

Hall Jackson Kelly wrote that by 1834 the Multnomah Indians "who formerly occupied the Wappatoo islands, and the country around the Wallamette (sic) and who numbered 3,000 souls, are all dead, and their villages reduced to desolation (Powell 1917:294).

Settler Era 1850-1870

In 1852 James Swan left a prosperous New England business, a wife and two children, and moved to a remote part of the Northwest Coast, Willapa Bay. This is just north of the mouth of the Columbia River. He lived for three years among the Chinook, and recorded first hand impressions of many aspects of Chinook life. He writes of the wapato:

On the Columbia River, an excellent root called the wappatoo, which is the bulb of the common *Saggitafolia* or arrow-head, is found in abundance, and is a favorite food of the wild swans, which are very plentiful. The wappatoo is an article much sought after by the interior Indians, but there is none found along the coast except in small quantities (Swan 1977:89-90).

Though wapato was rare on the lowest portion of the river, it grew in the marshes a few miles upstream from the mouth. The local harvest was not enough to sustain the population, and wapato was imported from upriver to the people at the mouth.

Jim Attwell's father had a claim of 320 acres near Skamania, located just upriver from the Cascades on the Washington side of the river. However, he was born on the

Oregon side of the river. He the first male child born in Hood River County, Oregon on January 5, 1855. According to the boy, 300 Indians lived on the Skamaina area claim.

As a boy, my playmates were Indian Children. The older Indians almost considered me another Indian boy. I was often invited into their homes. Adult Indians loved their children and allowed them to do as they pleased from the time they could walk until they were teenagers (Atwell 1974:6).

He mentions that they cooked meat in a wooden bowl or a water-tight woven basket by putting red hot stones into the water. "Sometimes an herb or wapatoe was added with the meat and then the ashes and smoke on the stones helped flavor the stew," (Atwell 1974:7).

The following account is by Robert Brown, who traveled through the Northwest in 1865. He visited several groups, including the Chinook, Nisqually, the Nez Perce, Kootanie, and Colville.

The roots of the *Sagittaria sagittaria*, Linn., were at one time very extensively eaten by the Indians, under the name of Wapattoo; and on the Columbia River there is an Island called Wapattoo Island, from the abundance of this plant. Since the introduction of the potato the use of the roots of the *Sagittaria* has much declined, and the name is now transferred to the potato. In the vicinity of nearly every Indian village are small patches of potatoes; but the ground is merely scratched up, and the cultivation far from being properly attended to. (Brown 1868:379).

Later in the article he states that they have no other cultivated plant besides the potato, though he mentions that "Some of the Indians of Oregon used to grow a little wild tobacco, but they now buy it from the whites," (Brown 1868:385).

ETHNOGRAPHIC ACCOUNTS: THE GREATER LOWER COLUMBIA

Ethnographic materials for the people of the Greater Lower Columbia are quite limited, largely due to the epidemics which eliminated most groups prior to visits by

anthropologists. Fieldwork with the few survivors was limited to mainly memory ethnography (Hajda 1984:4). Though Gibbs did some ethnology in the 1850's, the first ethnographic work in the region was Albert S. Gatschet, a linguist with the U.S. Government. He spent two months among the Tualatin and others on the Grand Ronde Reservation in 1877. In 1890 and 1891 Boas was able to obtain descriptions of previous lifeways from Charles Cultee, who was Clatsop, Chinook, Kathlamet and Kwalhiokwa. This data was generally in the form of stories which Boas recorded for the Bureau of American Ethnology, under the title *Chinook Texts* published in 1893, and *Kathlamet Texts* in 1901. In 1931 and 1936 Vern Ray worked with two elderly Lower Chinook (downriver Indians) who lived on Willapa Bay. They were part Lower Chehalis, and spoke very little Chinook. His *Lower Chinook Ethnographic Notes* was published in 1938. He relied on Boas' previous work as well as ethnohistoric accounts of various aspects of the Lower Chinook culture. In 1929 and 1930 Melville Jacobs collected Clackamas Chinook myths, tales and songs from Victoria Howard, one of the last two surviving speakers of the Clackamas dialect of Chinook. Leslie Spier and Edward Sapir wrote an ethnology of the Wishram people (1930). These were upriver speakers of Chinook who lived around The Dalles.

The Tualatin

The Tualatin branch of the Kalapuyan called *S. latifolia* ma'mptu (Zenk 1976:85). The Kalapuya occupied most of the lowlands of the Willamette River drainage basin above Willamette Falls. The group living nearest to Wapato Valley were the Tualatin, which occupied upwards of 15-20 winter villages in the Tualatin Valley, which is the next major

drainage system south and west of Wapato Valley. They were participants in a regional network of economic and political interrelationships centered in Wapato Valley (Zenk 1976:5). Manifestations of this interrelationship included marriages between and Chinookan families, and the existence of the practice of head-flattening among the band of the Kalapuyan (but not Kalapuyan bands further south).

Zenk, in his thorough study of the Tualatin, noted that they were one of the better documented Kalapuyan divisions (Zenk 1976:12). In 1877 Albert S. Gatschet spent two months among the Tualatin and others on the Grand Ronde Reservation. His main informants were Peter Kenoyer, the son of a prominent chief, and Dave Yatchkawa, a shaman. Gatschet's manuscripts and notes contain information on ethnobotany, subsistence, village locations, and linguistic data. This material was reviewed and partially corrected in ca. 1915 by Frachtenberg who interviewed Peter Kenoyer's son, Louis. He left an unfinished typescript that Melville Jacobs worked on, again with Louis, in 1936. Though incomplete due to Louis' death in 1936, this material was published by Jacobs in 1945.

The ethnobotanical descriptions these informants provide for the Tualatin Valley are probably the closest reflection of how wapato was used in Wapato Valley in early historic times. The following is Zenk's rendering of Jacob's rendering of Gatschet's text based on an interview (probably Peter Kenoyer) describing the harvest at Wapato Lake:

I myself know that in autumn the wapato were gathered. The women dug them, they made holes...and they put them in it so that they could preserve them for wintertime to be eaten in wintertime. They got them at the lake, the women got (wapato) underneath the ground, they picked them up, they got them. When the lake was

overflowed we named it 'step in the water,' the women stepped in the water (Zenk 1976:56).

Zenk notes that the storage pits for wapato described in the Gatschet manuscript were four or five feet deep.

The following is a description of a wapato oven built by a Tualatin group. Though the informant is unreferenced, Evelyn Dickson interviewed several native informants for her thesis *Food Plants of Western Oregon* (1946), including John Hudson (according to Zenk 1976:57).

The Indians near Gaston, Oregon [Wapato Lake] would build a fire on top of the ground as you build a bonfire today. They, would spread the ashes apart, put the Wapato in these ashes and cover them up with more ashes. Over the top of the fire the natives spread a layer of dirt and cooked the tubers for 15 to 20 minutes. When done, the Wappato was mealy like a potato (Dickson 1946:38).

Chinook

Franz Boas collected the following story in 1891 from a speaker of the "Upper Chinook dialect which was spoken farthest down the river, from Astoria to Rainier" (Boas 1901). Famine was a concept the Chinook understood, and they took precautions to ensure that salmon would return each year. There must have been knowledge of failed runs in their cultural memory. John Kirk Townsend wrote in his journal that the Indians invariably remove the heart of each salmon they trade to the whites. Townsend said this was done for 'superstitious reasons' (Townsend 1812). The following segment is from a story about a salmon run failure, and how the plants saved the people. It is titled *Myth of the Salmon* (Boas 1901:6).

The people of mythical times were dying of hunger. They had only sagittaria-roots to eat. They had only small sagittaria-roots and skunk-cabbage and ---roots and rush

roots to eat. In the spring of the year the Salmon went up the river. They went some distance. Then the Skunk-cabbage said : “At last my brother’s son has arrived. If it had not been for me your people would have been dead long ago.”

The story continues with the Salmon people giving the Skunk-cabbage gifts. They continued their journey, and *Sagittaria* root addressed the Salmon in the same way, and identified herself as the Salmon’s aunt, saying if it weren’t for her all their people would be dead. The Salmon gave the *Sagittaria* root three woodchuck [muskrat] blankets and some dentalia. The same thing happened with the large *Sagittaria* root, except that she got five woodchuck blankets and some dentalia. The same theme is repeated with the rush root. The story ends at the Cascades. The stated moral of the story is that it takes five days to reach the Cascades from the sea (Boas 1901; No.26:50-54). An implied lesson is that plant foods, including two forms of *Sagittaria*, saved the people from starving in mythical times.

Wishram Chinook

The Wishram had several words that referred to different ‘potatoes’. Their word for wapato was wakxa’t (Spier and Sapir 1930:183). They describe a “wild dwarf potato” which may be *Sagittaria cuneta*, which grows on the Columbia River shore from about Bonneville Dam to The Dalles.

ARCHAEOLOGICAL CONTEXTS

Introduction

In archaeological sites where root foods were exploited Thoms argues that there would be tools for mashing fresh roots a variety of chipped stone knives and scrapers, and an abundance of fire cracked rock (Thoms 1989:310). Root processing sites would either be located near procurement sites or well-removed from residential structures (Thoms

1989:120). The bulk processing of camas (another important root food discussed below) required large earth ovens that were typically built near the procurement site for several reasons including minimizing the load to be taken to a storage facility, and to prevent spoilage. Wapato does not need to be cooked or processed before it is stored, so large bulk processing sites would not be an indicator of intensification.

The following descriptions are of sites where wapato has been found. Physical evidence in archaeological sites of wapato are rare. Wapato needs little processing, and was often consumed whole. Starch grain and phytolith analysis of the surfaces of ground stone tools are useful for identifying plant remains that were processed with the ground stone tools, but not ones that were not. In archaeological contexts plant tissues have a lower chance of survival than faunal materials. It is also possible that the lack of archaeological evidence for wapato exploitation indicates that wapato was not exploited.

Great Basin

There is archaeological evidence for the use of *Sagittaria spp.* from coprolites found in Dryden Cave, Nevada (Neuman et al. 1989). Analysis indicated that the prehistoric population exploited fish, freshwater tubers and seeds. The tubers were identified as *Sagittaria*, most likely from the *latifolia* species. The coprolite data suggested a lacustrine pattern of diet and subsistence at this site. The data was compared to data from other sites in Nevada and Utah. One of the sites was Lovelock Cave, where coprolites were also found to have “tuber fragments.” These comparisons suggested to the authors that many native peoples in the Great Basin foraged along lake margins.

This Lacustrine Subsistence Pattern was presumably the product of a long-term increasingly intense subsistence regime that may have developed in the Early Archaic (8000-6000 yr B.P) as a means of exploiting the post-Lahontan lakes that were prevalent in this region...The data suggests that rhizomatous plants comprised a portion of the diet for the early inhabitants of the Great Basin region and that *Sagittaria* was more likely a dietary component rather than medicinal (Neumann et al. 1989).

Northwest Coast

Macro remains of *Sagittaria latifolia* roots have recently been recovered in excavations near Puyallup, Washington at the White Lake Site (45K1438 and 45K1438A). These remains were recovered in two features. The first was a “pavement hearth”, composed of hot stones placed close together. Typically pavement hearths were used to steam food, and in the case of this hearth it was probably used to cook mussels and wapato. The second feature containing wapato was a basin-shaped pit that also contained charcoal (Lynn Larson, personal communication).

SUMMARY AND DISCUSSION

The accounts of *Sagittaria* spp. use in east Asia and North America demonstrate the cosmopolitan use of this root for food. Asian and American species of *Sagittaria* grow in similar environments and share the following botanical traits: sagittate leaves, white flowers with three petals, and the late summer production of starchy tubers. Descriptions of the taste (slightly bitter) and texture (like a potato) of the vegetable are in accordance. Chinese immigrants in California and Colorado recognized this wild plant as a relative of the Chinese Arrowhead, and harvested the roots. Widespread utilization of *Sagittaria latifolia* roots by aboriginal groups in what is now the United States is indicated by the above

ethnographic and ethnohistoric descriptions. There are some consistencies in descriptions of harvesting, cooking, storage and seasonal availability.

Harvest

Sagittaria spp. roots were harvested both by digging and by treading the substrate in shallow water. The Iroquois and groups who lived on the San Joaquin and Sacramento Rivers harvested the root on river islands. The latter two groups used canoes while harvesting (suggesting the treading method). Accounts of the Kalapuyan Tualatin, Chinook (both of the Greater Lower Columbia) and the Katzie of the Lower Fraser River also describe how women treaded on the substrate until the roots floated up to the surface of the water. The Klamath dug for the roots on the banks of the Chewakan River. The Cocopa of the Lower Colorado river also reportedly dug the roots. Some of the midwest Indians collected the roots from muskrat and beaver caches.

Cooking

A variety of cooking methods were described, though roasting the roots in ashes or boiling were the most frequently mentioned. In my trial experiments I found that the roots cook in 10 minutes when roasted in hot ashes. Roasting eliminated the bitter taste more effectively than boiling. When roasted the tubers have a flavor similar to corn. The tubers burn if exposed to embers.

The most detailed description of cooking was from the Tualatin ethnography (Zenk 1976). They roasted wapato in the ashes left from a 'bonfire'. Archaeological evidence from the Puget Sound area described two types of hearth features where macro-remains of wapato were recovered; a "pavement" hearth and a pit oven (Larsen, personal

communication). Ethnographic descriptions of both cooking methods are found in Kuhnlein, et al. (1982) of clover and Pacific silverweed roots used by Native people on the coast of British Columbia.

The Nitinaht used a pit technique where hot rocks lined the bottom and specific vegetation was used in layers separating bundles of silverweed roots, clover roots and camas bulbs...The Nuxalk Indians preferred clover roots cooked on top of hot rocks either in pits or on top of the ground (Kuhnlein, Turner and Kluckner 1982:90).

Storage

The accounts of storage indicate that wapato could keep well under several conditions. Wapato can be dried whole or in fragments, stored in baskets or in underground pits, or “stored” in the marsh and collected as needed. In my trial experiments I found that in this region in late October, wapato dries to a hard nugget over a period of seven to ten days, depending on air temperature and humidity. The dried tubers which needs several hours of soaking in water before it can be cooked. If kept dry, it can be stored indefinitely.

The Tualatin of the Greater Lower Columbia area stored wapato in pits. At least one group of Chinook (Shahalas at Neerchokioo) stored wapato in baskets under bed platforms (Clark in Thwaites 4:208). Lewis remarked that when they first visited this village it had twenty-four straw houses and one wooden one. By spring only the wooden one was left, and the explanation given to Lewis was that relatives came in the fall to hunt game and collect wapato. This house was a low, rectangularly massed (probably gabled) structure 50’ in length built on the grade (i.e. not semi-subterranean). The location of the door was on one side of the gable-end (rather than centrally located) which may have been

advantageous in providing more unbroken length for storage space. This house may have functioned as a permanent dwelling for a few of the Shahala people, and warehouse for stores belonging to the greater Shahala population who lived in several villages around the Cascades. The nearest Shahala village was Wahclellah, twenty-seven miles upstream (Hajda 1984:119).

Seasonality

The journals of Lewis and Clark mention wapato over ninety times. Their first reference to wapato in their diary is on November 4, 1805 near what is now the Sandy River, in Wapato Valley. This plant dies back considerably after a hard frost, and apparently temperatures had been moderate because Lewis and Clark noted that this plant was growing throughout the valley. Since the plants were still visible, and roots were served to the corps, one can only conclude that the roots were being harvested before the plants had died back completely. Wapato was procured from the people at the mouth of the river for the corps on several occasions in November, December, and early January.

The Journals do not mention wapato procurement between January 11 and March 23, 1806. This gap in procurement may reflect a gap in availability. Lake levels are at their highest point in late January and February (Wessen 1984:8). During the low water months (August, September, October) women would be wading in water from knee level to neck level. High water would preclude harvest altogether in the deeper areas. High lake levels, and cool water temperatures were likely limiting factors for a late winter harvest of wapato. Some winter harvest could have occurred in the shallower areas. Water begins to recede in March, opening up the patches to harvest once again.

On their return journey, Lewis and Clark stopped at Neerchokioo (Fig 5-1), a village of the Upper Chinook Shahalas. They were informed that the relatives whose permanent residence was at the Cascades, had just returned home, presumably to prepare for salmon fishing. These relatives would have had at least three weeks prior to their leaving when the water levels would have permitted a spring wapato harvest.

Spring harvest would be over by the end of May, when the tubers sprout and begin to form new plants. I found no specific mention of wapato being traded or consumed in the summer months in any of the journals and accounts I reviewed. In one case, the absence of a mention was conspicuous: Bishop's detailed log of the voyage of the *Ruby* on the Columbia in June of 1795 doesn't mention wapato, though he wrote an excellent description of the root upon their return in October of that year. Wapato was available at least until May 9, as evidenced by the account of Dr. White and his wife who ate roasted wapato at an Indian campfire around May 9, 1837 (Allen, 1850). I am assuming they were roasting fresh roots. John Boit's "ground Nut" that grows along the river banks and was a good substitute for bread or potatoes was probably wapato. Boit was on the river between May 12 and May 20, and this reference was written on May 18, 1788. Ground nut is an archaic term that was used to refer to root foods.

Chapter Four :DIET AND SUBSISTENCE

Introduction

In this section I discuss major subsistence resources reported for Wapato Valley. Binomials and common names of these resources are in Table 4-1. Several authors have made estimates of the use and contribution to the native diet of particular food types (Keeley 1980, Hunn 1981, Norton 1980, Schalk 1977) The relative contribution of these food types is discussed, as well as the nutrient composition of several important root foods.

Some Major Subsistence Resources

A major economic investment of the native people of the Lower Columbia was the seasonal capture and processing of several species of salmon (Norton et al. 1984, Schalk 1977). Fish were a principal food of the Chinook, and enormous quantities of salmon were dried and processed by several techniques for later use. Six species of salmon (*Oncorhynchus*) serially enter the Columbia River. These include chinook, sockeye, coho, humpback, steelhead, and chum, the most important of which were chinook and coho (Boyd and Hajda 1987:Table 2, Ray 1938). These were not the only important fish; large shoals of eulachon migrated up the Columbia, and were caught in dip nets or raked. White Sturgeon was important because a single catch could supply a large quantity of food, often several hundred pounds.

Elk, whitetail deer and blacktail deer were important mammalian species used for food as reported in the ethnographic literature (Boyd and Hajda 1987:Table 2). Major root

Table Chapter Four -1. Classification of wild foods mentioned in ethnographic literature from the region.

Table 4-1. Wild foods mentioned in ethnographic literature from the region.

foods and greens reported ethnographically for Wapato Valley are as follows: Wapato, camas (considered staples); thistle, lupine, bracken, horsetail, bitterroot (Boyd and Hajda 1987:Table 2). Important berries were huckleberry (three varieties), blackberry, bearberry, cranberry and salal.

Over 40 edible species of berries are recorded for the Northwest, and Norton et al (1984) contend that berries were as much a mainstay of the pre-contact diet as salmon. That may be an overstatement, but its clear that diversity was significant. Dickson described over 100 plant species that were used as food in western Oregon in aboriginal times (Dickson 1946). Gunther lists even more for western Washington, and included medicinal plants (Gunther 1974).

Subsistence Dependence

In this section I present an overview of various estimates of caloric contribution of food types for aboriginal peoples in the Northwest. Hunn and Norton have made estimates of the percentage of caloric intake from a particular food type for the Native American pre-contact diet. Hunn's estimates are for the Columbia Plateau, and Norton's are for west of the Cascades [These estimates are reported as personal communication in Keeley (1980)].

Hunn estimated that the diet of people occupying the Columbia Plateau south of the 49th parallel consisted of 30% fish, 48% roots, 12% fruits, and 10% small and large game animals (Hunn, in Keely 1980). Previous workers did not rate the contribution of roots higher than the contribution of fish (Murdock 1967, Ray 1933). Hunn (1981) developed this model using ethnohistoric data to calculate per capita consumption rates, annual harvest totals and lengths of harvest season for various root sources. He also used his own time-

and-motion studies of contemporary Indian root-digging. There was a close accord between his estimates of daily harvest of *Lomatium cous* (1 bushel in 7.5 hours) and the ethnohistoric data (Hunn 1981:129). He reasoned that since this food was available, and numerous ethnohistoric accounts describe large scale harvest of other specific root foods, that these foods contributed greatly to the aboriginal diet.

For the region west of the Cascades, Norton gives a higher figure for the contribution of fish (Norton, in Keeley 1980). Her estimates are as follows: 40% fin fish, 10% shell fish, 49% plant foods (29% roots and sprouts, 20% fruits), and 1% small game and animals. The difference between the contribution of salmon on the east side of the Cascade mountains and the west is due in part to the loss of body fat and mass in salmon as they ascend the river.

Schalk estimated that the Chinook ate over 500 kg of salmon per capita per year (Schalk 1986, in Thoms 1989:239). Salmon average 170 kcal/100 grams (Hunn 1981:127). This would mean that each individual ate over 2,300 calories of salmon per day, every day of the year. This seems high. A value of 2000 kcal/person/day is the Minimal Daily Requirement (MDR) accepted by Hunn in the absence of estimates of body weight and population structure for aboriginal groups on the Columbia Plateau (Hunn 1981). Thoms suggests that the MDR was closer to 2500 kcal (Thoms 1989:221). If one accepts Schalk's estimates of salmon consumption, the caloric contribution of other game, roots, berries and sprouts would be less than Norton estimated, unless the MDR was much higher. Ethnographic and ethnohistoric data describe a varied diet for the Chinook (Boyd and Hajda

1987), so it is difficult to reconcile Schalk's salmon consumption estimates with these data. Schalk's estimates of salmon consumption are probably too high.

There are nutritional problems associated with high-protein, low-carbohydrate diets like the diet that would result if Schalk's estimates of salmon consumption are correct. These include elevated metabolic rates with correspondingly higher caloric requirements, and deficiencies in essential fatty acids. Both fat and carbohydrates enhance a high protein diet, but carbohydrate is a more effective supplement than fat (Speth and Spielmann 1982:1). Applying this evidence to the intensification process, it would mean that as the carbohydrate source became intensified, the metabolic rates of the consumers would drop along with their caloric requirements. This evidence has applications towards understanding sedentism.

Salmon provided protein in adequate amounts, as well as vitamin A and D (Hunn 1981). Berries and shoots were a significant source of ascorbic acid and minerals. Fresh and dried native roots contributed to the calcium, iron, magnesium and zinc content of the aboriginal diet (Keeley 1980). According to Turner and Kuhnlein (1983) the carbohydrate composition of root foods contributed the major proportion of carbohydrate energy and fiber in pre-contact Northwest Coast native diets.

Nutrient composition of wapato compared to other Northwest selected roots foods, and cultivated species per gram dry weight are expressed in Table 4-2. These are among the foods analyzed by Norton, Hunn, Martinsen and Keeley (1984). Values for fresh potato

Table 4-2. Composition of selected Pacific Northwest root foods, per gram, dry weight, compared with the white potato.

ROOTS	Calories kcal	Protein (g)	Carbohydrates (g)	Ca (mg)	Fe (mg)	Mg (mg)
Wapato						
<i>Sagittaria latifolia</i>	3.60	0.16	0.80	0.35	0.41	0.63
Biscuit Roots						
<i>Lomatium canbyi</i>	3.81	0.08	0.85	3.05	0.25	0.57
<i>Lomatium cous</i>	3.97	0.05	0.93	1.18	0.03	0.23
Camas						
<i>Camassia quamash</i>	3.90	0.13	0.80	1.67	0.23	0.40
Bitterroot						
<i>Lewisia rediviva</i>	3.87	0.1	0.85	2.35	0.33	0.74
Riceroot						
<i>Fritillaria pudica</i>	3.45	0.15	0.71	2.02	0.88	0.96
Silverweed						
<i>Potentilla pacifica</i>	----	0.04	0.21	0.41	0.91	0.08
Potato						
<i>Solanum tuberosum</i>	3.76	0.10	0.85	0.35	0.03	1.09

Values are from Keeley 1980, except Silverweed, calculated from Kuhnlein, Turner and Kluckner 1982

Table Chapter Four -2. Nutrient composition of selected root foods.

are used for comparison because it is this food which native people say has replaced traditional foods (Kuhnlein, Turner, Kluckner 1982:92). Wapato contains an average of 0.16 grams protein per gram, dry weight, which is slightly more than potato, which contains 0.10 grams protein. Camas has 0.13 grams protein. Wapato has the same amount of calcium as potato (0.35 gram) and only 0.63 grams of magnesium compared to 1.09 for the potato. Wapato is richer than potato in protein, carbohydrates, iron and zinc.

The nature and digestibility of the “starch” component in wapato has not been analyzed. The preferred native cooking methods for *Camassia* spp. and wapato, namely prolonged pit-cooking for the former and rapid baking or boiling for the latter, can be linked to the difference in the nature of their carbohydrates. Lengthy cooking is necessary for maximum conversion of the inulin in camas to fructose (Turner and Kuhnlein 1983:214). The main carbohydrate component of wapato may be starch, which is digestible in the raw state or with short term cooking.

Discussion and Conclusions

The Lower Columbia had abundant and diverse flora and fauna resources which could have provided the full range of necessary chemical molecules in ratios suitable for optimum nutrition (Wing and Brown 1979:169). Nutritional analyses show that *Sagittaria latifolia* roots used as a staple would have provided aboriginal populations with substantial quantities of energy (carbohydrates), fiber, and trace elements. Wapato meets Thoms' criteria that an intensifiable root food should be rich in carbohydrates (Thoms 1989:175).

Chapter Five : Wapato Production on Sauvie Island

Introduction

In order to address the questions of abundance and productivity, and the potential use of this resource as a staple for the local population, an ecological model of annual wapato production on Sauvie Island is presented in the first part of this chapter. This is followed by a cost\benefit analysis of wapato production which is then compared to other important root foods found in the Northwest.

This model is not intended to be representative of the whole Greater Lower Columbia region. As a model, it is an artificial construct. The main purpose is to illustrate the amount of food available in a year, compared to population estimates of people that were on or visiting Sauvie Island when Lewis and Clark make their calculations. It is important to understand that wapato was an important resource and trade commodity in a region where many groups were linked by systems of exchange, and rights to resources. This model assumes that the people who lived on the island all had rights to the resource, and that no others from the region came in to exploit it. This was not the case in the region, but was a necessary assumption to construct the model.

Five aboriginal villages were located on the island in 1805-6. Sauvie Island had a denser human population, at least in spring, than the rest of the region, and was richer in wapato as well. This model calculates the annual available productivity of this particular

location, and how many people this could have fed. The results are compared with aboriginal population estimates.

The Setting: Sauvie Island

Sauvie Island is 15.1 miles long and 4.55 miles wide at its widest point, comprising 24,064 acres of land and lakes (Spencer 1950:3). The island was formed by alluvial deposits from both the Columbia and the Willamette Rivers. Water covers much of the surface of the island. There were at least 79 named lakes on the island before the island was diked, and much of the wetlands and lakes were drained in the first part of this century. The largest lake is Sturgeon Lake, located in the center of the island.

One of the tenets of this thesis is that stands such as the one that currently exists at Crane Lake on Sauvie Island, covered much of the island. The Crane Lake patch is over a mile long and one quarter mile wide. A thick stand of wapato covers over 90% of its surface in summer (Figure 1-3 in Chapter 1). The U.S. Surveyor General Office surveyed the townships covering Sauvie Island in 1853 and 1854. The surveyor's notes describe the water level in the lakes as follows:

The lakes in this township at lowest stage of water are shoal & muddy & can be forded in many places. They are affected some by the tide, which ebbs and flows with a very strong current through the Gilbert River (notes, 22 Nov 1853, 3N 1W WM, spelling as in original).

In another entry the surveyor records that there are "really high banks on the rivers and bayoues & low indefinite ones on the lakes (unreadable) swamps," (notes for 3N 1W, WM, spelling as in original). On the north boundary of section 3, 2N 1W, the surveyor intersected "a shoal muddy lake filled with wapatoes," (3N 1W WM, notes pg. 59).

Before dike construction in 1938, the lowlands of the island were frequently flooded. Figures published by the U.S. Army Corps of Engineers indicate that flooding occurred when the discharge at the Dalles reached 600,000 second-feet, which happened 43 times in a 73 year period between 1858 and 1930 (Saleeby 1983:163-164).

Native American Villages on Sauvie Island

A large group of Indians, collectively referred to by Lewis and Clark as “Wappato Indians” were concentrated on Sauvie Island. Lewis and Clark identified five villages on Sauvie Island; Clannarminamon, Cathlahnaquiah and Clanninata on Multnomah Channel, and Clannaqueh and Multnomah on the Columbia River. Each village was within one mile or less of a pond or lake (Fig. 5-1). Lewis and Clark reported two population figures for each village. Boyd and Hajda argue that both estimates accurately depict seasonal variations in Lower Columbia populations. The first estimate was made in October and November of 1805. This was recorded in the Codex 1 manuscript. The second estimate was taken on the return journey in the spring, when the Lower Columbia permanent population was hosting many friends and relatives. Both estimates are deemed correct, and reflect the population shifts during those seasons. The following descriptions are from the Journals, maps and manuscripts of the Corp. These were all villages of Chinookan people.

Clannarminnamun. This was a village of twelve houses located on the west side of the northernmost lobe of the island above Warrior Rock. This whole section was low and marshy, with a few small ponds. This was across Multnomah Channel from Scappoose Bay, called by Lewis and Clark “Wappato Inlet”.

Clannahqueh. This was a village of at least one house on the east side of Sauvie Island. This was adjacent to numerous small sloughs and ponds and two small islands.

Multnomah. This was a mile or so south of Clannahqueh, and a much larger village consisting of six houses.

Clanninata. This was on Multnomah Channel on the west coast of the island, adjacent to many lakes including Steelman Lake, which is still extant and has many patches of wapato.

Cathlahnaquiah. This was on Multnomah Channel and south of Clanninata by three or four miles. It was adjacent to several shallow lakes, most now drained.

Table Chapter Five -1. Sauvie Island Village populations in the two versions of Lewis and Clark’s “Estimate of the Western Indians” (Boyd and Hajda, 1987, Table 1)

Village Name	Manuscript Estimate	Printed Estimate
Clannarminnamon	280	280
Clannahqueh	130	130
Multnomah	200	800
Clanninata	100	200
Cathlahnaquiah	150	400
Total	860	1,810

Quantifying Productivity

Productivity

Wetlands (estuaries and marshes) are resilient because they are the most highly productive ecosystems in the world, producing between 8,800 and 9,600 kilocalories of energy per square meter per year. In comparison, temperate forests produce about 5,600 kilocalories per square meter annually, and agricultural land produces an average of only 2,400 kcal (Miller 1993:94). Many wetland plant species such as *Sagittaria latifolia* are r-strategists, producing a large quantity of offspring, of which only a small percent survive to reproduce.

Annual production as expressed in dry weight in grams per square meter, per year of below-ground biomass of *Sagittaria spp.* has been calculated by two researchers. Visser (1989) measured the end of season underground biomass productivity in a freshwater marsh in Louisiana. She was interested in documenting differences in vegetation under various conditions (including grazing), so her study discusses productivity *range*. This productivity ranged from 233 to 1199 (fresh) grams per-meter per year, depending on elevation and flooding.

Gilbert (1990) was looking for *average* or normal productivity in the ecosystem. In her careful study of above- and below-ground annual productivity of vascular plants in the freshwater marsh of the St. Lawrence River near the Quebec City, Gilbert determined that *Sagittaria latifolia* reached its peak above-ground biomass at the end of August (Gilbert

1990:855). By the end of September on the St. Lawrence, the below-ground biomass of the tubers reaches approximately 300-400 dry grams per square meter, (approximately 600-800 grams of fresh tubers).

The normal productivity measured by Gilbert fits well into the range of productivity estimated by Visser for this plant. The productivity data from Gilbert's study provides the best analogy for the Lower Columbia. This study will use the productivity estimates generated by Gilbert's work on the St. Lawrence. Both study areas (the Columbia and the St. Lawrence) are in the northern part of *Sagittaria latifolia*'s range. This study is interested in normal or typical productivity as was Gilbert. In addition the specific variety of *Sagittaria latifolia* Gilbert was studying is the same taxonomic variety found on the Lower Columbia; i.e. Smith's 'northern dioecious' variety (Smith 1895:38, Giroux and Bedard 1987:773).

My own informal trials indicate that Gilbert's estimates of tuber productivity per meter correspond to a typically productive patch on Sauvie Island. Gilbert excavated several areas throughout the growing season, and dried the total biomass at a constant temperature. It was not within the scope of this study to replicate her experiments. If the average density of the plants per square meter, and the average number of tubers per plant, and the average weight of the tubers were known, productivity could be calculated.

I designed two experiments to calculate productivity. My first experiment was to measure four meter-square units and count the number of plants within each unit. The plants are thick in typical patches, and there are plants of all sizes growing adjacent to each other, though most of the plants are about the same maturity. The uniform density of the

patches made it easy to find a typically productive patch. I found that in early October the average number of plants per square meter in a typically productive patch on Sauvie Island is 28 plants.

In the second experiment, conducted in the beginning of October when the plants were still green, but beginning to deteriorate. I pulled up over forty plants chosen randomly from a typically productive patch. This was done in order to find the number of tubers produced by each plant by counting the number of rhizomes attached to the base of each plant. I found that there were 2 to 5 rhizomes on each plant at any one time, with an average of 2.8 rhizomes, indicating the presence of that many tubers. This is a conservative estimate because rhizome production is on-going, and evidence of earlier rhizome production may not be evident. Another reason I believe it is conservative is that earlier in the season I pulled up several plants, and counted more tubers per plant than later when this trial was conducted.

The average weight per tuber recovered in my harvesting experiments is 7.75 grams. Calculating that there are conservatively 2.8 tubers produced per plant, and 28 plants per square meter, tuber productivity per square meter would be approximately 78 wapato per square meter, or 604 fresh grams. The close accord between my estimates and Gilbert's figure (600-800 grams per meter) is encouraging.

It is possible that this is an underestimate. Under controlled conditions in a greenhouse, with a single plant per container, plants from Lower Columbia *Sagittaria latifolia* seeds produced an average of eight tubers each. These weighed 1 to 12 grams, averaging 6 grams each (Tanimoto, personal communication). Based on these estimates,

annual tuber production per meter would be 1,344 grams. However, under controlled conditions plant grown can vary significantly, and not be comparable to field conditions.

For this model, the most conservative productivity estimate of 600 fresh grams per meter annual production will be used. Based on this figure, the annual production of wapato per hectare is six metric tons.

In order to insure viability and equilibrium, a certain number of the tubers need to survive in order to reproduce. As mentioned above in a typical patch there are on average 28 plants per square meter. Almost all the plants exhibited a lateral rhizome, indicating that the plant either grew from a rhizome thrown off by a parent plant, or was the parent itself. It is difficult to estimate the number of tubers necessary to survive in order to maintain an equilibrium. It has been my observation that even plants just beginning to emerge are forming rhizomes which produce new plants in short order. Potentially, in one growing season, one tuber could produce a plant that throws off several more rhizomes from spring through the summer, creating several growing plants, which in turn create more plants, and subsequently more tubers. A conservative estimate on the number of tubers necessary for reproduction to be maintained, would be half the count of the number of plants per meter present in a typical patch, or fourteen tubers. This is 18% of the total productivity of 78 tubers per meter.

Waterfowl grazing has already been discussed. In Chapter 2, it was estimated that waterfowl foraging on Sauvie Island reduced the below-ground biomass in *Sagittaria* habitat by about 60%, leaving 22% of productivity for humans, muskrats and other predators.

Quantifying Surface Area of Sauvie Island

Method

In order to quantify productivity, it was necessary to estimate the surface area of Sauvie Island that was prime *Sagittaria* habitat. Current maps show that much of the southern portion of the island is now farmland. Historically much of this area was occupied by lakes, ponds, marshes and sloughs. The survey for the nautical charts of the Lower Columbia was done by the Coast and Geodetic Survey in 1890. These maps were updated periodically (1914, 1923, 1940) but the original lake and slough configurations were not changed. The only information updated on the charts concerned the navigation channels. The subsequent maps were in essence showing ‘relic’ lakes and sloughs, many of which have been drained. I used the 1940 nautical chart (with the 1890 era lake and wetland designations) to calculate *Sagittaria* spp. habitat. Therefore, the estimates are based on marshes and sloughs that existed in 1890, and given the dynamic nature of shallow alluvial lakes, they may not be representative of a contact-era configuration (Figure 5-2).

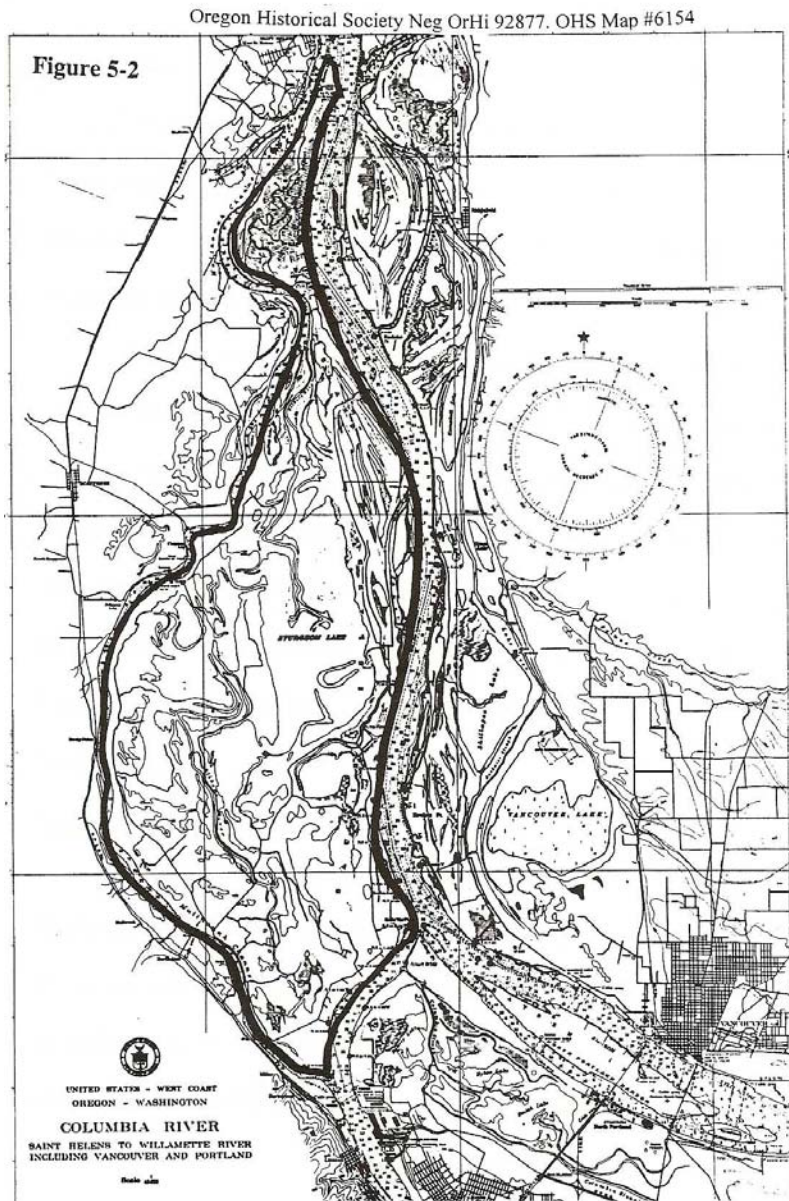


Figure 5-2. Coast and Geodetic Survey Chart: Sauvie Island

There were no depths indicated for the lakes on Sauvie Island on this chart, though most of the lakes were probably not more than two meters deep. The chart indicates that Vancouver Lake had an average depth of one meter over most of its area. Since *Sagittaria* spp. can grow from a meter's depth or more, Vancouver Lake may have been almost completely covered with *Sagittaria*.

Using the 1940 nautical chart I measured the square meter area of marsh and lake habitat. This was calculated by drawing a grid on the chart, and estimating the overall fraction of marsh and lake area within each 1000 x 1000 meter grid square. Most of Sturgeon Lake was not counted because much of this lake is known to be deeper than four feet. The fractions were added, and the estimated area of wapato habitat analyzed on this map totaled over 2,985 hectares. If the lake coverage indicated on the 1940 (1890) map is typical, there would have been a total of 17,910 metric tons of wapato produced on Sauvie Island annually.

Available Harvest

The equation for estimating the total amount of wapato available to humans on Sauvie Island is as follows: 60% of the net below-ground primary production (NBPP) is the proportion of wapato removed by waterfowl herbivory; subtract .18 (NBPP), which is the proportion of wapato not preyed upon to insure viability; which equals (X), energy available to the human population. The condensed formula is as follows:

$$.60 (\text{NBPP}) - .18 (\text{NBPP}) = X$$

Thus, with a NBPP of 17,910 the mass available to the human population is 3,940.2 metric tons.

One of the limiting factors in the harvest would have been what percentage of the tubers float at any one time. This is difficult to ascertain, and further experiments need to be done to quantify this production with accuracy. However, during my field research wapato was harvested on five occasions by one to two people.

The methodology of these experiments was simple. The gatherers waded into the water and agitated the substrate with their feet. The work was done in measured areas. The amount of time gathering was noted, and the production of wapato was counted and weighed. The first two occasions were in April and May of 1995 at Catfish Slough on Sauvie Island.

Spring harvest production varied; between 9 tubers and 29 tubers floated up out of the substrate per square meter. The heaviest person weighed approximately 160 lbs, and was more productive perhaps because he sank in deeper, and agitated the substrate more effectively than the person who weighed 130 lbs. Twenty-nine wapato per meter were recovered by the heavier person, and ten recovered by the lighter person. Another explanation may be that the heavier person was harvesting in an area that was overlooked by waterfowl and other predators, while the lighter person was in an area that had been harvested by predators. There was some evidence of furbearer predation in this slough. The lighter person matched the productivity of the heavier person during the October 1995 harvest, where 29 wapatos per meter were recovered.

If the average number of buoyant tubers per meter recovered in water was the “low” recovery of 10 tubers, (average weight 7.75 gms), the total metric tons available on Sauvie

Island would be 2,313 tons per year. The harvesting efficiency would be 59% of available biomass.

Population

With estimates of yields in hand, one of the pertinent, productivity-dependent questions is: how many people could the Sauvie Island wapato production support per year?

The energy necessary to support an individual or populations is a function of their metabolic rate (Ellen 1991:102). Daily caloric requirements vary according to sex, age, weight, activity, climate and diet (Thoms 1989:221). My model will borrow two assumptions that Thoms (1989) uses for his model of camas intensification. The first assumption is that the caloric requirements for the average member of an average hunter-gatherer family in the Pacific Northwest is 2,500 kcal per person/day. The second assumption is that roots provided at least 20% of the annual caloric intake of each individual.

Using the estimates developed by Thoms, the annual caloric intake of a family of five would be 4,562,500 kcal, of which 20% or 912,500 kcal would come from root foods. Thoms estimates it would require a metric ton of fresh camas (1000 kg) to provide enough calories for a family of five when accounting for “spoilage, wastage, and other losses (eg. rodents) and including an extra portion in lieu of unanticipated shortfalls, or 125% of the required minimum (Thoms 1989:222).

Fresh camas contains approximately 70% moisture (Thoms 1989), and fresh wapato contains approximately 50% moisture (calculated from Keeley 1980:31). The minimum amount of fresh wapato that would be needed to provide the same caloric contribution

would be .507 metric tons (507 kilograms). Following Thoms, 125% of this amount is 633 kilograms (.633 metric tons) per year of wapato. The high estimate of available wapato on Sauvie Island in a typical year is 4,656 metric tons. The low estimate, based on what percentage of tubers floats, is 2,313 metric tons. If .633 metric tons of wapato would feed a family of five, the highest estimated annual wapato harvest would feed 36,777 people. If we use the low estimate of 2,313 metric tons, this production would feed 18,270 people. Lewis and Clark's highest population estimate for the island is 1,810. I have already noted the highest estimate for the region in 1805-6 was 27,000 (excluding Tualatin)(Lewis and Clark in Hajda 1984). Estimated wapato production on Sauvie Island could have supported a significantly higher population than has been reported for the island. This number is representative of early nineteenth century populations "and are probably significantly below the pre-contact totals, which would have been much reduced by the 1775 and 1801 smallpox epidemics," (Boyd 1989:286).

Boyd estimates that the mortality rate for the 1770 epidemic was minimally 33%, and suspects that the mortality for the 1801 epidemic was probably slightly less than in 1775, due to some individuals having developed an immunity in the previous epidemic. Estimating a 25% population reduction in 1801, and a 33% population reduction in 1775, there may have been about 3,008 individuals living on and/or seasonally visiting the island before the epidemics. This is still significantly below the estimated populations that could have been supported by the annual wapato harvest.

Cost/Benefit Analysis

Following Lawton (1973 in Ellen 1982:99) there are six kinds of activity in the appropriation of food: locating food supply, gathering food, transport and storage, maintaining food supply, processing food supply, and eating. In the case of wapato, the local residents lived adjacent to the wapato patches on the island, so locating and transporting wapato were very low cost activities. The storage and maintenance of wapato involved digging storage pits, and the weaving of carrying and storage baskets. Other activities that have high energy costs are the building and maintenance of houses to store the food, and the construction of canoes to collect the wapato. Canoes and houses last for years, and were used for other purposes than storing wapato, so the costs of these will not be figured into this model. Settlements were located adjacent or close to wapato habitat, so locating and traveling to resource areas was not a large energy drain. Wapato requires little or no processing, so processing costs were low, and will not be considered here.

It is difficult to measure how many calories would have been burned by individuals, generally women, while they ‘danced’ around on the wapato-bearing substrate in cool water temperatures for several hours at a time. The native women of the Lower Columbia were described by Clark as follows:

The Womin of the Chinook Nation have handsom faces [they are] low and badly made with large legs and thighs which are generally sewlled from a stopage of the circulation in the feet (which are Small) by many strands of Beeds or curious Strings which are drawn tight around the leg above the ankle, their legs are also picked [i.e. tatoood] with defferent figures. (spelling as in original, Clark in Thwaites 4:241).

Deposits of subcutaneous fat on the women's legs and thighs would have provided some insulation from cool water temperatures. For this model I have estimated that the effort needed to harvest wapato may have been about equal to riding a bike, which would be 4.5 kcal per hour, per kilogram of body weight. Estimating the average weight of these women is also conjecture. For this model we will estimate body weight to be 140 lbs, or 63.5 kilograms. Based on an eight hour day, each woman would expend 2,286 kcal during the eight hours she spent on the harvest.

Wapato was gathered on four occasions. The first was on April 27, 1995 where I was in the patch for fifteen minutes and recovered 38 wapato tubers. If I had sustained this recovery rate and continued gathering for one hour, I may have recovered approximately 152 wapato, or approximately 1,178 grams of fresh wapato. The second gathering was on May 19, 1995 when a male colleague gathered for fifteen minutes and recovered 88 wapato. This person was heavier, and more effectively agitated the substrate than I did, resulting in a high recovery of wapato. If he had sustained this recovery rate for one hour he would have recovered 352 wapato, or approximately 2,728 grams of fresh wapato. In the fall of 1995 this worker returned to the same patch (Catfish Slough on Sauvie Island) and gathered for fifteen minutes and recovered 58 wapato. If I had sustained this rate for one hour, I may have recovered 232 wapato, weighing about 1,798 grams. The range of recovery per hour in these studies was 152 to 352 wapato per hour. These results are summarized by date and location in Table 5-2.

These time and motion studies indicate that between 1,178 and 2,728 grams of fresh wapato could be extracted in one hour. This must be qualified by the fact that we are

inexperienced gatherers. People who gathered wapato on a regular basis may have developed techniques to expedite the process.

For this model, I will use the 1,800 gram per hour figure for recovery estimates based on the fall gathering episode, which generated approximately 1,800 grams of wapato per hour. This amount is close to the average recovery of all these events, and was the only fall gathering that was recorded. Fall is when the below-ground biomass is at its peak, prior to predation.

Cost benefit has been adjusted upwards since 1997 see next table. Note of author 2007 Melissa.

Table 5-2. Productivity experiments by date and location

DATE	METHOD	LOCATION	(N)	GMS	gm/corm
NOV 18, 1994	DIGGING	STEELMAN LAKE	33	152	4.60
DEC 1, 1994	DIGGING	STEELMAN LAKE	22	224	10.18
APRIL 27, 1995	TRAMPING	CATFISH SLOUGH	38	309	8.13
MAY 19, 1995	TRAMPING	CATFISH SLOUGH	69	512	7.42
MAY 19, 1995	TRAMPING	CATFISH SLOUGH	88	741	8.42
OCT 6, 1995	TRAMPING	CATFISH SLOUGH	58	450	7.76
TOTAL			308	2388	7.75

11/14/97 Tramping Farmersfield 231 3005 133

- Best place!
- Best productivity!

Table Chapter Five -2 . Productivity experiments by date and location.

Based on the 1,800 productivity estimate, the daily harvest would be 14,400 grams. The dry weight of this amount is 7,200 grams. The calories available per dry gram of *Sagittaria latifolia* tubers is 3.6 kcal. The calories harvested in one day would be 25,920 kcal. The cost/benefit ratio is 2,286/25,920 or 1 kcal expended for every 11.32 kcal gained.

Comparative cost/benefit ratios of several important root foods found in the Northwest are in table 5-2. Daily harvest estimates have been analyzed by Couture, Ricks and Housley (1986) for desert parsley (*Lomatium canbyi*), biscuit root (*Lomatium cous*), and bitterroot (*Lewisia rediviva*). The harvest data was from observed collection practices of contemporary Burns Paiute women. The cost benefit analysis was calculated figuring a 200 kcal/per hour expenditure for digging roots, as compared to a higher 285.75 kcal/per hour cost for tramping wapato patches, due to exposure in cold water. Wapato was a cost effective root to harvest, grossing 3,240 kcal per hour, though estimates of hourly yields of camas and desert parsley were higher, 5,279 kcal and 3,631 kcal respectively.

Calculating handling costs to arrive at an overall net gain figure requires inclusion of all costs incurred for transportation, processing and storage, which is beyond the scope of this study. The cost/benefit analysis only compares daily harvest costs and benefits of extracting the roots, and does not address transportation or processing costs, which would reduce the cost-effectiveness of these roots. In general it can be said that wapato was lower in transportation and processing costs than bitterroot, biscuit root, desert parsley and camas.

Table 5-3. Cost/Benefit ratios of selected important wild roots in the Northwest (kcal/person/hour) Gathering costs only.

SPECIES	Common Name	cost (kcal)	gross (kcal)	cost/benefit	Reference
<i>Lomatium canbyi</i>	desert parsley	200	3631	1 to 18.15	Couture et al.
<i>Lomatium cous</i>	biscuit root	200	1019	1 to 5	Couture et al.
<i>Lewisia rediviva</i>	bitterroot	200	1174	1 to 5.87	Couture et al.
<i>Camassia quamash</i>	camas	200	5279	1 to 26.39	Thorns
<i>Sagittaria latifolia</i>	wapato	286	3240	1 to 11.32	This model
Sources: Thorns 1989, Couture, Ricks, Housley 1986.			5418	1 to 18.9	

Table Chapter Five -3. Cost/Benefit ratios of selected wild roots

TABLE 5-3 COST /BENEFIT RATIOS OF SELECTED WILD ROOT FOODS

Often in the case of camas and bitterroot, root grounds were not adjacent to habitation sites and roots had to be hauled overland to their destination. Camas required baking in large earth ovens in order for it to be preserved well. It was often further processed into cakes. Biscuit root can be eaten fresh, and was often dried and ground for future use, as was bitterroot and desert parsley. These roots need to be peeled before drying (Hilty 1980), whereas wapato does not require peeling.

Hunn (1981) estimates the harvest season for biscuit root to be 30-40 days, bitterroot 60 days, and camas from 14 to 21 days. Thoms (1989) suggests that the camas season lasted about 35 days. The people who relied on these roots needed to concentrate their efforts during the short time when these roots were available. My studies indicate that wapato is in season over 250 days of the year (see chapter 2). At an extraction rate of 14,400 fresh grams per day, it would take a woman 44 days to harvest enough wapato for a family of five. The long season would give the food provider several options on how best to supply her family, and she would not have to concentrate her harvest efforts within a short time span. The ethnohistoric evidence suggests that the main harvests were in the fall and spring.

Discussion and Conclusions

The quantitative model presented here demonstrates that wapato was abundant and productive, and could have fed a larger population than was estimated to live on the island in pre-epidemic times. Wapato was a cost-effective root to harvest, and compares well with other important wild roots of the Northwest in harvest cost and net caloric gain. Wapato habitat was close to permanent village sites in wapato valley, and transportation costs were

minimal for the local population. As modeled, wapato meets Thoms' criteria that an intensifiable root food should be available and predictable, and accessible.

Chapter Six : ADDRESSING THOMS MODEL OF ROOT-FOOD INTENSIFICATION

Introduction

Land use intensification models developed in population ecology have been employed to examine subsistence intensification, particularly as it relates to the development of community sedentism, agriculture, and complex social systems. These models have met with varying degrees of predictive success. However a foraging-based population model for hunter-gatherers can be very useful to anthropologists and archaeologists as a means of constructing and testing hypotheses about the role subsistence plays in human population dynamics. These models can be judged by how well they fit with the predicted outcome.

Thoms has proposed a model for the intensification of wild roots in his dissertation *The Northern Roots of Hunter-Gatherer Intensification : Camas and the Pacific Northwest* (1989). His model includes conditions, causes and consequences of geophyte intensification, as well as spatial components, and archaeological correlates. Thoms devised a test of his model of geophyte intensification composed of five expectations.

RESEARCH DESIGN AND METHODS

I compared *Sagittaria* spp. to Thom's expectations for the role of camas in the Pacific Northwest from his model of geophyte intensification. To the extent that wapato is consistent with his geophyte intensification model, the archaeological, ethnohistorical, ethnographic and ecological data should be consistent with the following five expectations

that Thoms outlines as part of his model for camas exploitation (Thoms 1989:184). These expectations are copied from his text, except I substituted the word “wapato” for camas (Thoms 1989):

1. Given the tendency toward optimal foraging, groups relying on wapato as a staple resource should be those lacking adequate supplies of higher ranked and intensifiable foods. Other things being equal, the intensity of geophyte exploitation should vary inversely with the availability of anadromous fish.

In his assessment of the “fit” between his modeled expectations for camas exploitation and the ethnographic data Thoms found that this expectation was not met for all groups. “It is evident that groups using camas as a staple were *not* confined to regions lacking ready access to salmon” (Thoms 1988:238). He found that groups living directly on the Northwest Coast conformed to the predicted pattern of this expectation. However, he argues that this was due to the limited availability of camas rather than the abundance of higher ranked resources. Interior groups who had limited access to salmon included the Coure d’Alene, Kalispel, and Flathead. This expectation for camas exploitation fits these groups, but not the Nez Perce, Klickitat, Yakima, Wanapum, Palus and others.

He found that his model especially did not fit the Chinook, who consumed 500 kg. of salmon per capita per year (Schalk 1986). “The Chinook...used more salmon than any other group, but, like other coastal groups, camas was probably a managed supplemental resource, and it may have been of secondary important to arrow-head root or wapato,” (Thoms 1989:238).

In my assessment of the “fit” between this modeled expectation for wapato exploitation and the ethnographic data, I have found that there is no inverse correlation

between the availability of salmon and the exploitation of wapato. Wapato was available fresh from early fall to late spring (except during high water), which partially overlapped the times of various anadromous fish runs on the Lower Columbia. Chinook salmon were available in the spring and summer. Coho runs occurred in the fall. Chum salmon were in the river in October. Steelhead were available in the summer and early fall (Hajda and Boyd 1987: Table 1). For the lower Fraser River, Hanson notes in his study of the Katz site, that the “appearance of wappatoes coincides with the passing of ...sockeye and chinook runs. Coho salmon pass Katz from early October to mid-November, and chum salmon spawn in the Fraser below Hope from mid-November until the end of December, “ (Hanson 1973:45).

One reason why this expectation of a correlation between the availability of anadromous fish and the intensity of geophyte exploitation is not met is that Thoms makes the assumption that all foods are ranked on the same scale, and will be selected by rank. Carbohydrates and proteins satisfy different needs. Though salmon may be a higher ranked food, the body needs carbohydrates to function well. One does not replace the other. Norton (1980) estimated the pre-contact diet of groups who lived west of the Cascade Mountains had a varied diet rich in roots and sprouts and fruits as well as protein foods. It is evident that a suite of food types was desirable, and necessary for a balanced diet.

2. Given the principle of optimal foraging and the lack of adequate supplies of less costly foods, and other things being equal, there should be a positive correlation between the intensity of wapato exploitation and the size of productive wapato grounds in a group's territory.

This expectation is met. There is a positive correlation between the intensity of wapato exploitation and the size of productive wapato grounds on the Lower Columbia. Lewis and Clark noted that wapato grew extensively in the center part of the Greater Lower Columbia Valley, and named it Wapato Valley. Ecological data support the contention that wapato habitat was once much more extensive than it is at the present. Ethnohistoric and ethnographic data suggest that wapato was an important food, as well as a trade commodity for the people of the region.

This expectation assumes that a lack of less costly foods would be a circumstance that would direct the people to intensify the use of the resource in direct proportion to the size of the productive grounds. I have demonstrated that wapato is a cost effective food to procure. The ecological data demonstrate that wapato was intensifiable, the ethnohistoric and ethnographic data describe wapato as being very abundant in the area very important to the people. These data sets combined indicate that wapato was intensively exploited on the Lower Columbia. I suggest that it was not a lack of less costly foods that drove intensification, but it was the quantity and cost effectiveness of this resource that caused it to be intensively exploited. In conclusion, there is a positive correlation between the intensity of wapato exploitation and the size of productive wapato grounds in a group's territory.

3. Wapato is a bulky food, and as such, its intensive use is likely to be dependent on ease of transportation. The use of wapato as a staple should be evident among groups with productive wapato grounds near winter village sites where much of the wapato is likely to be consumed, as well as by groups whose territories also encompassed low gradient watercourses conducive to watercraft transportation, or substantial grasslands where large

horse herds could be maintained. Horses and watercraft transportation would significantly reduce transportation costs and increase the potential to exploit wapato grounds located at some distance from overwintering sites. Other things being equal, the degree to which groups rely on wapato should vary inversely with transportation costs.

This prediction is well supported by the data. Lewis and Clark noted that wapato was often collected in canoes that may have been made especially for women who may have chiefly used them for food gathering. Transportation costs were minimal for the local groups because there were many areas to harvest wapato. Chinookan villages clustered in strategically favorable areas along the river's banks, often directly adjacent to low marshy islands or ponds where wapato could have been procured.

The expected positive correlation between low gradient navigable watercourses and the exploitation of wapato is obvious. One can expect that wapato would be heavily exploited in part because the transportation costs were so low. The ethnohistoric and ethnographic data support this supposition.

4. From the principle that people tend to select and use habitats optimally, it follows that they should exploit wapato in a cost-effective manner, given the nutritional needs of the population in question. Other things being equal, there should be a positive correlation between the use of wapato as a staple, and bulk processing as measured by the use of large earth ovens and storage facilities.

This expectation is only partially consistent with the available data. The ethnographic and ethnohistoric accounts consistently describe wapato as being like a potato, and cooked like a potato either by boiling or baking on embers. One account mentions that if wapato is overcooked, it dissolves and becomes a paste. In my experience, wapato cooks

fast, and can be pierced with a fork after about ten minutes of cooking. Camas, on the other hand, needs to be baked for long periods of time. It is more likely that large earth ovens are an indicator of camas, rather than wapato use.

However, large storage facilities would be necessary if each family of five needed almost a metric ton of wapato per year. Wapato has been described as not needing to even be washed before it is stored (Suttles 1951), and it keeps well without any processing. Clark noted that wapato was stored in baskets under the bed platforms. The Tualatin stored wapato in large storage cellars, or pits, under the floors of houses (Zenk 1976).

The ethnographic evidence indicates that there is a positive correlation between the use of wapato as a staple, and bulk processing as measured by the use of earth ovens and storage facilities. This should be amended with the note that wapato ovens were generally smaller and designed for shorter baking times than the camas ovens which were often built for mass quantities of camas and lengthy baking times. Wapato is available over a long period of time, so storage needs would be minimal except for warehousing surplus for trade.

5. Given the principle that normal population growth is a force toward instability in the ratio between the supply of available goods and the demands of the population, there should be a positive correlation between the intensity of “management” techniques at wapato grounds and population density. Manifestations of this relationship should include ownership and management of root grounds.

If one accepts the ecological data on annual wapato production and population estimates, there was apparently not enough population pressure on wapato to create instability in the ratio of supply and demand, though control and inheritance of wapato patches may have existed. The assumption this expectation makes is that population growth

and packing creates an unstable relationship between supply and demand, and is a major causal factor in geophyte intensification and management of a limited supply of geophytes. On the Lower Columbia, population density was high, but the ecological evidence and human population estimates suggest that the supply of wapato was not nearly tapped.

The existence of control and management of the root grounds was not a reaction to control of an increasingly scarce resource, but rather (I suggest) a reaction to the density of the population, and the need to clarify where specific groups could congregate and harvest in order to avoid conflict or chaos.

In order to address this expectation, it is necessary to understand how the people of the Lower Columbia defined 'territory'. In a letter from Captain William Clark to Biddle in 1810, Clark described a group he identified as the 'Shahalas' which had four settlements around the Cascades of the Columbia River where they maintained permanent settlements, and "the little colony of Neckokee [probably Neerchokioo] near the Multnomah [Willamette River] where they gather Wappatoe," (Jackson 1962:543, Clark to Biddle 1810, my brackets). This suggests a pattern of exclusive use of specified resource areas that other groups recognize and respect. The Cascades, occupied by the 'Shahalas' was a well known fishing site for migrating salmon. Their 'colony' was specifically occupied in the fall and spring for the purpose of collecting wapato (Jackson 1962:543).

In 1851, after most of the Indians in western Oregon had died from disease, the local Indian Agent was given the task of grouping together the remaining people. However, the people resisted, and were reluctant to move elsewhere. In a letter from agent to his superior he wrote the following:

“...the natives of western Oregon, so far as we have seen, without exception, are possessed of local attachments of the strongest kind...the habitations of these people are, so far as regards place, not only permanent, but hereditary. Divided into bands or families, now reduced in number, but retaining each their separate chiefs, occupying their own lodges in the different districts of the country...it has been found generally impossible to amalgamate portions of even the same people,” (Dart 1851 as quoted in Boyd 1985:469).

Territoriality on the Lower Columbia may resemble territoriality expressed by the Katzie who lived on the Lower Fraser River where some patches belonged to the Katzie tribe, while others belonged to families. Families could seasonally claim parts of a patch by clearing along the shore so the plants could be collected more easily (Suttles 1951:27).

In terms of supply and demand ratios, Harris (1977) makes the point that “past and present hunter-gatherer populations have normally stabilized at levels below the maximum carrying capacity of the environment exploited at a given level of technology,” (Harris 1977:180). He goes on to say that this equilibrium with their local environment is from limiting population levels, rather than a lack of correlation between population density and available food resources (Harris 1977). This brings up the question of whether population levels were controlled in the region, and if they were, how were they controlled. The possibility exists also that our estimates of pre-epidemic population levels may be incorrect, and that there were considerably more people in the region just before contact.

Thoms’s expectation that the people “managed” root gathering grounds is supported by at least one account. Harriet Smith wrote a book about wapato and her experiences harvesting wapato in Skamania County with a family descended from the original Native American population. She mentioned that she successfully harvested wapato, though it was difficult because the root mat and substrate need to be thoroughly tromped on and loosened

up every year in each patch. A properly maintained loose root mat released more roots (Harriet Smith, personal communication).

Sagittaria latifolia often grows with a companion plant, *Ludwigia palustris* (L), which is an herbaceous small-leaved plant, growing close to the surface of the water. Underwater it forms a network of small, brittle twigs through which *Sagittaria l.* grow easily. I have found that this brittle mat needs to be punctured and agitated in order for the wapato in the substrate to effectively be released and float to the surface. I have also noticed that the twigs of this plant scratch and cut the skin on my legs as I am tramp the substrate. This work would be easier, and more productive if the brittle *Ludwigia* twigs were broken up. There are some flat, heavy cobble tools (weighing over 300 grams) which are peripherally flaked over 180 degrees that are found in archaeological sites near wapato collection areas, including Vancouver Lake (Wessen 1984) and the site where Indians from Cathlapotle portaged their canoes to the pond where they collected wapato. These tools may have been used to break up the *Ludwigia* root mat. The use of this tool has never been fully analyzed, and its possible use in this context needs to be tested.

Discussion and Conclusions

I conclude with an assessment of the predictions made earlier about the expected role of wapato in the Greater Lower Columbia region in the ethnographic period. Thoms' first expectation that there would be an inverse relationship between the exploitation of wapato and the availability of anadromous fish is not met at all. The Lower Columbia was one of the world's best salmon streams. The second expectation regarding a positive

correlation between the intensity of wapato exploitation and the size of productive wapato patches is met.

Expectation 3, regarding a correlation between transportation costs and intensive use is met. There were remarkably low transportation costs for wapato for the permanent population because their settlements were adjacent to wapato patches. Wapato was traded out of the area by canoe to the mouth of the river and to the interior regions. Expectation 4 asserts a correlation between the use of large ovens and storage facilities and wapato intensity. This expectation is only partially met, due in part to the fact that large earth ovens are not necessary to process wapato.

Expectation 5 states that normal population growth is a force toward instability and increased control over the resource. Though there was increased control of the resource, it may have been driven by a need for order rather than an increased scarcity of the plant resource itself.

Chapter Seven : CONCLUSIONS

Several important findings have emerged from this study. I have demonstrated that wapato was intensifiable, and an intensively exploited root food in the Greater Lower Columbia Region in early historic times. This finding is based on ethnohistoric and ethnographic accounts, and ecological data. The ecological data demonstrate that wapato was intensifiable, and the ethnographic and ethnohistoric accounts describe wapato as being a staple. These data sets combined demonstrate that wapato was intensively exploited in

the Greater Lower Columbia region. This finding has implications in regards to economic issues such as trade, exchange systems, and wealth in the region.

Another important finding that gives us a better understanding of settlement patterns and population movement in the Greater Lower Columbia region was that wapato was in season over a remarkably long period of time for a wild root food growing in the Northwest. It was available from early fall to late spring, with a harvest hiatus of a month (more or less) during high water in mid-winter.

In a discussion about salmon intensification, Ames (1994) notes that documenting the history of salmon's non-subsistence role is a major cultural-historical problem. This is true for wapato as well. The earliest accounts of contact with people of the Lower Columbia describe the use of wapato. The uniformity of these and other early reports makes it extremely likely that wapato intensification preceded contact.

If the intensification of a plant puts the gatherers on the continuum towards an agricultural lifeway, where on this continuum were the Chinook? The region had the elements Harris (1980) identifies are necessary for an emergent stable agricultural system: high species diversity, crop ecology that lends itself to intensification, and the intensive management of the resources within the ecosystem (Harris in Green 1980:332). Gorman (1977) suggested that agriculture began in marsh environments in Southeast Asia with crops such as rice and yams. The Greater Lower Columbia region fits some of Sauer's model of the 'first farmers' who were fisherfolk who lived in a wooded and diverse environment on freshwater streams in the tropics (Sauer 1952). According to Sauer, the first agriculturists

grew crops vegetatively which made the selection of desirable traits easy, and eventually led to plants that lost their capacity to bear viable seeds.

Plowing, weeding, selecting and planting are farming techniques that change the genetics of a plant, and increase the plant's dependence on human protection. Wooten demonstrated that *Sagittaria latifolia* exhibits deep dormancy of its seeds, which is occasionally cited as an indicator of domestication. Ethnographic and ethnohistoric evidence suggests that this plant was intensively exploited by the human population. However, there is scant evidence that wapato had become domesticated. Seed dormancy in *Sagittaria latifolia* was most likely a product of waterfowl grazing on the seedheads, not selection of desirable traits by humans. There is one late ethnographic account that indicates that the Indians of the Puget Sound region transplanted wapato from one area to another (Haeberlin 1930). Ethnohistoric and ecological evidence suggests that the plant was sufficiently prolific naturally in Wapato Valley, and did not need to be transplanted.

On the Northwest Coast several theorists link the evolution of complex hunter-gatherer societies in part to salmon intensification (Matson 1983, Fladmark 1975, Schalk 1977, Burley 1994). Burley's model suggests that salmon intensification occurred first in streams, particularly the Fraser River, rather than the coast, because salmon were more easily caught in streams (Burley 1994). Wapato was exploited in the Fraser River as well, and intensification of both resources may have led to complexity in this location. This is a matter of further study.

Ames suggests that circumscription played a part in the development of complexity in the Northwest. The Greater Lower Columbia had a high population density, but the

effects of circumscription that Binford cites such as tension zones between sedentary and migratory populations, and defense of boundaries did not appear to manifest themselves as one would expect if circumscription was a crucial element in the development of complexity in the Greater Lower Columbia area. However, the Greater Lower Columbia is too small an area of study to draw implications about complexity for the entire Northwest Coast.

Another subject of further study is to determine how, when and to what extent the Chinook utilized muskrat. I suggest that muskrat was an important late winter food, and provided a unique trade commodity; the muskrat skin robe. Burley notes that an effect of a food surplus beyond subsistence needs would be a widespread trading pattern in non-utilitarian or primitive wealth items. A secondary effect would be specialization in crafts for the trade market (Burley 1980:71). The muskrat skin robe may have been just such a specialized craft item produced in Wapato Valley, and traded to the coast and other locations, along with baskets of wapato.

One tool type that may be associated with wapato intensification is a large, flat, peripherally flaked cobble tool that has been found on the Vancouver Lake shore, and at a portage site linking Lake River with a pond where the people of Cathlapotle gathered wapato (45CL04). These tools show little or no use-wear. This tool may have been used to break up the *Ludwigia* bed, and its presence may be an indicator of intensification of wapato where wapato grows in association with *Ludwigia palustris*. This is also a matter of future study.

Another important finding that has emerged from this study is that large earth ovens and ground stone tools are not always indicators of the intensive use of a root food. Ethnographic and ethnohistoric accounts from the region describe wapato as being roasted whole and generally eaten, peel and all. Tools for processing plant foods such as grindstones, mortars and pestles, and knives and scrapers for peeling and cutting vegetables are considered indicators of plant food intensification. These tool types are common in archaeological sites on the Lower Columbia, but ethnographic information suggests that these tools were typically used for plant foods other than wapato. The implication of this is that evidence of exploitation of wapato by humans would be difficult to find archaeologically, both due to the taphonomy of root parts in general, and because stone tools and large amounts of fire cracked rock would not be use indicators. Archaeologists need to look for other lines of evidence to study the exploitation of *Sagittaria latifolia* roots. This applies specifically to questions of human subsistence in the late Pleistocene in The Great Basin and northern United States, where this plant is believed to have been much more prolific than it is today (Stuckey 1993:289).

Chapter Eight :BIBLIOGRAPHY

- Aikens, Melvin C. and Takayasu Higuchi
1982 *Prehistory of Japan*. Academic Press, New York.
- Aikens, Melvin C.
1978 The Far West. In *Ancient Native Americans*. Jesse Jennings ed. W.H. Freeman and Co., San Francisco.
- Allen, A. J.

1850 *Ten Years in Oregon; Travels and Adventures of Doctore E. White and Lady, West of the Rocky Mountains*. Press of Andrus, Gauntlett, & Co. Ithaca, N.Y.
- Allen, Paul
1961 *The Lewis and Clark Expedition*. Nicholas Biddle and Paul Allen editors. First published 1814.
- Ames, Kenneth M., William L. Cornett, and Stephen C. Hamilton
1995 *Archaeological Investigations (1991-1994) at 45Cl1 (Cathlapotle), Clarke County, Washington: A Preliminary Report*. Wapato Valley Archaeological Project Report Number 5. Department of Anthropology, Portland State University, U.S. Fish and Wildlife Service.
- Ames, Kenneth M.
1994 The Northwest Coast: Complex Hunter-Gatherers, Ecology, and Social Evolution. *Annual Review of Anthropology*. 1994. 23:209-29.
- Ames, Kenneth M.
1991 Sedentism, a temporal shift or a transitional change in hunter-gatherer mobility strategies. In *Between Bands and States: Sedentism, Subsistence and Interaction in Small Scale Societies*, ed. S Gregg, pp 103-33. Carbondale: S. Ill. University Press.
- Ames, Kenneth M.
1984 Hierarchies, Stress, and Logistical Strategies among Hunter-Gatherers in Northwestern North America. In *Prehistoric Hunter-Gatherers, The Emergence of Cultural Complexity*, pp. 155-180. Academic Press, Inc. New York.

Ames, Kenneth M.

- 1983 Towards a General Model of the Evolution of Ranking among Foragers. *The Evolution of Maritime Cultures on the Northeast and Northwest Coasts of America*. Edited by Ronald Nash. Publication No. 11, pp. 173-184. Department of Archaeology, Simon Fraser University.

Ames, Kenneth M., Alan G. Marshall

- 1980 Villages, demography and subsistence intensification on the Southern Columbia Plateau, *North American Archaeologist*, Vol. 2(1), 1980-1981, pp 25-47.

Anderson, E. N.

- 1988 *The Food of China*. Yale University Press. New Haven and London.

Anonymous

- 1898 Revival of the Wapato. *Oregonian*. Article in Scrapbook 35, Oregon Historical Society Archives. Portland.

Anonymous

- 1892 *Carp and the Wapato*. July 17, 1892. Scrapbook 35, page 189. Oregon Historical Society Archives, Portland.

Anonymous

- 1925 Wapato, An Indian Food Found on Sauvies Island. *Oregonian*, September 14, 1925.

Arnold, Jeanne E.

- 1995 Transportation Innovation and Social Complexity among Maritime Hunter-Gatherer Societies. *American Anthropology* Vol. 97, No. 4:733-747.

Atwell, Jim

- 1974 *Columbia River Gorge History*. Volume Two. Tahlkie Books; Stevenson, Washington.

Bagley, Clarence B.

- 1932 *Early Catholic Missions in Old Oregon*. Volume 1. Lowman and Hanford Company, Seattle.

Belovsky, Gary E.

- 1988 An Optimal Foraging-Based Model of Hunter-Gatherer Population Dynamics. *Journal of Anthropological Archaeology*. 7:329-327.
- Bender, Barbara
 1978 Gatherer-hunter to farmer: a social perspective. *World Archaeology* 10:204-219.
- Bender, Barbara
 1975 *Farming in Prehistory, From Hunger-Gatherer to Food-Producer*, St. Martin's Press, New York.
- Benson, Adolf editor
 1770 *Peter Kalm's Travels in North America*. The English Version revised from the original Swedish. Vol. I. Dover Publications, New York.
- Binford, Lewis R.
 1968 Post-Pleistocene adaptations. *New Perspectives in Archaeology*. Edited by L.R. Binford and S.R. Binford.
- Blakenship, J.W.
 1905 *The Native Economic Plants of Montana*. Montana Agricultural Department Experiment Station Bulletin 56, pg. 36.
- Boas, Franz
 1911 *Handbook of American Indian Languages*. Bureau of American Ethnology, Bul. no. 40. Part 1, pg 563. Washington, Government Printing Office.
- Boas, Franz
 1901 *Kathlamet Texts*. Smithsonian Institution, Bureau of American Ethnology: J.W. Powell, Director. bulletin 26. Government Printing Office, Washington D.C.
- Boyd, Robert T.
 1985 *The Introduction of Infectious Diseases Among the Indians of the Pacific Northwest, 1774-1874*. Ph.D. dissertation, University of Washington.
- Boyd, Robert T. and Yvonne P. Hajda
 1987 Seasonal population movement along the Lower Columbia river: the social and ecological context. *American Ethnologist* 1987, 14:309-326.
- Bronson, Bennet

- 1977 The earliest farming: demography as cause and consequence. In *Origins of Agriculture*, edited by Charles A. Reed. Aldine Publishing, Chicago.

Broughton, W.R. Lieutenant

- 1792 *The Exploration of the Columbia River*. An extract from the journal of Captain George Vancouver. Compiled by the Sons and Daughters of the Oregon Pioneers, Rufus Holman, president. Press of the Longview Daily News, Longview.

Brown, R.

- 1868 On the vegetable products used by the Northwest American Indians as food and medicine, in the arts and In superstitious rites, *Botanical Society Edinburgh Transactions* 9:378-396. Reprinted in *The North American Indian*, David Hurst Thomas, editor. 1986, Garland, New York.

Burley, David V.

- 1980 *Marpole, Athropological Reconstructions of Prehistoric Northwest Coast Culture Type*. Department of Archaeology, Simon Fraser University, Publication No. 8. Burnaby, British Columbia.

Butzer, Karl W.

- 1990 *Archaeology as Human Ecology*. Cambridge University Press, Cambridge.

Canniff, Kiki

- 1981 *Sauvie Island, A Step Back in Time*. Ki2 Enterprises. Portland, Oregon.

Carter, George

- 1977 *A Hypothesis Suggesting a Single Origin of Agriculture*. In *Origins of Agriculture*, edited by Charles A. Reed. Mouton Publishers, The Hague, Paris.

Chang, K.C.

- 1970 The Beginnings of Agriculture in the Far East. *Antiquity*, 44, 175.

Child, V.G.

- 1936 *Man Makes Himself*. London: Watts.

Clark, William R. and Darryl W. Kroeker

- 1993 Population Dynamics of Muskrats in Experimental Marshes at Delta, Manitoba. *Canadian Journal of Zoology*. Vol 71:1620-1628.

Clarke, Chuck

- 1975 *Background Information for Water Resources Planning in the Lower Columbia Basin*. Water Resources Information System. State of Washington Department of Ecology.

Cohen

- 1977 *The Food Crisis in Prehistory*. Yale University Press, New Haven.

Couture, Marilyn D.

- 1986 Foraging Behavior of a Contemporary Northern Great Basin Population. *Journal of California and Great Basin Anthropology* 8(2):150-160.

Coville, F. V.

- 1892 Notes on the Plants Used by the Klamath Indians of Oregon. *U.S. National Museum Contributions U.S. National Herbarium* 5:87-108.

Cox, Ross

- 1957 *The Columbia River or scenes and adventures during a residence of six years on the western side of the Rocky Mountains among various tribes of Indians hitherto unknown; together with "A Journey across the American Continent,"*. (1832) Edited by Edgar I. Stewart and Jane R. Stewart. University of Oklahoma Press.

Darby, Melissa

- 1991 Historic Artifacts, in *Archaeological Excavations at Cowlitz Falls, Lewis County, Washington*, by David V. Ellis, Jeffrey Scott King, David E. Putnam, David Francis, Gail Thompson of Historical Research Associates, Inc. Report prepared for Bechtel Corporation, San Francisco.

Delesalle, V. A. and S. Blume

- 1994 Variation in Germination and Survival Among Families of *Sagittaria latifolia* in Response to Salinity and Temperature. *International Journal of Plant Sciences*. Vol. 155, Iss 2, pg 187-195.

Delesalle, V.A. and Menchow

- 1992 Opportunities for selfing and inbreeding depression in *Sagittaria* Cognens Alismataceae with Contrasting Sexual Systems. *Evolutionary Trends in Plants*, Vol. 6, Iss. 2, pg 81-91.
- Densmore, F.
1923 Uses of Plants by the Chippewa Indians. *Bureau American Ethnologist Annual Report*. 44:319.
- Dickson, Evelyn M.
1946 *Food Plants of Western Oregon Indians*. Thesis, Leland Stanford Junior University.
- Dufour, Terry
1996 personal communication, Oregon Fish and Wildlife Department.
- Eaton, Boyd S. and Melvin Konner
1985 Paleolithic Nutrition. *The New England Journal of Medicine*. Vol 312, No. 5, pp. 283-289.
- Ebeling, Walter
1984 *Handbook of Indian Foods and Fibers of Arid America*. University of California Press, Berkely.
- Ellen, Roy
1982 *Environment, Subsistence and System*. University of Kent at Canterbury. Cambridge University Press. Cambridge.
- Elliott, T.C. editor
1927 Journal of the Ship Ruby, by Captain Charles Bishop. *Oregon Historical Society Quarterly*, Vol. 28, No. 3.
- Falter, C. Michael, James Leonard, Richard Naskali, Fred Rabe, Helen Bobisud
1974 *Aquatic Macrophytes of the Columbia and Snake River Drainages*. College of Forestry, Department of Biological Sciences, University of Idaho. Moscow, Idaho. Report submitted to the U.S. Army Corps of Engineers, Walla Walla.
- Fee, Chester Anders
1941 Oregon's Historical Esperanto--The Chinook Jargon. *Oregon Historical Quarterly*. 1942, Vol. 42:176-180.
- Farnham, Thomas J.

- 1906 *Travels in the Far Northwest*. Edited by Reuben Gold Thwaites. The Arthur H. Clark Company.

Fladmark, Knut R.

- 1975 *A Paleoecological Model for Northwest Coast Prehistory*. National Museum of Man, Mercury Series. Archaeological Survey of Canada Paper No. 43. Ottawa.

Franchere, Gabriel

- 1854 *Narrative of a Voyage to the Northwest Coast of American in the years 1811, 1812, 1813, 1814, or the First American Settlement on the Pacific*. Englished and edited by J.V. Huntington 1854. Republished by the Arthur H. Clark Company, 1904.

Franchere, Gabriel (translated and edited by Hoyt Franchere)

- 1967 *Adventure at Astoria, 1810-1814*. Diaries of Gabriel Franchere. University of Oklahoma Press, Norman.

Franchere, Hoyt C.

- 1973 *The Overland Diary of Wilson Price Hunt*. Translated from the French and Edited by Hoyt C. Franchere. The Oregon Book Society.

Franklin, Jerry F., and C.T. Dyrness

- 1973 *natural Vegetaion of Oregon and Washington*. USDA Forest Sevice General Technical Report PNW-8. Portland.

Gatschet, Albert S.

- 1877 Texts, Sentences and Vocables of the Atfa'lati Dialect of the Tualatin Language of Willa'met Valley, Northwestern Oregon. (Manuscript field notes, catalogue no. 472-a, National Anthropological Archives, Smithsonian Institution, Washington D.C.).

Geertz, Clifford

- 1963 *Agricultural Involution, The Process of Ecological Change in Indonesia*. University of California Press, Berkeley and Los Angeles.

Gilbert, Helene

- 1990 Productivite vegetal dans un marais intertidal d'eau douce, Quebec. *Canadian Journal of Botany* 68:825-856.

Gilkey, Helen M. and La Rea J. Dennis

- 1980 *Handbook of Northwestern Plants*. Oregon State University Bookstores, Inc. Corvallis, Oregon.
- Gilmore, M. R.
1919 Uses of Plants by the Indians of the Missouri River Region. *Bureau American Ethnology Annual Report* 33:65.
- Giroux, J.F. and J. Bedard
1987 The effects of grazing by greater Snow Geese on the vegetation of tidal marshes in the St. Lawrence estuary. *Journal of Applied Ecology* 24, 773-778.
- Godfrey, Robert K., Jean W. Wooten
1979 *Aquatic and Wetland Plants of Southeastern United States, Monocotyledons*. University of Georgia Press, Athens.
- Gorman, Chester
1977 *A Priori Models and Thai Prehistory: A Reconsideration of the Beginnings of Agriculture in Southeast Asia*. In *Origins of Agriculture*, Mouton Publishers, The Hague, Paris.
- Green, Stanton W.
1980 Toward a General Model of Agricultural Systems. In *Advances in Archaeological Method and Theory*. Vol. 3:311-355.
- Gruenhagen, Ned M. and Leigh H. Fredrickson
1990 Food use by migratory female mallards in Northwest Missouri. *Journal of Wildlife Management* 54(4):622-626.
- Gunther, Erna
1974 *Ethnobotany of Western Washington*. University of Washington Press, Seattle and London.
- Gunther, Erna
1928 A Further Analysis of the First Salmon Ceremony. *University of Washington Papers in Anthropology*. University of Washington Press. Seattle.
- Haeberlin, Hermann and Erna Gunther
1930 *The Indians of Puget Sound*. University of Washington Publications in Anthropology, vol. 4, no. 1, pp. 1-84.
- Hajda, Yvonne P.

- 1984 *Regional Social Organization in the Greater Lower Columbia, 1792-1830.*
Ph.D dissertation, University of Washington.

Hale, Horatio

- 1846 *Ethnography and Philology, United States Exploring Expedition during the years 1838,1839,1840,1841,1842 Under the Command of Charles Wilkes, U.S.N.* Reprinted 1968. The Gregg Press.

Hanson, Gordon William

- 1973 *The Katz Site: A Prehistoric Pithouse Settlement in the Lower Fraser Valley, British Columbia.* A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts, University of British Columbia.

Harris, David R.

- 1977 *Alternative Pathways Toward Agriculture.* In *Origins of Agriculture*, edited by Charles A. Reed. Aldine Publishing, Chicago.

Harris, David R. and Gordon C. Hillman.

- 1989 *Foraging and Farming, The Evolution of Plant Exploitation*, edited by David R. Harris, and Gordon C. Hillman. Unwin Hyman, London.

Harvey, Athelstan George

- 1947 *Douglas of the Fir.* Harvard University Press, Cambridge.

Havard, V.

- 1884 *Food Plants of the North American Indians.* *Bulletin Torrey Botanical Club.* 24:105.

Higham, F. G.

- 1977 *A Priori Models and Thai Prehistory: A Reconsideration of the Beginnings of Agriculture in Southeast Asia.* In *Origins of Agriculture*, edited by Charles Reed. Mouton Publishers, The Hague,

Hilty, Ivy E., Jean Peters, Eva Benson, Margaret Edwards, Lorraine Miller

- 1973 *Nutritive Values of Native Foods of Warm Springs Indians.* Oregon State University Extension Service.

Hitchcock, Leo C., Arthur Cronquist

- 1973 *Flora of the Pacific Northwest.* University of Washington Press. Seattle.

Hodge, Frederick Webb

- 1907 *Handbook of American Indians North of Mexico*. Smithsonian Institution, Bureau of American Ethnology, Bull 30, Part 1. Washington, Government Printing Office.

Hohman, William and Dennis W. Woolington

- 1990 Food Habits of wintering canvasbacks in Louisiana. *Canadian Journal of Zoology*. Vol. 68, 1990.

Howay, F.W. and T.C. Elliott

- 1943 Extract from the Journal of Thomas Manby, master of the Chatham. *Oregon Historical Quarterly*. Vol 43, no. 4:318-327.

Howay, F.W.

- 1927 Early Followers of Captain Grey. *Washington Historical Quarterly* Vol. 18 no.

Howell, Thomas

- 1903 *A Flora of Northwest America*. Vol. 1. Phanerogame, C.C. Lane. Portland, Oregon.

Hu, Peter, David B. Hannaway, Harold W. Youngberg

- 1992 *Forage Resources of China*. Beijing Agricultural University and Oregon State University. Pudoc Wageningen.

Hunn, Eugene s.

- 1981 On the relative contribution of men and women to subsistence among hunter-gatherers of the Columbia Plateau: A comparison with Ethnographic Atlas summaries. *Journal of Ethnobiology* 1 (1): 124-134.

Hussey, John A.

- 1949 *Preliminary survey of the History and Physical Structure of Fort Vancouver*. U.S. Department of the Interior, National Park Service, Region 4, San Francisco.

Jackson, Donald

- 1978 *Narrative of a Journey Across the Rocky mountains to the Columbia River*. University of Nebraska Press. Originally published in 1839.

Jackson, Donald and Mary Lee Spence

- 1973 *The Expeditions of John Charles Fremont*. Vol. 1, University of Illinois Press. Urbana. Edited by Donald Jackson and Mary Lee Spence.

Jackson, Donald

- 1962 *Letters of the Lewis and Clark Expedition, with related documents. The Biddle letters.* University of Illinois Press, Urbana.

Jacobs, Melville

- 1945 *Kalapuyan Texts. University of Washington Publications in Anthropology 11.* Seattle.

Dorothy O. Johansen, editor

- 1960 *Voyage of the Columbia Around the World with John Boit, 1790-1793.* Edited by Dorothy O. Johansen. Beaver Books, Portland.

Jones, Roy

- 1972 *Wappato Indians of the Lower Columbia River Valley.* Privately Printed.

Kane, Paul

- 1968 *Wanderings of an Artist.* Charles E. Tuttle Co.: Publishers, Rutland.

Kaul, Robert B.

- 1979 *Inflorescence Architecture and Flower sex Ratios in Saittaria Brevirostra.* *American Journal of Botany* 66(9):1062-1066.

Keely, Patrick Byron

- 1980 *Nutrient Composition of Selected Important Plant Foods of the Pre-Contact Diet of the Northwest Native American Peoples.* M.S. Thesis, University of Washington, Nutritional Sciences and Textiles Dept.

Kew, M.

- 1992 *Salmon availability, technology, and cultural adaptation in the Fraser River watershed. In A Complex Culture of the British Columbia Plateau: Traditional Stl'atl'imx resource Use,* ed. B. Hayden. Vancouver, University B.C. Press.

Kuhnlein, H.V. and Nancy J. Turner

- 1982 *Nutritional Significance of Two Important Root Foods (Springbank Clover and Pacific Silverweed) used by the Native People on the Coast of British Columbia.* *Ecology of Food and Nutrition* 12:89-95.

Lampman, Ben Hur

- 1946 *The Coming of the Pond Fishes,* Binfords and Mort, Portland, Oregon.

Larson, Lynn

- 1995 personal communication

- Link, Terry
1995 Oregon Fish and Wildlife. Personal Communication.
- Lucas, Jannette May
1945 *Indian harvest, Wild Food Plants of America*. J.B. Lippincott Company. Philadelphia and New York.
- Mackey, Harold
1974 *The Kalapuyans, A Sourcebook on the Indians of the Willamette Valley*. Published by the author in cooperation with the Mission Mill Museum Association. Salem, Oregon.
- MacNeish, Richard S.
1992 *The Origins of Agriculture and Settled Life*. University of Oklahoma Press: Norman and London.
- Matson, R.G.
1983 Intensification and the Development of Cultural Complexity: The Northwest Versus the Northeast Coast. In *The Evolution of Maritime Cultures on the Northeast and Northwest Coasts of America*. Edited by Ronald Nash. Publication No. 11, pp 125-149. Department of Archaeology, Simon Fraser University.
- Megaw, J.W.S., editor
1977 *Hunters, Gatherers and first Farmers Beyond Europe*. An archaeological survey. Leicester University Press, Great Britain.
- Miller, G. Tyler
1994 *Living in the Environment, Concepts, Problems, and Alternatives*. Wadsworth. Belmont, California.
- Minor, Rick
1983 *Aboriginal Settlement and Subsistence at the Mouth of the Columbia River*. PhD. Dissertation. University of Oregon.
- Moran, Emilio F., editor
1992 *The Ecosystem Approach in Anthropology*. Ann Arbor, The University of Michigan Press.
- Moulton, Gary E. editor

- 1983 *The Journals of the Lewis and Clark Expedition*. University of Nebraska Press, Lincoln and London.
- Muenchow G., and W.A. Delesalle
 1994 Pollinator Response to Male Floral Display Size in Two *Sagittaria* spp.. *American Journal of Botany*. Vol. 81, Iss. 5, pg 568-573.
- Muenchow, G., W.A. Delesalle
 1992 Patterns of Weevil Herbivory on Male, Monoecious and Female Inflorescences of *Sagittaria latifolia*. *American Midland Naturalist* 127:355-367.
- Nash, Ronald J.
 1983 *The Evolution of Maritime Cultures on the Northeast and Northwest Coasts of America*. Publication No. 11. Department of Archaeology, Simon Fraser University.
- Neumann, Alan, Richard Holloway and Colin Busby
 1989 Determination of Prehistoric Use of Arrowhead (*Sagittaria*, Alismataceae) in the Great Basin of North America by Scanning Electron Microscopy. *Economic Botany* 43(3), 1989, pp. 287-296.
- Norton, H.H. E.S. Hunn, C.S. Martinson, and P. B. Keely
 1984 Vegetable food products of the foraging economies of the Pacific Northwest. *Ecology of Food and Nutrition*. Vol. 14, pp 219-228.
- Norton, Helen H.
 1979 The Association between Anthropogenic Prairies and Important Food Plants in Western Washington. *Northwest Anthropological Research Notes*. Fall 1979, Vol. 13, No.2, pp. 175-200.
- Oregon Department of Fish and Wildlife
 nd Statistics of Waterfowl use days 1980-1994.
- Parker, A. G.
 1910 Iroquois Uses of Maize and other Food Plants. *N.Y. State Museum Bulletin*. 144:105.
- Parker, Samuel
 1967 (1838) *Journal of an Exploring Tour Beyond the Rocky Mountains Performed in the Years 1835, '36, '37*. Ross and Haines, Minneapolis, Minnesota.
- Peterson-del Mar, David

- 1995 Intermarriage and Agency: A Chinookan Case Study. *Ethnohistory* 42:1, pp. 1-30.
- Powell, Fred Wilber
 1917 Memoir of Hall Jackson Kelley. *Oregon Historical Society Quarterly*, Vol. 17 no. 4 p. 271-295.
- Powell, Fred Wilber, editor
 1932 *Hall J. Kelley on Oregon, Narratives of the Trans-Mississippi Frontier*. Princeton University Press.
- Ray, Vern
 1938 *Lower Chinook Ethnographic Notes*. University of Washington Publication in Anthropology 7(2): 29-165. Seattle
- Ray, V.
 1933 The Sanpoil and Neselem: Salishan Peoples of Northeastern Washington. University of Washington Publications in Anthropology 5:1-237.
- Reed, Charles A., editor
 1977 *Origins of Agriculture*. Mouton Publishers. The Hague, Paris.
- Reidhead, Van
 1980 The Economics of Subsistence Change: A Test of an Optimization Model. In *Modeling Change in Prehistoric Subsistence Economies*, eds. Timothy K. Earle and Andrew L. Christenson. Academic Press, New York.
- Rindos, David
 1984 *The Origins of Agriculture: An Evolutionary Perspective*. Academic Press, Orlando.
- Ross, Alexander
 1966 *Adventures of the First Settlers on the Columbia River*. Ann Arbor, University Microfilms, Inc.
- Ruby, Robert and John H. Brown
 1976 *A Guide to the Indian Tribes of the Pacific Northwest*. University of Oklahoma Press: Norman and London.
- Saleeby, Becky Margaret

- 1983 *Prehistoric Settlement Patterns in the Portland Basin of the Lower Columbia River: Ethnohistoric, Archaeological, and Biogeographic Perspectives.*

Saleeby, Becky and Richard M. Pettigrew

- 1983 Seasonality of occupation of the ethnohistorically-documented villages of the Lower Columbia River, in *Prehistoric Places on the Southern Northwest Coast*, ed. by Robert E. Greengo, pp. 169-193.

Salaman, Redcliffe N.

- 1949 *The History and Social Influence of the Potato.* Cambridge University Press, Cambridge. Reprinted 1987.

Sauer, C.O.

- 1952 *Agricultural Origins and Dispersals.* New York, American Geographical Society.

Schalk, Randall

- 1978 *Foragers of the Northwest Coast of North America: The Ecology of Aboriginal land Use Systems.* Dissertation. University of New Mexico. Albuquerque.

Schiffer, Michael B., editor

- 1980 *Advances in Archaeological Method and Theory.* Vol. 3, Department of Anthropology, University of Arizona. Tucson. Academic Press, New York.

Sidorskii, A.

- 1992 Adaptive Abilities of Sexual Differentiation in *Sagittaria sagitifolia*. *Botanicheskii Zhurnal*, Vol. 77 Iss. 3 pg 60-72.

Sims, Laura S., Beatrice Paolucci, and Portia M. Morris

- 1972 A theoretical model for the study of nutritional status: An Ecosystem approach. *Ecology of Food and Nutrition.* Vol 1, pp. 197-205.

Skarsten, M. O.

- 1964 *George Drouillard, Hunter and Interpreter for Lewis and Clark.* The Arthur H. Clark Company. Glendale, California.

Slacum, William

- 1912 Slacum's Report on Oregon, 1836-1837. *Oregon Historical Quarterly*, 1913. Vol 13: 175-224.
- Smith, Harriet L.
1976 *Wonderful Wappato*. Smith, Smith and Smith Publishing company, Lake Oswego, Oregon.
- Smith, H.H.
1923a Ethnobotany of the Menomimi Indians. *Milwaukee Public Museum Bulletin* 4:61.
- Smith, H.H.
1923b Ethnobotany of the Meskwaki Indians. *Milwaukee Public Museum Bulletin* 4:254.
- Smith, H.H.
1933 Ethnobotany of the Ojibwe Indians. *Milwaukee Public Museum Bulletin* 4:396.
- Smith, Jared G,
1894 A Revision of the North American Species of *Sagittaria* and *Lophotocarpus*. *Annual Report of the Missouri Botanical Garden*. Vol. 6, 1884.
- Spencer, Omar C.
1950 *The Story of Sauvies Island*. Binfords and Mort, Portland.
- Speth, John D. and Katherine A. Spielmann
1983 Energy Source, protein Metabolism, and Hunter-Gatherer Subsistence Strategies. *Journal of Anthropological Archaeology* 2(1):1-31.
- Spier, Leslie and Edward Sapir
1930 Wishram Ethnography. *University of Washington Publications in Anthropology*. Vol 3, No. 3, pp. 151-300.
- Spinden, H.J.
1908 The Nez Perce Indians. *Memoirs American Anthropological Association* 2:204.
- Stoffle, Richard W. and David B. Halmo

- 1990 Calculating the Cultural Significance of American Indian Plants: Paiute and Shoshone Ethnobotany at Yucca Mountain, Nevada. *American Anthropologist*. 92:416-432.
- Stuckey, R.L.
1994 *Sagittaria*: The Distribution of its Species in Relation to Physiography and Glaciation in Eastern North America. *American Journal of Botany*, Vol. 81, Iss. 6, suppl 4.
- Suttles, Wayne
1951 *Katzie Ethnographic Notes*. Anthropology in British Columbia, Memoirs Nos. 2 and 3.
- Suttles, Wayne
1951 The Early Diffusion of the Potato among the Coast Salish. *Southwestern Journal of Anthropology*. Vol 7, no. 3, pp 272.
- Swan, James G.
1977 *The Northwest Coast*. University of Washington Press, Seattle and London. First published in 1857, Harper and Brothers.
- Tanimoto, Tadayoshi
1989 Promotion of Flowering and Seed Germination in Chinese Arrowhead *Sagittaria trifolia* var. *edulis*. In *Japanese Journal of Breeding* 39: 345-352.
- Thomas, David Hurst, ed.
1986 *The North American Indian: An Ethnobiology Sourcebook*. Garland, New York.
- Thoms, Alston
1989 *The Northern Roots of Hunter-gatherer Intensification: Camas and the Pacific Northwest*. In partial fulfillment of the requirements for the degree of Doctor of Philosophy, Washington State University.
- Thwaites, Ruben Gold, editor
1904 Ross's Adventures of the First Settlers on the Oregon or Columbia River, 1810-1813, in *Early Western Travels 1748-1846*. Vol. VII. The Arthur H. Clark Company. Cleveland, Ohio.
- Thwaites, Ruben Gold, editor

1904 Franchere's Voyage to the Northwest Coast, 1811-1814. In *Early Western Travels 1748-1846*. Vol. VI. The Arthur H. Clark Company. Cleveland, Ohio.

Thwaites, Reuben Gold, editor

1969 *Original Journals of the Lewis and Clark Expedition 1804-1806*. Vols. 3 and 4. Antiquarian Press Ltd. New York. First published 1904-1905, Dodd, Mead and Co.

Turner, Nancy J.

1982 *Food Plants of British Columbia Indians, Part 1--Coastal Peoples*. British Columbia Provincial Museum, Handbook NO. 34.

Turner, Nancy J. and Harriet V. Kuhnlein

1983 Camas and Riceroot, Two Liliaceous "Root" Foods of the northwest Coast Indians. *Ecology of Food and Nutrition* 13:199-219.

U.S. Department of Commerce

1930 Columbia River Chart: St. Helens to the Willamette River. Oregon Historical Society maps library.

U.S General Land Office

1853-1854 Willamette Meridian T4N,R1W (maps and notes).

Visser, Jenneke Maria

1989 *The Impact of Vertebrate Herbivores on Primary Production of Sagittaria marshes in the Wax Lake Delta, Atchafalaya Bay, Louisiana*. PhD. Dissertation, Louisiana State University, Part B. Vol 51, Iss. 2.

Wessen, Gary

1983 *Archaeological Investigations at Vanacouver Lake, Washington*. Richard Daugherty, Principal Investigator. Western Heritage Inc

White, Joyce C.

1989 *Ethnoecological observations on wild and cultivated rice and yams in northeastern Thailand*, in *Foraging and Farming, The Evolution of Plant Exploitation*, edited by David R. Harris, and Gordon C. Hillman. Unwin Hyman, London.

Winterhalder, B.

- 1984 Reconsidering the Ecosystem Concept. *Reviews in Anthropology* 11(4):301-330.

Wooten, Jean W.

- 1968 *Systematic Studies of Seven Species of Sagittaria in the Eastern North America*. University of Florida.

- 1971 The Monoecious and Dioecious Conditions in *Sagittaria latifolia*. *Evolution*, 25:549-553.

Wright, Herbert E. Jr.

- 1977 Environmental Change and the Origin of Agriculture in the Old and New Worlds. *Origins of Agriculture*, edited by Charles Reed. Mouton Publishers, The Hague, Paris.

Zenk, Henry B.

- 1976 *Contributions to Tualatin Ethnography: Subsistence and Ethnobiology*. M.A. Thesis, Portland State University.

