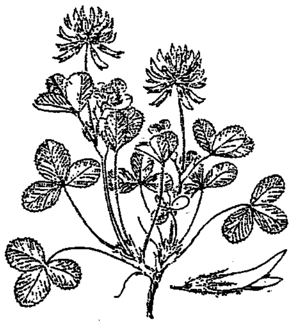

Chapter 3

Intensification of Food Production on the Northwest Coast and Elsewhere

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The techniques of plant food production described in the chapters that follow are very likely the result of an evolutionary process known as intensification, or, in other words, producing more food. The causes and possible effects of increasing food production are central research question to many disciplines, Northwest Coast anthropology and archaeology among them. This chapter examines intensification on the Northwest Coast and among complex hunter-gatherers. I first very briefly outline several issues in the archaeology of the Northwest Coast and of complex hunter-gatherers to which intensification of food production is directly relevant. In the sections that follow, I place the concept of intensification in a broader perspective, both in terms of theory and application. From this general consideration of intensification, I discuss the intensification of plant food production on the Northwest Coast using models either developed by evolutionary ecologists or based on their work. One set of models is quite general in its application, and a second set of two models specifically focuses on the intensification of root harvesting. The archaeological record for intensification is then examined against the predictions of the general models. Following that discussion, I review the evidence for the intensification of root food production on the Intermontane Plateau of south central British Columbia and Interior Washington and Idaho. I also review the evidence for plant use during the Locarno Beach and Marpole phases of the Gulf of Georgia region of the southern Northwest Coast.

Issues in Northwest Coast Social and Economic History

It has only been within the last thirty years that the subsistence economies and ecology of Northwest Coast peoples have been of central concern to anthropologists and archaeologists working on the coast. Prior to that time, the coast was assumed to be an exceptionally rich and productive place, one

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that permitted, but did not cause, the development of Northwest Coast societies. Wayne Suttles (e.g., 1962, 1968) and others (Vayda 1961) placed the interplay among the coast's dynamic environments and coastal peoples' complex social organization at the center of anthropological inquiry in the early 1960s. Knut Fladmark (1975) put salmon production at the center of archaeological investigations of the evolution of Northwest Coast societies in 1975.

Nineteenth-century Northwest Coast societies are world-famous for, among other things, their extraordinary art. Other attributes of these societies include complex forms of sedentism (people living in one place year-round); large towns and villages; some degree of occupational specialization among at least some groups; and ranking of their members. These are all traits that anthropologists and other social theorists long assumed were associated exclusively with agriculture; that, indeed, in order to develop, they require the high levels of food production that only agriculture can produce. These traits can be placed together under the term "social complexity." Since Northwest Coast peoples were not farmers, as classically defined, then how did they evolve social complexity? The question that Suttles tried to answer remains: What are the relationships between subsistence production, ecology, and social complexity on the Northwest Coast (and, by extension, among other, so-called "complex hunter-gatherers" in the world)?

The issues arising from these questions have been extensively reviewed elsewhere, and the reader is referred to Ames (1994) for a thumbnail sketch of them. However, to introduce both this chapter and those that follow, I will quite briefly outline some of the research questions immediately relevant here (for more complete discussions, and bibliographies, see Ames [1994], Ames and Maschner [1999], and Matson and Coupland [1995]).

SOCIAL COMPLEXITY: INTENSIFICATION AND FOOD STORAGE

For most of the past century, researchers around the world have assumed a direct link between the evolution of complex societies (such as those on the Northwest Coast, as well as modern society, the Roman Empire, etc.) and increased levels of food production in the form of farming. It was long held that hunter-gatherers simply could not produce enough food to create the surpluses required to enable the development of social complexity. In a significant intellectual shift, it is now recognized that intensification of food production can lead to social complexity, regardless of economy.

All the debates about intensification on the Northwest Coast, until this volume, focus on the role and relative importance of salmon. Many researchers regard increasing salmon production as the crucial economic change driving almost all other social and economic changes in the long history of the coast's peoples. Others, myself included, regard salmon as only one among many resources whose intensification has been important in causing, or affecting, social and economic change. In other words, we argue that salmon intensification is not the key economic change on the coast. I have termed this the debate over "secondary resources" (Ames 1994). This continuing debate, to which this book is a contribution, is essentially over our basic understanding of Northwest Coast economies.

Northwest Coast subsistence economies of the nineteenth century were heavily dependent on food storage, and the development of this heavy dependence was also probably central to many other social and economic changes on the coast. As with salmon production, key questions are when did Northwest Coast societies become heavily dependent on food storage, and why.

Food storage must be understood to mean: (1) the acquisition of the food to be stored; (2) the methods and tools used to process it for storage, and then (3) the methods and facilities used to store it. It also involves the social and economic relationships that storage creates: Who controls the stores, who looks after them, who has rights to them? It is also important (but far beyond the scope of this chapter) to distinguish between food storage to sustain a household through the winter, and the production of a surplus (Ames 1985; Miller 1997; and Sahlins 1972). Food storage also requires storable foods.

SEDENTISM

A useful, simple definition of sedentism is that the members of a community live in a single settlement or place for over one year, or they may occupy it regularly (i.e., seasonally) over several years or generations (see Ames 1991a). Sedentism, like social complexity, has long been seen as a major development in human history worldwide, making its presence on the Northwest Coast of considerable interest to archaeologists. It, too, has long been regarded as a cause of social complexity. Not all sedentary peoples are socially complex, but most socially complex peoples are sedentary to one degree or another. Successful sedentism on the coast would require food storage, since most food resources are highly seasonal and very little is available for harvest during the winter and early spring.

SUBSISTENCE HISTORY

Archaeologists working on the Northwest Coast have long debated the relative roles of aquatic versus terrestrial resources in the evolution of Northwest Coast subsistence economies. They have focused exclusively on animal resources, dismissing plant resources as being of little consequence (see Lepofsky in press for a full discussion of these issues). As will be shown in the chapters that follow, this has been a significant error.

Over the past 10,000 years of known Northwest Coast prehistory, the peoples of the coast increased their production of food resources. What we now wish to know is what resources, how they did it, and why. We also wish to know: What effects did those changes in production have on how their societies were organized, and vice versa? And we wish to know, What effect did the coast's ecology have on the way their subsistence economies changed (and vice versa: How did changing subsistence economies affect the coast's ecology)? We have some answers to these questions, but much remains to be learned.

Answers to these questions are of concern not only to archaeologists and anthropologists working on the coast, and to the people living on the coast, but to the development of our understanding of the evolution of complexity and of hunting and gathering worldwide. The coast's peoples are the world's best-known examples of complex hunter-gatherers, and the more we understand of their history, the better we are able to use that understanding to elucidate similar developments elsewhere in the world over the past 30,000 years or so.

Intensification Among Complex Hunter-Gatherers: Issues and Problems

Despite an apparent theoretical focus on intensification of food production among hunter-gatherers over the past two decades, we still know little about it. This chapter, in part, is an attempt to engage potentially significant questions of production and intensification in the archaeology of complex hunter-gatherer societies. Binford has recently defined intensification as "any tactical or strategic practices that increase the production of food per unit area. Production can be increased by investing more labor in food procurement activities or by shifting exploitation to species occurring in greater concentration in space" (Binford 2001: 188). His definition is close to how intensification is generally understood by archaeologists. As useful (and precise) as it is, it has some conceptual limits. A more general definition would be that intensification is the processes by which one or more elements of production (e.g., labor, land, technology, skill, knowledge, organization) are increased relative to other elements in order to maintain or increase food production (or the production of some other commodity). This definition, unlike Binford's, recognizes intensification through increased efficiency. It also stresses that intensification is always relative to some measure (see below).

INTENSIFICATION AND AGRICULTURE

Conceptually, researchers have tended to blur and link the concepts of hunter-gatherer intensification and the origins of agriculture. One basic reason for this is that over the past half-century most of the research producing useful insights into increased food production by foragers has been research on the origins of farming, not on the study of highly productive hunter-gatherer economies as phenomena in their own right—phenomena that may or may not lead to full-time agriculture.

There is a yet more fundamental underlying cause of conceptual problems. Hunter-gatherers and farmers are viewed as the polar extremes of a single continuum (see Smith, this volume, for a fuller but different treatment of this issue). At some point along this continuum, hunter-gatherers pass over a threshold and are farmers. We sometimes recognize gradations in the continuum: we may speak of gardening, horticulture, a domesticated environment, and then finally agriculture. This continuum has certain qualities that limit our ability to see our subject matter. It works in only in one direction, from not-a-farmer to fully-a-farmer. It does not go the other way, from not-a-hunter-gatherer to fully-a-hunter-gatherer, for example. We discuss proto-farming, but not proto-foraging. This is reminiscent of the linguistic continuum in the English language between wet and dry. I can be wet, sodden, soggy, soaked, damp, moist, or dry. I can say "I'm a bit damp," and the sentence does not ring odd to English-speaking ears. But the continuum does not go the other way. How do I contrast in English between exceedingly dry and only slightly dry? I can say, "It is very dry," as opposed to dry, but if I say, "I am a bit dry," the sentence is odd, even though grammatical, and does not really make sense. However, the continuum between wet and dry actually does go both ways. The unidirectionality of the forager-farmer continuum of course reflects deep-seated notions of progress, in which farming succeeds hunting and gathering as a natural corollary of complexity inevitably arising from simplicity.

Beyond that, this conceptualization leads to a focus on the boundary (Smith, this volume) rather than on understanding variation in subsistence patterns and what that variation means in the evolution of economies. Rather than looking at that variation, we focus on locating where along the continuum a particular ancient economy lies. This has long been a crucial first step in interpreting ancient cultures. If they were hunter-gatherers, we expect one kind of economy, population size, and social and political organization. If they were farmers, we expect something very different. While these expectations hold generally (at the broad level of agricultural empires versus small, mobile hunter-gatherer bands), they often collapse at the level of particular societies, such as those of the Northwest Coast.

As a result of these expectations, the research issues become: What constitutes the threshold, and where along the continuum do we put it? How many corncobs do we need to declare agriculture? How many rice grains in pots equals farming? Does any evidence for cultigens, no matter how sparse, mean that these people were not hunter-gatherers? The debate over the economy of the Jomon tradition of Japan offers an excellent example of the difficulties. There is evidence for cultigens, but it is usually quite sparse before about 3000 years B.P. Crawford (1992a, 1992b) suggests that gardening played a minor role in Jomon economies in some places in Japan. Barnes (1993) treats them as complex hunter-gatherers, with some domesticates; Imamura (1996) dismisses what he sees as very thin evidence for Jomon farming, while Smith (this volume) classes them as low-level food producers with domesticates. Our understanding of Jomon is in part dependent on how we classify it, where we place it on the continuum. In the meantime, we have learned very little about the actual dynamics of Jomon subsistence and have added little to our knowledge of the variability in human subsistence arrangements.

There are at least three solutions to this general issue. We could apply Yoffee's rule for establishing whether a particular ancient polity is a state or not: If we have to debate it, it is not a state (Yoffee 1993). The revision here would be that if we have to debate whether an ancient group were farmers, they were not. This, however, merely puts the threshold far over at the farmer end of the continuum, and requires quite clear-cut evidence for agriculture. On the other hand, it places a whole range of subsistence economies into a single category—not-farmers—and continues to obscure important variability elsewhere along the continuum.

The second approach is to reconceive the continuum itself. It should minimally be seen as a field, with at least three points: pure farmers, pure foragers, and something else that is neither. It might be even more useful to see the evolution of subsistence economies as a bush with many branches. We actually know little about these economies, which Bruce Smith calls low-level food producing societies in the previous chapter. I suspect that in terms of production they may have more in common with some forms of farming, like swiddening, than they do with generalized foraging; but they may be distinctive economies quite unlike either foraging or farming, as ethnographically known, in their fundamentals, despite superficial similarities.

The third solution (these last two are not mutually exclusive) is to focus more directly on production itself, as difficult as this can be for archaeology. We often know a great deal about food production but very little about how food production was organized into subsistence systems, with all that that implies. We do not know because our focus has been on these particular societies as transitional to agriculture, or on food production as simply the means by which enough food is produced to permit, or allow for, the evolution of social inequality. In either option two or three, we should abandon (*pace* Smith) the whole notion of a continuum, and think in terms of "bushy variation."

INTENSIFICATION AND HUNTER-GATHERER SOCIAL COMPLEXITY

There have been divergent views on the relationships between intensification of food production and the development of social complexity, and even about what "complexity" means. Arnold (1996) has recently restricted the definition of complex hunter-gatherers to those displaying permanent forms of inequality. Other scholars (e.g., Hayden 1996) define the class more broadly, as minimally including higher population levels and/or densities than are common among generalized hunter-gatherers, and a productive subsistence economy. Maschner and I (Ames and Maschner 1999) propose a longer list, which includes, in addition to the foregoing, some degree of sedentism, production of large amounts of processed and stored foods, a broad diet breadth coupled with an emphasis on a few resources, a complex material culture, and, in addition to social inequality, some degree of social differentiation, which is probably accompanied by some occupational specialization. A final, crucial attribute is participation in large-scale social and economic interaction networks. However, at base, a productive subsistence economy is required to sustain most of these attributes. Recent theory building recognizes this necessity to some extent, but decouples production from the development of social inequality. The recent work of Hayden and Arnold can serve as examples.

Hayden (1996) stresses that the environment, or the economic base, must be sufficiently productive and stable so that no one in the society is threatened by starvation. He makes no strong connection between production (how food is acquired from this rich environment) and social complexity/inequality. Arnold (e.g., 2001) argues that social inequality arose on the Channel Islands of southern California in part as a response to environmental stress in the local ecosystem, and through efforts to gain access to food production on the California mainland through the production and exchange of craft items, such as shell beads. Thus, while production is a factor in her thinking, it is not food production. However, food production and its intensification are implicitly central, although unaddressed, issues. In Arnold's model, for example, people on the mainland either had to intensify their own food production to meet the needs of the Channel Islanders, or their subsistence economies produced a sufficient surplus to meet those needs without intensifying. Either way, food production is crucial.

Until rather recently, intensification of food production was treated as a central process, along with population growth and social and economic exchange, among others, in the development of complex hunter-gatherers (e.g., papers in Price and Brown 1985). It is now clear that while relatively high levels of food production are enabling conditions for the development of social and economic complexity among hunter-gatherers, they do not lead ineluctably to it. At this level, I am in agreement with Hayden, Arnold, Maschner (e.g., 1992), and many others. With this recognition, researchers searching for the causes of the evolution of social complexity shifted their attention away from food production. Arnold (1996) has emphasized how emerging elites reinforce and strengthen their positions by gaining control of labor and of the production of crucial craft items. Hayden (1996) shows how ambitious individuals can build up relationships of inequality through debt, social obligations, exchanges of prestige goods, and so on. With this new focus on the development of inequality among complex hunter-gathers, there has been correspondingly little direct attention paid to subsistence and economic production among these people.

Consequently, there has been declining interest in production and intensification as issues and as significant concepts in hunter-gatherer archaeology over the past fifteen years. Bender (1978) made intensification an important idea for archaeologists, but its theoretical use-life seems to have been quite short. To my knowledge, the last extensive discussions of hunter-gatherer (as opposed to agricultural) intensification were in Price and Brown's volume on complex hunter-gatherers (Price and Brown 1985). As Gould observes in his summary commentary on the book, "(t)he idea of intensification pervades this collection . . . " (Gould 1985: 429). The word "intensification" appears 22 times in the index, for example. Intensification of production was seen as a significant process in the evolution of social complexity among hunter-gatherers, leading, among other directions, to permanent social inequality.

In contrast, the term "intensification" does not appear at all in the index of a more recent volume co-edited by Price (Price and Feinman 1996) on the development of inequality. There are only seven entries for it in a recently published edited volume on hunter-gatherers (Burch and Ellanna 1994), and only one paper in that volume that discusses intensification to any extent (Yesner 1994). The term does not appear in the index to Kelly's encyclopedic book on hunter-gatherers, though it does appear here and there in the text (Kelly 1995). A recent key-word search using the CARL Uncover electronic periodicals database found the words "intensification" and "intensifications" used in 415 journal titles over the last decade or so. Of these, 5 dealt with archaeological topics, while 20 treated current issues in agricultural intensification and were published in journals both anthropologists or archaeologists might read (e.g., *Current Anthropology, Human Ecology*). The other 390 titles were papers in chemistry journals. Arnold (1996) does not discuss intensification, except in passing, in her review article on complex hunter-gatherers, and she does not treat it as a significant issue. It does not figure at all in Hayden's recent theory-building on the causes of complexity among hunter-gatherers. Most recently, however, Binford has given it a central explanatory role in accounting for global variation in hunter-gatherer economies (Binford 2001).

Despite (or perhaps in response to) this lack of interest, problems in complex hunter-gatherer production remain unresolved. How did they finance complexity? In other words, How were resources extracted from the environment and converted to wealth? How did they support the large populations that are one of the criteria for being classified as complex hunter-gatherers? How did they produce what they produced and why? How was increased production—intensification—accomplished? And what does "increased production" actually mean?

Intensification and Production

This section discusses the concept of intensification, tying it to the more basic concept of production. As part of this discussion, it also reviews other definitions of intensification as necessary. It makes the argument that the essential archaeological indicators of intensification are technological, economic, and social. Most recent work on intensification, at least on the Northwest Coast, focuses on faunal remains, on the debris produced by the harvesting and processing of fish and mammals. This is essential evidence, but it must be viewed within the context of a system of production, and tied to technological, social, and economic evidence for intensification. In contrast to the emphasis on food remains, Zvelebil (1986b) insists that intensification can only be measured through evidence of increased labor. He argues that shifting or changing frequencies of faunal (and floral) remains may reflect adjustments to resource availability, but not to intensification as an economic strategy. Long-term environmental changes may cause changes in subsistence economies as people adjust to changes in available resources. This is not intensification in Zvelebil's thinking, unless there is evidence for increasing labor effort. He does not provide any means of measuring increased labor, however. We will discuss how that can be done below.

Archaeologists often use the term "intensification" to mean increasing the amount of something being produced. To intensify salmon production is to increase the amount of salmon being harvested (and/or processed for storage); to intensify pottery production is to increase the amount of pottery being made. However, the term carries broader implications. One of these is the issue of measurement: increasing the amount relative to what? The answer often given is "relative to an earlier period." An alternative answer is that some resource, salmon for example, so dominates the faunal assemblages that the resource must have been being intensified. In theory, however, intensification needs to be measured against some standard more precise than simply saying that there is more of something than there used to be, or that there is a whole lot of it.

Jochim (1976) suggests time, space, or labor as these standards for measuring intensification. The amount of pottery made increases per unit time, per unit space, or per unit labor. Zvelebil (1986b) strongly asserts that intensification is an increase in the amount of labor invested in production. In his thinking, the only appropriate measures of intensification are those that track increases in labor (amount or effort). Using Jochim's measures, evidence for salmon intensification might be more salmon caught per fishing season, more salmon caught per linear mile of stream bank, or more salmon caught per person. For Zvelebil, evidence of salmon intensification would be evidence of increasing effort or work to produce more salmon. For archaeologists, of course, these measures can be very difficult to operationalize. We will also return to that issue below.

Boserup (1965), whose work sparked current approaches to the intensification of food production, defined it in terms of units of land. In preindustrial agricultural economies, she thought farmers would intensify food production by increasing the area farmed, and by increasing the number of crops harvested annually from a given piece of land (Boserup 1965: 43). She saw, as a major implication of her definition, that while both of these approaches would probably (*but not necessarily*) result in higher workloads, they would also cause lower overall efficiency. People would work harder, producing more food overall, but less food per hour—agricultural production, then, would increase more slowly than would work effort. Broughton (1997: 646) put this succinctly, "*resource intensification* [is] classically defined as a process by which the total productivity or yield per areal unit of land is increased at the expense of declines in overall caloric return rates or *foraging efficiency* [emphasis his]." Thus there are two aspects to the classic definition of intensification: increased production and (following Boserup) lower overall efficiency. This clearly is implicit in Zvelebil's definition.

Implicit to Jochim's measures, in contrast, is the possibility of intensification through increasing productivity. Bender (1978) first drew the distinction between increasing production and increasing productivity in the archaeological literature. Increased productivity is simply increasing production by increasing efficiency. In her thinking, it might or might not lead to increased production, and people could invest the time and labor saved in social activities, such as participation in exchange networks. Gould (1985) sees the distinction as processually insignificant, arguing that increases in efficiency will almost inevitably lead to increased production in the long run, regardless of the original reasons for increasing efficiency. The point here is to stress that in contrast to the "classic" definition of intensification, production can be intensified both by increasing labor and by increasing efficiency.

There are other ways in which increasing production is a broader concept than just "making more." Increasing salmon production is not the same thing as just harvesting more salmon. According to Halperin (1994: 41), "All production processes require assembling and allocating resources." Production includes the raw materials used, the tools, techniques, technological processes, work effort, and labor organization required to extract other raw materials from the environment and turn them into something humans use (Ellen 1982, Elster 1986). It also includes the allocation and distribution through the society of both raw materials and the end products of production.

Production also creates value. Things produced by humans have value within the social and cultural context in which they are produced. Their production gives them their value (or enhances the value of the raw material) and the value of that class of object affects production (Ellen 1982). An object's value may reflect its rarity, or the effort or skill required in its production or acquisition, and so on. Nonindustrial diamonds are extremely valuable in part because they are relatively rare, but also because of the incredible skill and knowledge required to cut them to make them suitable for jewelry. They are thus markers of wealth and status, which in turn fuels their value and their continued production. The values an object has in a culture need not be restricted to any single sphere of life. A food resource may be revered for its links to a spirit world, convey social prestige, and be eaten with gusto in large amounts. A Mercedes-Benz station wagon can still convey a message of wealth while it hauls babies, groceries, and fertilizer.

Production can also be conceptualized as a technological process, as a chain of steps or tasks. In the case of pottery, for example, the chain includes a range of activities from the acquisition of the clay at the clay pits to the use of the pot. Thinking of it in this manner is important, since initial increases in levels of production are likely to involve overcoming bottlenecks along the production chain. Increasing the salmon harvest for storage, for example, would be pointless if the fish rot before they can be transported. Solutions to bottleneck problems can be technological (reorganize the old technology, invent new tools), or organizational. For example, Donald (1983, 1997) argues that the sexual division of labor on the Northwest Coast was a potential bottleneck in the processing of foods for storage (men harvested foods, women processed them), one that was resolved by slavery. At some points in the chain, production may be increased by a straightforward increase in production (working longer, harder, or adding more workers), while at others production may be increased through an increase in productivity. While technological innovations can increase productivity (the potter's wheel vs. coiling), specialization can also increase productivity (specialized potters are likely to be more adept at making coiled pots than are nonspecialists).

How tasks themselves are accomplished can also be changed. Wilk and Rathje (1982) draw a useful distinction between linear tasks and simultaneous tasks. Linear tasks are those in which the steps of the tasks can be accomplished in a sequence, while simultaneous tasks are those in which the steps are done by a group at the same time. They further distinguish between simple simultaneous tasks and complex ones. In simple simultaneous tasks, everyone performs the same step in the task at the same time. In contrast, complex simultaneous tasks require that different steps in the process be done at the same time "all work at the same time, but do different parts of the job" (Wilk and Rathje 1982: 622). Intensification can proceed if linear tasks are performed as simultaneous tasks. This increases the amount of labor devoted to the task, and can increase productivity. Instead of one person coiling pots, have ten do it. A simple simultaneous task can be a complex one, with specialists. No change in technology may be required.

Intensification, then, is more than more food, and has wider implications. In a sense, though, the issues can be boiled down to two questions: "How is more food produced?" and "What happens to it then?" A third question, of course, is "Why?"

Measuring and Modeling Intensification

The definition of intensification outlined above allows two broad lines of evidence about intensification: evidence of increased labor input (either more labor, or greater labor efficiency, either of which may involve changes in technology and/or changes in social organization), or evidence of changes in what is produced. In this second instance, demonstrating intensification of food production often becomes a problem in zooarchaeology and paleobotany. There is also the issue, noted above, of distinguishing between intensification and subsistence adjustments to short- and medium-term environmental changes. (Did they take more herring because they needed more food, or because of declines in the availability of sea mammals, or increased numbers of herring?)

One can also look for artifacts that may indicate increasing emphasis on a particular class of resource, or greater efficiencies at some crucial task (e.g., Mitchell's [1971] suggestion that a certain kind of spaul tool might represent a fish knife, speeding up the filleting of fish prior to drying them), or the capacity to harvest more of a resource. Moss et al. (1990) dated fish weirs in Southeast Alaska, and found that they dated to ca. 3500 B.P. and later. Moss and others (e.g., Ames 1994) suggested that the presence of these weirs indicated the presence of the technological capacity to catch large amounts of fish by that time, and therefore served as evidence of the intensification of fish production. Eldridge and Acheson (1992) replied, arguing they had evidence of an older fish weir along the lower Fraser River, so that intensification of fish production may have been earlier on the Fraser than in Southeast Alaska. This raises issues in the history of Northwest Coast technology, which is rather poorly understood. Croes (e.g., 1991, 1995; Croes and Hackenberger 1988) makes what are among the few general statements explicitly linking changes in technology with economic changes along the coast. Often, local technological changes are treated as the result of shifting ethnic boundaries (e.g., Mitchell 1988). We will return to these issues in more detail below.

All of these approaches are employed in a rather ad hoc fashion. With a single, notable exception (Croes and Hackenberger 1988), there has been no effort to develop a comprehensive model of what intensification of production on the coast might have looked like. Rather, there has been an implicit and powerful assumption that intensification of food production will be indicated by ancient subsistence economies becoming increasingly like those of the Early Modern period (ca. from about 1775 to 1875; see Ames and Maschner [1999], Suttles [1990]). However, sufficient evidence has accumulated to indicate that this assumption is not tenable. It is clear that Early Modern economies may have differed in important ways from those of the centuries just before contact (e.g., Acheson 1991; Hanson 1991). It is equally clear, as the chapters in the rest of this volume make evident, that we do not yet have as good an understanding of Early Modern economies as we have thought.

One powerful alternative approach to these questions is modeling. Modeling can be a rigorous means to develop predictions about the way economic changes, such as intensification, may appear in the archaeological record. Given the nature of the archaeological record, multiple lines of evidence are almost always required to address and answer archaeological research questions. Archaeologists therefore need several parallel answers to a question such as "What will the intensification of plant resources look like in this place and at this time?" There are two ways to answer this question and to develop predictions: either examine modern cases—analogies—that parallel the ancient one (e.g., find modern, complex hunter-gatherers who are intensifying production of plant foods and compare the modern cases with the archaeological case), or develop models. There are no obvious analogies in the modern world for the processes of interest here,[1] so it is necessary, even essential, to construct models. Both the utility of models and the predictions made from them rely on a number of factors, including the basic assumptions underlying the model itself, as well as the rigor with which predictions are derived from the model.

Three models of intensification are presented in the rest of this chapter. None are original to this chapter; they are taken from the literature. The first is a general model of intensification and domestication developed by Winterhalder and Goland (1997). The second and third are more narrowly focused models, developed by Thoms (1989) and Peacock (1998), of the causes and effects of the intensification of root harvesting, including of camas (*Camassia quamash*) and balsamroot (*Balsamorhiza sagittata*), on the Intermontane Plateau. The first model (with three outcomes) permits an evaluation of the evidence for intensification along the entire coast, while the Thoms and Peacock models are the most detailed models and tests for the intensification of a plant food ever developed for western North America. The modeling approach used by Winterhalder and Goland, and that of Thoms, are based on evolutionary ecology. The first models are very simple and general, though they can be made quite explicit as the camas model shows. The approach differs from that used by Croes and Hackenberger (1988) in their simulation of economic changes at the Hoko River archaeological complex. As I argue elsewhere (Ames 1998), this last model, while extremely powerful and thought provoking, is too specific and too complex to permit its use to model economic changes along the entire coast. In contrast, the approach developed in evolutionary ecology permits the formulation of predictions that have widespread applicability but that can also be tailored to fit very specific circumstances.

Peacock's (1988) model focuses on root intensification on the Canadian plateau, which includes the part of the Intermontane Plateau along the Washington State–British Columbia border and extending north into central British Columbia. She explicitly rejects the assumptions about optimization that underlie evolutionary ecology. Her work and predictions offer an interesting comparison to those developed here.

Both the Winterhalder and Goland and the Thoms models are based on the diet breadth model, a very general model focusing on how foragers select resources to exploit, along with a consideration of the effects of risk on these choices and on the outcomes of these choices. The reader is referred to E. A. Smith (1991: 1–64) for a thorough discussion of evolutionary ecology. Bettinger (1991) analyzes the approach and outlines several of the models applied by evolutionary ecologists to human foraging behavior. Broughton (1994a,b; 1997) presents particularly powerful applications of these approaches to the faunal records of northern California.

In the diet breadth model, foragers rank resources to exploit according to the decreasing net efficiency in acquiring the resources. Resources vary according to: "(1) their abundance; (2) amount of energy produced per item; (3) amount of energy needed to acquire the energy from each [resource]; and (4) the amount of time needed to acquire that energy once the item is selected" (Bettinger 1991: 84). The net efficiency of a resource is the total overall energy costs of those activities less the energy gained by harvesting the particular resource. According to Winterhalder and Goland, "the summary rule is this: add the next item if its pursuit and handling efficiency is greater than the overall efficiency of the diet without it, and, conversely, stop expanding the diet and ignore the [next] item for which the return . . . is less than the average return . . . of higher ranked items" (Winterhalder and Goland 1997: 128). Top-ranked resources are those for which net efficiency is the highest of the available resources. Top-ranked resources are always in the diet, irrespective of the resource's density, and low-ranked resources are never in the diet, irrespective of their density (Winterhalder and Goland 1997). In other words, top-ranked resources are always pursued, whether they are common or rare; low-ranked resources are never pursued, whether they are common or rare.

Some of the foregoing may seem to contradict aspects of the discussion of intensification—they do. One of the goals in constructing models of this kind is to keep their basic assumptions as simple as possible. These models assume that people make their decisions about resources on the basis of net energy return. While this may not seem realistic, models that attempt to be realistic and include such concepts as "value" become increasingly complex. The approach in evolutionary ecology would not be to ignore value, for example, but to construct a separate, but still simple model that uses value as its currency, not net energy return, and to compare the results. For the purposes of the discussion here, it is best to continue with the models based on net energy return.

Items will be added or dropped from the diet for two kinds of reasons, one reflecting the entire diet, and a second having to do with the particular resource. If the overall net efficiency of acquiring all items currently in the diet declines, resources will be added to the diet (their net return is no longer less than the overall efficiency); if overall efficiency of acquiring items increases, then low-ranked resources will be dropped from the diet. On the other hand, if the net efficiency of acquiring a single resource goes above the overall net efficiency, it will be added to the diet. If it goes below the overall efficiency, it will be dropped.

"Risk" refers to variability in the outcome of resource harvesting (E. A. Smith 1991: 53; see also Hayden 1981). In this sense of the term, the returns of an activity vary over some period. One goes hunting once a week, for example. Sometimes the hunter finds nothing; other times the hunter kills several animals, and yet other times, only one. Calculated over a year, the hunter averages two animals per trip. However, there is considerable variation (or not) from trip to trip. That variation between trips is one element of what is meant here by risk. Over some period, harvested resources have a mean return and a variance in return that can be measured, for example, by the standard deviation in return. This is not the same meaning the word "risk" has in everyday speech, where one might be concerned about one's risk in flying in an airplane (How likely is the plane to crash?), or in investing money in the stock market (How likely is it that the stock market will crash and the person will lose all their money?).

Bamforth and Bleed (1997) have argued that the concept of risk should be expanded to include risk as the cost of failure. This is closer to the everyday sense of the term than the notion of variability in outcome. It is important to consider the cost of failure. Planes may not crash very often, but the costs of failure are high for the participants. Salmon runs on a particular stream may not vary much year to year (have low risk in that sense), but as human populations grow, the cost of failure, the risk, from even a rare failure, increases. Implicit here is that the costs of failure will change with changing economic and social conditions, while the variability in the resource does not. The cost of failure will be considered here, but not included in the definition of risk, in order to maintain definitional clarity. "Cost of failure" will be termed cost of failure rather than risk.

As noted above, risk can have other meanings, including danger. Northwest Coast whaling was risky in that it was dangerous, and if Jewitt's accounts of whaling among the Nuu-chah-nulth of western Vancouver Island are any indication, even when everyone returned home, they often failed to strike a whale (Jewitt 1807 [1987]). Danger may be one of the costs of failure, but we are primarily concerned with other costs, such as starvation. Considerations of risk (and variation in risk) have led to the following generalizations: When faced with lower average returns than needed, foragers should be risk seeking (because a single major success or windfall may cover their needs); when faced with higher returns than required, foragers should be risk avoiding (to avoid a shortfall) (E. A. Smith 1991; Winterhalder and Goland 1997).

Foragers can reduce, or buffer, the effects of variance in relatively few ways (e.g., Winterhalder and Goland 1997). It has long been recognized that one major way is through food sharing among the members of a social group. Foragers are also often highly mobile, shifting residences according to the availability of food. They develop social ties to allow them access to the territories of other groups (Kelly 1991). And they can also improve methods and technologies of food storage. On the Northwest Coast food storage was central to the economy for at least 3500 years and is a crucial factor in considering the effects of intensification on the coast.

Storage by hunter-gatherers has one characteristic that makes it, as a form of delayed consumption (Schalk 1981; Woodburn 1980), structurally similar to farming. Many modern foragers, particularly those in the tropics, consume food immediately or shortly after it is harvested. Immediate food consumption tracks closely with the availability of food resources, and the cycles of search, pursuit, and processing are short. People can respond rapidly to failure. With storage, the production interval lengthens to the months that pass between the time the food is acquired and when it is consumed. If resources fail, or stored foods are insufficient, months may pass before sufficient food is available again, or even before it is realized there is not enough food to pass the winter. This can increase the costs of failure associated with storage, particularly given the higher population densities usually associated with storage economies. As an economy becomes more dependent on storage, it becomes more vulnerable to failure or even periodic low returns on the stored resource. With this background, we can now turn to discussing specific models (Table 3.1).

THE WINTERHALDER-GOLAND MODEL

There are three outcomes in the Winterhalder-Goland model.

TABLE 3.1. MODEL OF PLANT INTENSIFICATION

	Rank of resource	
	Low	High
RISK ↑	1. Intensified resource dominates diet; diet breadth broad; human population increases in density: highly ranked resources depleted. RISK HIGH	2. Intensified resource dominates diet; diet breadth narrow; human population increases in density; some highly ranked resources unexploited. RISK HIGH, but lower than #1
	3. Intensified resource small part of diet; diet breadth broad, no significant increase in human population density, minimal additional depletion of highly ranked resources. RISKS RELATIVELY LOW	
	Density of resource	

(from Winterhalder and Goland 1997)

Outcome 1. In the first outcome within this model, the intensified resource comes to dominate the diet, though diet breadth remains broad. Human populations increase in density, and highly ranked resources, since they are always exploited, are depleted as populations grow. Risk is high (there is a great deal of variation in returns). The cost of failure may increase as populations grow. The intensified resource was abundant and dense, and may have originally ranked low. It would have been added to the diet only if overall subsistence efficiency declined, or if there was an increase in the efficiency at which this particular resource was harvested.

At first glance, the first outcome seems closest to the generally accepted picture of Northwest Coast subsistence economies, with salmon dominating the diet, but also with a broad range of dietary resources. The available ethnographic and archaeological data seem to indicate that a very wide array of resources was harvested on the coast for several millennia. Additionally, the same basic suite of mammals and fish was exploited throughout the coast's known 11,000-year prehistory. We will return to that point below. There is no equivalent information for plant use, because archaeologists on the coast have not seriously attempted to retrieve evidence for plant use until very recently (see Lepofsky in press).

However, in this outcome the dominant resource is a low-ranked, very abundant, high-density resource. It is low ranked because of processing costs. We would expect at first to see salmon appear as one resource among many, and then gradually (or rapidly) come to dominate faunal collections. Schalk originally argued (1977) that salmon was at first low ranked and was added to the diet mix when population growth made it worthwhile and possible to harvest large numbers of salmon and to store them. He also suggested this happened because of innovations in storage, which made storing large amounts of fish possible. Archaeological evidence to evaluate this outcome is skimpily and widely scattered along the coast and through time. There is apparent evidence for high levels of salmon harvesting at an early date (ca. 11,000–8000 B.P.) at the Five Mile Rapids in the Columbia River Gorge (Cressman et al. 1960). However, Five Mile Rapids is located at the upstream end of what was the best place to catch salmon in the entirety of western North America, given the available technology. Therefore, finding evidence of salmon fishing there seems at best to indicate that people were taking advantage of an excellent place to catch fish, rather than pointing to anything about regional subsistence patterns. Finally, the faunal record for Namu on the central British Columbia coast indicates relatively early, heavy reliance on salmon (Cannon 1991). However, this does not seem to be the case everywhere. Data from Glenrose Cannery, on the Fraser River near Vancouver, suggests a very broad diet, without heavy reliance on any particular resource (Matson 1976). Evidence for storage is discussed below.

This outcome also predicts continued exploitation of a wide range of resources, a prediction that seems to be met, particularly when the faunal remains from a number of sites in an area are examined (e.g., Calvert 1970; Hansen 1991). Even at sites such as Namu, where salmon comprise the overwhelming majority of faunal remains, the rest of the assemblages are diverse.

The issues of risk and cost of failure arise. According to this outcome, increased reliance on the intensified resource leads to population growth, in turn exposing that growing population to increased cost of failure, and to unpredictable variation that may have been insignificant to a smaller population but that becomes significant with higher numbers of people. From this, we can also predict that we will see both risk-seeking and risk-avoiding strategies, depending on local return levels. If risk increases with increasing population, then we can predict increasing risk-seeking strategies, strategies where the possibility of failure is high but in which the occasional returns are also quite high. Whaling along the west coast of Vancouver Island, Washington State, and at least parts of Haida Gwaii may be exactly this: a high-risk, high-return strategy in areas with low average returns (relative to what is needed).

This outcome also predicts resource depletion. Croes and Hackenberger (1988) review evidence for depletion of intertidal resources at Hoko River during the Late Pacific Period, and shellfish are generally not considered a high-ranking resource (cf Moss 1993). However, the outcome predicts depletion of high-ranked resources. Little work on this topic has been done on the coast. Butler (2000) found evidence for depletion of high-ranked resources on the Lower Columbia River. Broughton (1994a,b; 1997) examined the issue for the San Francisco Bay area. He demonstrates archaeological evidence of widespread reductions in the numbers of high-ranked resources, including sturgeon, salmon, elk, deer, and large pinnipeds, such as sea lions, with resulting shifts to lower-ranked resources, and argues that these changes reflect resource depletion beginning about 2500 B.P. His inclusion of salmon among these resources is interesting, given the widespread opinion among workers on the coast that Native fishing technology could not have depleted major salmon runs to any degree. Large pinnipeds, such as seals and sea lions, are also animals Northwest Coast archaeologists assume would be hard to deplete. However, there has been little discussion or analysis of the effects of Native subsistence practices on Northwest Coast animal resources. Hewes (1947, 1973) has suggested that native fishing techniques significantly lowered salmon productivity. He argued that the very rich runs observed by early Euro-American travelers were actually the result of a "rest period" produced by the catastrophic decline of human populations in the area in the Early Modern period. Schalk (1987) maintains, contra Hewes (1947, 1973), that native fishing methods either had no negative effect, or actually enhanced salmon productivity. At present, no data exist with which to test either of these ideas. However, one of several possible reasons for intensification of plant resources could be depletion of high-ranked animal resources because of population growth in limited geographic areas (i.e., there might be an inverse relationship between depletion of animal resources and intensification of plant resources).

In any case, Outcome 1 has two testable implications for the initial cause of resource intensification: increased foraging efficiency for a resource (such as postulated by Schalk, or listed in Table 3.5), or an overall decline in foraging efficiency, which could have a variety of causes, including increasing human populations.

Outcome 2. In the second outcome within the Winterhalder-Goland model, the intensified resource was always both dense and highly ranked. In this case, the outcome of intensification is a narrow diet breadth (few resources being harvested), dominated by the intensified resource—that is, a specialized economy. Human population densities are high, and, because of the narrow diet breadth, some formerly high-ranked resources are no longer exploited. Risk is high, but not as high as in Outcome 1.

The second scenario meets the expectations of some researchers for salmon intensification (e.g., Carlson 1996a). In this outcome, the resource was originally dense and highly ranked. In Fladmark's (1975) model, for example, intensification of salmon harvesting began on the coast as soon as salmon became dense as a result of sea level stabilization. Carlson argues that what he terms intensive exploitation of salmon begins wherever and whenever the fish are available in large numbers. Consequently (in the general model), populations grow, and the economy becomes increasingly specialized, focusing on this resource, and some high-ranked resources are dropped from the diet. I am aware of almost no archaeological data from the coast that approximate the complete scenario. Diets seem always to have been quite wide everywhere, even where salmon dominate faunal remains. Nor I am aware of any demonstrated, significant cases where previously highly ranked resources were completely dropped from the resource mix. The point here is that while this outcome fits many archaeologists' assumptions about the role of salmon in regional economies through much of Northwest Coast prehistory, that prehistory, as it is presently known, does not fit the predictions of this outcome (Ames and Maschner 1999).

There is emerging evidence suggesting extreme fluctuations of salmon runs through time (Finney et al. 2002). If correct, then this would suggest that salmon were not the reliable resource generally assumed.

Outcome 3. Finally, in Outcome 3 within the Winterhalder-Goland model, the intensified resource remains a small part of the overall diet; diet breadth is broad, populations remain stable, and there is minimal risk. In this option, the resource has low abundance, and may be either low ranked or high ranked. In other words, it may be a very desirable resource but, because of its low abundance in time or space (or other qualities), its intensification has little overall impact.

This scenario is central to this volume. Does it describe the overall role of plant resources on the Northwest Coast? Were plants resources that were exploited when possible, but that had little overall impact on the subsistence economy and on labor organization? If the answer is yes, then the contents of the present volume are interesting, but perhaps of little importance to our understanding of cultural evolution on the Northwest Coast. If the answer is no, then perhaps Outcomes 1 and 2 are applicable to plant intensification along the coast. None of these models would apply to the entire coast, but to particular places at particular times, perhaps.

The rest of this volume discusses methods introduced to reduce the risks associated with plant resources (reduce the variability over time in plant harvests) and to increase the density of desired plants. In western Oregon, for example, regular burning of the floor of the Willamette Valley would probably reduce variation in acorn production (reducing risk) while increasing overall production of acorns by oak trees (e.g., Shipek 1989). Maintaining berry patches by burning would have a similar effect on berry harvests (Lepofsky et al., this volume). This outcome may describe the role of plant foods in early Northwest economies before significant intensification of food production. To explore this possibility, we turn first to the general record of intensification on the Northwest Coast, and then look specifically at plants.

Intensification on the Northwest Coast

I do not intend to review the entire record of intensification, especially the faunal record, for the coast. That has recently been done elsewhere by several authors (Ames 1994, 1998; Ames and Maschner 1999; Cannon 1998; Carlson 1998; Coupland 1998; Erlandson et al. 1997; Matson 1992; Matson and Coupland 1995; Moss 1998). Rather, I wish to make a few points.

The available record clearly suggests that the same animal resources were exploited throughout the last 10,000 years, the current length of the archaeological record for the coast. Nothing in the record suggests that significant new animal resources were added to the diet at any point during that span. This does not preclude shifts in emphasis, either as a response to local and regional environmental changes or to efforts to intensify production. However, there is presently no good evidence for significant expansions of diet breadth (in the number of resource species exploited) during the past 10,000 years. The evidence suggests the regional diet was always broad. Plants may represent the only category of resources on the coast that could be added to the diet as part of intensification. The implication of this for animal resources (including fish) is that significant intensification of animal harvesting on the coast could only have occurred by increasing production of resources already in the diet.[2]

There are a number of possible ways to accomplish this. Broughton (1994a,b; 1997), as well as other workers, stresses that as intensification proceeds among hunter-gatherers, there should be shifts from large-bodied, highly ranked animal resources to smaller-bodied prey. Hayden (1981) argues for shifts from k- to r-selected[3] species, which will also be smaller bodied. If these predictions hold for the coast, smaller-bodied prey species should become increasingly important in the diet. We might expect to see, for example, increased harvesting of herring. Following Boserup (1965), a second approach would be either to more intensively harvest particular resource habitats (with the implication of decreasing prey size) or to exploit new resource habitats, but for the same resource species. Kew (1992) suggests this latter strategy was a significant form of intensification on the coast. These options all involve lowering overall foraging efficiency.[4] A fourth set of strategies would be to raise foraging efficiency or to raise the rank of a particular resource. The increased collection of mollusks along many portions of the coast that occurred ca. 5500 years ago (and which led to the widespread formation of large shell middens) reflects increased harvesting of very small-bodied organisms. It also probably indicates increased harvesting per unit area.

Alternative strategies involve increasing foraging efficiency. Winterhalder and Goland (1997) suggest a number of such strategies, most of which seem to have been employed on the Northwest Coast (Tables 3.2 and 3.3).

The Northwest Coast strategies include ones that are not usually thought of in terms of resource intensification. Perhaps the most important of these is the construction and use of large canoes. While it seems extremely likely that people along the coast always had canoes, what is crucial here is the appearance of the large freight canoes that could carry substantial loads of raw and processed foods over open water, and which would also permit the transportation of entire villages to new locations where resources were available. Current evidence for their development is quite indirect, and may ultimately have to be derived from evidence of the capacity to transport large volumes of material, or very heavy objects, long distances over water. Other indirect evidence includes the evolution of large, mature stands of cedar by ca. 4500 B.P. (Hebda and Mathewes 1984; Hebda and Whitlock 1997), providing raw materials for large canoes, and the presence in the record of the tools and skills to make them. The available record suggests these tools and skills were widespread on the coast not long after 4500 B.P. Evidence for the northern British Columbia coast points to exploitation of small but possibly productive offshore habitats as well as transportation of large volumes of fish by 2000 B.P., if not much earlier (Ames 1998).

Woodworking skills were also very crucial in the development of the wooden storage box, the Northwest Coast's functional equivalent of pottery. Boxes were used for storage of a wide range of processed foods, including oils, as well as for cooking by boiling with fire-heated rocks. Watertight baskets could also be used for these purposes, but boxes have many advantages. They have flat bottoms, and are easily stacked and packed. I have elsewhere discussed the role of Northwest Coast houses in resource intensification (Ames 1994; Ames and Maschner 1999.). The large wooden houses of the coast were, for all intents and purposes, large food processing and storage facilities, in which animals were butchered and, along with the plants, were processed and stored.

While these strategies and others listed in the table may have increased foraging efficiency, they also required increased labor. A 20 m long canoe capable of passage from Haida Gwaii to the mainland required the investment of considerable labor and skill, and such vessels may appear directly in the archaeological record in the form of increased labor (more woodworking tools, specialized woodworking tools, and tools such as celts, which are themselves costly in labor and time).

INTENSIFICATION OF PLANT PRODUCTION: THE THOMS AND PEACOCK MODELS OF ROOT FOOD INTENSIFICATION

Until quite recently, there has been very little interest among archaeologists in plant use on the Northwest Coast, despite long-term interest in the topic by anthropologists and ethnobotanists working in the region. There has been greater interest in the role of plant use, particularly of camas and other roots,

Table 3.2. Possible causes of increased foraging efficiency on the Northwest Coast

General processes	*Possible Northwest Coast Strategies*
1. Increase in the density of high-ranked dietary items, increasing the forager's encounter rate, through habitat improvement, game population cycles, release from over-exploitation, etc.	Gardens, patch creation, and maintenance by burning, coppicing, weeding, use of traps and weirs, to concentrate available prey
2. Reduced search costs perhaps due to decreased energy expenditure in movement	Use of boats, positioning strategies, periodic movement of villages, collapsible houses
3. Changes in resource distribution (resources become more spatially aggregated)	Gardens, patch creation, and maintenance by burning, transplanting, traps, weirs, exploitation of new patches
4. Increase of pursuit and handling efficiencies of items in diet.	See Table 3.3

(modified from Winterhalder and Goland 1997)

among researchers on the Intermontane Plateau east of the Coast and Cascade ranges, and in the Willamette Valley of western Oregon. The most detailed model and thorough test for the intensification of plant food production anywhere in western North America was conducted by Thoms (1989). He was particularly concerned with geophytes (plants whose nutritious organs are below the ground), such as roots, bulbs, and corms, and especially with members of the lily family (Liliaceae) of plants. His model had the same theoretical basis as that of Winterhalder and Goland and is briefly reviewed here. Peacock (1988) is also interested in the intensification of geophytes in her model but takes a somewhat different approach than does Thoms. Both models, as well as the archaeological record for geophyte intensification, provide an excellent touchstone for discussing intensification of plant production on the coast. The evidence for root exploitation also indicates what can be expected for long-term trends in plant exploitation on the coast.

Thoms's Model. Thoms developed a general model for geophyte exploitation (Table 3.4) and a more specific model for camas (Table 3.5). These can provide a basis for modeling plant intensification on the coast, particularly since Thoms was interested in the relationship between intensification of plant foods

TABLE 3.3. POSSIBLE CAUSES OF INCREASED RANK OF FOOD ITEMS (e.g., increased efficiency in the pursuit and handling of that item)

General processes	*Possible Northwest Coast strategies*
Improved transportation in pursuit	Canoes, including specialized canoes, and related equipment
2. Improved technology of harvest	Ground-slate lance heads, toggling harpoon heads, floats for dead sea mammals, increased diversity in nets, expanded use, and improvement of basketry in traps and storage, berry combs
3. Increased capacity for transporting produce.	Large seaworthy freight canoes, boxes, baskets
4. Improved methods of food processing.	
a. More efficient tools for cutting, cracking, grinding, etc.	a. Filleting knives, mullers, and pounders
b. Better fuels (e.g., hotter firewood species)	b. Use of hot-burning fuel woods
c. Improved technology in heat transfer in cooking	c. Wooden boxes for stone boiling, changes in hearth design (?), pit cooking
5. More effective storage methods (e.g., those that reduce storage loss) or storage facilities that are more efficiently constructed	Waterproof wooden boxes in a range of sizes, basketry, large houses with interior fires and storage racks in rafters, subfloor storage and exterior caches, distinctive outdoor processing techniques, such as berry-drying trenches
6. Morphological changes to the resource increasing its profitability	Long-term effects of human selection and maintenance of particular desirable habitats by burning and culling? Short-term effects might include increased size of preferred part of the plant (e.g., corms, nuts) but (see # 1 in Table 3.2)

(modified from Winterhalder and Goland 1997)

Table 3.4. Thoms's general model of geophyte intensification

The general model of geophyte intensification:

A. Conditions:
   1. Population circumscription,
   2. Availability of an intensifiable geophyte(s) that are:
      a. Accessible, calorie-rich, capable of sustaining systematic harvests, and;
      b. The raw materials necessary for exploiting the plant, including fuels for processing,
   3. Be part of existing subsistence strategies,
   4. Technology available for efficiently exploiting resource, but these technologies must exist long before they are used for intensification.

B. Causes: Intensification is ultimately the result of an imbalance between the need for low-cost foods and the nutritional needs of the population caused by population growth, environmental fluctuation, or both.

C. Consequences:
   1. Increasing sedentism in localities near root grounds;
   2. Increasing use of root grounds,
   3. Increasing frequencies of geophyte-related artifacts and feature assemblages, including pestles, mortars, digging sticks, and earth ovens, and
   4. Increasing storage facilities.

(Thoms 1989: 121-22)

and intensification of salmon. Thoms's models rest on the same basic assumptions about foraging behavior as does Wintehalder and Goland's model. He also assumes that camas will not be a high-ranking resource (#1, Table 3.5). A recent test of his models' applicability to wapato in the Wapato Valley area of the Lower Columbia River suggests this assumption may not be met (Darby 1996 and this volume). His models also require that the resource, in this case camas, be a part of the diet mix before intensification, again, as do Winterhalder and Goland's models. Both the resource and the appropriate equipment are already in use. This precludes explaining intensification as the result of a fortuitous invention, as is often assumed.

Table 3.5. Camas intensification model

Groups relying on camas as a staple should be those lacking adequate supplies of higher-ranked and intensifiable resources. Other things being equal, the intensity of camas intensification should vary inversely with the availability of anadromous fish.
2. There should be a positive correlation between intensity of camas exploitation and the size of productive camas grounds in a group's territories.
3. The degree to which groups rely on camas should vary inversely with transportation costs.
4. There should be a positive correlation between the use of camas and bulk processing, as measured by the use of large earth ovens and storage facilities.
5. There should be a positive correlation between the intensity of management techniques at camas grounds and population density. Such techniques can include ownership, weeding, watering, seeding, and transplanting of root grounds.

(adapted from Thoms 1989: 184)

The basis for the latter point is important because, ultimately, explaining events, such as the intensification of some resource as the consequence of an invention, explains nothing. One still needs to explain why the invention was accepted and used, why people adopted the innovation, and what problem it solved for them.

Thoms's models also stress the importance of the size of resource habitats or patches (#2, Table 3.5), and the crucial role of transportation, arguing, for camas, that the degree to which groups rely on camas should vary inversely with transportation costs. In other words, he argues that people's reliance on camas will be directly dependent (1) on the size of the available camas stands (people are more likely to use big stands), and (2) on the distance to these stands. People will rely most heavily on stands that are close, but will be most willing to travel to distant stands that are large. These points have implications for some of the practices described elsewhere in this volume.

The gardens on Vancouver Island studied by Deur (this volume) are located very close to villages, where transportation costs will be slight. Many of the prairies and other burned areas discussed by, among others, Turner and Peacock (this volume) are sometimes also close to villages. This kind of intensification and location then seems predictable. However, berrying grounds that were maintained by burning were sometimes considerable distances from villages and towns over difficult terrain (Lepofsky et al. this volume). Berries are often highly desired foods, providing variation and sweetness, especially to a winter diet of dried fish and oil. Gatherings at berry grounds are also important socially and ritually. The berries themselves are also small, especially after they are dried, are transported in burden baskets, and sometimes have to be packed over some distances, often out of the mountains. However, the berry patches may also attract other, high-ranked resources such as deer and elk (wapiti). Thus berries themselves may be highly ranked, while in addition it may be that the patches that produce them are highly ranked and worth the costs of moving back and forth to them.

Finally, Thoms links population density with management practices, such as weeding and burning. I would generalize that and say, following Boserup, that these practices should become increasingly common as overall foraging efficiency declines, for whatever reason, population growth being a likely one.

Peacock's Model. Peacock sees the intensification of plant production as a means to reduce the effects of seasonal variation in plant productivity, particularly in temperate zones. In the terms used here, intensification is a consequence of efforts to reduce risk. She focuses on climate changes leading to increased seasonal and annual variability as the primary cause of intensification of plant food production, but other factors, including population growth, could increase the effects of risk by raising the costs of failure. She argues that there are three classes of strategies to reduce risk: cognitive, technological, and social, and focuses on technological strategies in her work. Three main technological strategies include active management of plants and landscapes, changes in food processing to increase the food energy available from foods collected, and, thirdly, increasing the amount of food stored to support winter populations.

Peacock describes a wide variety of management practices, which include ownership, weeding, watering, seeding, and transplanting of root grounds, as also specified by Thoms, as well as burning. She also recognizes management at the level of the individual plant or species of plant, the plant community, and the landscape. In terms of food processing, she, like Thoms, is particularly interested in the effects of cooking of food as a means of intensification that results from extracting more food energy and nutritional value from foods. In this regard, she sees the expanding use of earth ovens for pit cooking as a major step in intensification, as well as an indicator of it. In the terms defined at the beginning of this chapter, Peacock's emphasis is on increasing efficiency of production, rather than on increased labor.

DISCUSSION

The two models just discussed have a great deal in common, though they differ in details, and in some implications. In both, plants and roots originally rank low in the diet. This is explicit in Thoms's model and implicit in Peacock's. Intensification is a result of increased risk. In Peacock's formulation, risk increases as a consequence of environmental changes causing greater seasonal and annual variation. For Thoms, causes can be climatic change, and/or demographic change. For the latter, he specifies circumscription (Carniero 1970) and population growth. These can each have the effect of increasing either (or both) the risk and the costs of failure. Circumscription can increase risk by limiting or reducing the territory available to a group for harvesting resources, and therefore increasing the variability in resource availability. Rowley-Conway and Zvelebil (1989) show that smaller resource patches are more variable than large ones. Population growth can obviously increase costs of failure simply by producing more mouths to feed. Increased human density, either through population growth or circumscription, can cause environmental degradation through overharvesting of resources, again increasing both risk and failure costs. Peacock treats population growth as a corollary of intensification, but not as a cause.

Thoms requires the presence of both an intensifiable resource, which Peacock assumes, and the means to intensify that resource. While this may not seem significant in regard to intensifying plant production, it certainly may be with regard to other resources, for which intensification was not technologically feasible. Thoms also specifies that the technology for intensification already be available. This may be one of the crucial differences between Peacock and Thoms. Peacock does not make this requirement, or does not stress it. The effect of that absence in Peacock's formulation is to eliminate the possibility of fortuitous invention as a case of intensification.

Peacock identifies three different possible routes for plant intensification: management, increased food energy, and storage (Ford 1985a,b), all of which Thoms treats together. Peacock's approach allows a more nuanced testing of her model, since all three need not be expected. Indeed, the discovery, for example, that increased burning is not accompanied by an increased number of earth ovens (or visa versa) will indicate something of the direction and form intensification took.

Both predict that intensification of the harvesting of roots should produce increased numbers of earth ovens. Thoms also predicts, among other things, increased sedentism, while Peacock sees increasing sedentism as a possible corollary of intensification.

THE EVIDENCE FOR INTENSIFICATION OF GEOPHYTES

Currently, four archaeological data sets exist for geophyte production from Cascadia[5] that can be used to evaluate the various models presented in this chapter, though none are specifically from the coastal zone. These are: the Willamette Valley of western Oregon (Burtchard 1988; Connolly et al. 1997; references in Lepofsky in press); the Calispell Valley of northeastern Washington State (Thoms 1989; Thoms and Burtchard 1986); the Upper Hat Creek valley of south central British Columbia (Pokotylo and Froese 1983); and Komkanetkwa (Peacock 1998), also in south central British Columbia, near Kamloops. Peacock (1998) and Lepofsky and Peacock (in press) review the evidence from these localities (except the Willamette Valley) as well as several other localities in British Columbia in greater detail than I can here. These four data sets include usable numbers of excavated and radiometrically dated earth ovens.

The Willamette Valley evidence suggests that geophytes were harvested and processed there by 11,000 years ago (Connolly et al. 1997). Caution is necessary in interpreting these data since they come from only one part of the valley. Roots may have been sporadically exploited until about 5500 B.P., when their production seems to have expanded, continuing at relatively high levels for another 1500 years. Geophyte production fell to almost nil between 4000 and 3000 B.P. There may be another episode of expansion at ca. 3000 B.P., followed by another period of low production between 2500 B.P. and 1500 B.P. Geophyte production was again increased after that date, though Connolly et al.'s data suggest at least one brief period in those 1500 years when root production may again have ceased.

The Calispell Valley record shows regular but low-level root use after ca. 6500 years ago until ca. 4000 B.P., when production was dramatically intensified. Camas production remained high until about 2500 B.P., when it dropped; though it did not cease. Production increased again after 2000 B.P., but never reaching the levels it had previously. Thoms demonstrates that the fluctuations do not correspond to environmental changes (Thoms 1989).

The dated ovens in the Upper Hat Creek valley span the period between 2300 B.P. and contact. However, the temporal distribution of radiocarbon dates suggests that roots were most intensively processed there ca. 2300 B.P.–1900 B.P. (Pokotylo and Froese 1983). Peacock reports ten dates from Komkanetkwa that indicate the site was used for camas processing between ca. 2400 B.P. and the twentieth century. However, the most intensive period of use was between ca. 1800 and 800 years B.P. She concludes that edible root production began on the Canadian Plateau ca. 3300 B.P. While it is difficult to draw regional trends from these data, some general conclusions are possible.

Most important is that geophytes were a part of the diet in the Willamette Valley by 11,000 years ago. This suggests that edible roots were present in Cascadia where the conditions were right for them by the end of the Pleistocene. It is not too great a leap from this to think that they were exploited when and where available throughout the region, as needed, by the end of the Pleistocene. There is, in addition, other weak evidence for root exploitation elsewhere on the Plateau during the earliest Archaic, or Windust period (Ames 1988). Diet breadth during that period was probably quite broad. A range of small (rabbits) to large (bison and wapiti, or elk) mammals was taken, though the larger mammals were certainly preferred when available. There is also indirect evidence for nets and fishing. There are no data for vegetal foods for this time, beyond what is discussed here. Despite the diet's apparent breadth, human population densities were very low (see Ames 1988 for a review of all of this evidence).

The evidence also seems to be showing that levels of production of camas and other root resources fluctuated at each locality through time, though they were exploited more or less everywhere during the last 2000 years or so. The available record is a record of the use of particular root-digging grounds, not of root resources at a regional level. In fact, it is important to stress how profoundly local in scale these data are, and that they may be but dimly reflecting regional-level processes. I have suggested elsewhere (Ames 1991b) that intensification is a regional-level process that will look very different from place to place. Because edible root production, in the case of Thoms's work, was a part of much broader subsistence economies, then levels of geophyte production might be expected to vary as a consequence of changing subsistence strategies, even if those strategies were always aimed at increasing overall production. This would imply that roots were not a highly ranked resource, and were likely to be dropped from the diet periodically. This conclusion does fit the available archaeological data but not the ethnographic data (e.g., Peacock 1998). A second alternative is that geophytes were always highly ranked, at least within the last 5000 years.

In the latter alternative, geophyte production was always an important part of the resource mix. If this was the case, how do we account for these local fluctuations in production? These fluctuations could be pointing to shifting production locales. One reason to shift from one habitat to another would be local declines in productivity—a particular locale becomes less productive, even though edible roots continue to be available elsewhere. Changes in habitat could be the very local consequence of broad climatic shifts, of the kind known for the Holocene. However, these changes do not readily fit the known climatic sequence for the Plateau (e.g., Chatters 1995). Another alternative is that declines in production were a consequence of human exploitation of edible-root habitats—that is, it is possible to overexploit them, perhaps over time-spans making the overexploitation invisible to humans. At the moment this is speculation on my part and it contradicts what we know about the positive effects of management on geophyte productivity. I raise the possibility because resource depletion is an issue arising from the application of the Winterhalder and Goland models.

One of the interesting difficulties in this evidence is reconciling the camas record for the Willamette Valley with the paleoenvironmental record for environmental management there—i.e., burning. This evidence may indicate that extensive environmental management of the Willamette Valley may have begun as early as the middle Holocene (Boyd 1986), although Whitlock and Knox (2002) dispute anthropic burning in the Willamette Valley. The valley was regularly and deliberately burned during the late Holocene, until Euro-American settlement, producing a distinctive oak-savannah that was highly productive in acorns, deer, elk, and other resources. If burning of the valley did begin ca. 3900 B.P. (and that date is preliminary and even controversial), the initiation of burning may have followed, or been associated with, the decline in camas production observed by Connolly and his associates. Linkages among rising human populations, overproduction of camas and depletion of camas meadows, and valley floor burning are intriguing, but the dates for the beginning of burning are not yet firm. If the events are linked, burning could also simply have changed the foraging efficiency for other resources.

Considering all of this, it is almost impossible to use these data, taken as they are in isolation, to evaluate Thoms's or Peacock's models, let alone those of Winterhalder and Goland. That is also far beyond the scope of this chapter. However, a few summary comments can be made. Following the logic of these models, intensification occurred because of either: (1) an overall decrease in foraging efficiency, or (2) increases in risk and/or the costs of failure associated with food getting. Increasing risk would be an increase in the probability of failure in food getting, while increasing costs of failure might include an unacceptable increase in the consequences of failure, even if the probability of failure (risk) remained low. For Thoms, the cause of intensification is population growth, which could cause either result (1) or (2), while Peacock suggests a decline in regional temperatures at about 4500 B.P. to be the cause for the increase in risk (see also Chatters 1995). However, this date does not seem to fit well with the dates for camas intensification reviewed here.

Chatters' (1995) population curve for the southern Plateau, based on radiocarbon dates (cf Ames 1991a, 2000), can be used here. The curve (which extends only to ca. 7700 B.P.) suggests slow growth until ca. 5300 B.P., when populations rise rapidly, only to crash at 4500 B.P. (as a consequence of the fall in temperatures). Numbers fluctuate after that, with peaks around ca. 3300 B.P. and 2600 B.P., and with rapid, continual growth after 2000 B.P. The fit between his curve and the camas data is not very good, or the connections are not yet obvious. For example, the peak in numbers ca. 5300 to 4500 B.P. does occur when camas intensification first takes place in the Willamette Valley, but before the increase in the Calispell Valley. If Thoms's model is correct, then we should expect to see intensification of salmon across the Plateau at that time, except in salmon-poor areas, such as the Willamette and Calispell valleys, where geophyte intensification should occur. Intensification does occur in the Willamette Valley, but not the Calispell Valley. There is no evidence for the intensification of salmon on the Plateau at that time.

In Winterhalder and Goland's first scenario, geophyte intensification would lead to their coming to dominate the diet, although diet breadth remains broad; human population densities would increase, and other high-ranked resources depleted. In the second scenario, diet width should narrow as edible root production was intensified, and some other high-ranked resources would be dropped from the diet. In their third scenario, roots, despite intensification, would remain a small part of the diet, and we would anticipate there being no corresponding population increases or resource depletion. Based on the available archaeological evidence for the Willamette Valley and the Columbia Plateau, neither their second nor their third scenario seems applicable to intensification of edible roots. The first scenario is supported to some degree by the available ethnographic evidence for camas use (e.g., Peacock 1998; Thoms 1989). The implications of this scenario are that risk (in both senses) was high, and that there may have been problems of resource depletion. These implications cannot be pursued further here.

PLANT EXPLOITATION IN THE GULF OF GEORGIA REGION

The Gulf of Georgia region of the Northwest Coast, broadly defined, includes the waters, islands, and mainland coasts of a triangle with points at Victoria, British Columbia, on southern Vancouver Island, Vancouver, British Columbia, and Seattle, Washington. Much of it falls within the area inhabited by the Central and Southern Coast Salish. This region currently possesses the best-documented archaeological sequence for the entire Northwest Coast (e.g., Ames and Maschner 1999; Matson and Coupland 1995). The last three phases of this sequence are the Locarno Beach phase (ca. 3250 B.P.—1500 B.P.), Marpole phase (2500 B.P.—1500 B.P.) and Gulf of Georgia (1500 B.P. to contact). As originally defined (Mitchell 1971, 1990) these three phases differed markedly in their subsistence-related artifacts.

Locarno Beach assemblages include chipped-stone stemmed points, microblade cores and blades, microflakes produced by bipolar technology, large ground-slate points and blades, and net-sinkers. The bone and antler industry includes unilaterally and bilaterally barbed antler points, and composite and single-piece toggling harpoon heads. Most distinctively, hand stones (mullers) and grinding slabs are present, albeit probably in small numbers (it is hard to determine). These tools were probably used for grinding acorns although other plant foods and other purposes are certainly possible. Such tools occur to the south, along the Washington and Oregon coasts, and in sites along the Lower Columbia River, but are rare or completely absent in sites on most of the coast to the north (Ames and Maschner 1999).

The Marpole phase is commonly thought of by researchers in the Gulf of Georgia as the period when what is regarded as classic Northwest Coast culture appeared in the local area (e.g., Matson and Coupland 1995). Both flaked-stone and microblade technologies persist. The variety of toggling harpoons is replaced by large, unilaterally barbed harpoon heads. The grinding slabs and hand stones were still present, however. In the subsequent Gulf of Georgia phase, ground-slate points and blades became smaller and triangular in form. The large, unilaterally barbed harpoon heads were replaced by large composite harpoon valves and by bone bipoints and bone points in general. The grinding slabs and mullers disappear.

As noted above, the Locarno Beach grinding slabs and mullers are similar to those recovered in sites along the Lower Columbia River and in California, where they imply processing and use of acorns. In the Lower Columbia River region, both acorns and hazelnuts were exploited, and acorns at least appear to have been relatively high-ranked resources (Boyd and Hajda 1987). It is plausible that acorns were exploited during Locarno Beach and Marpole times in some areas of the Gulf of Georgia. The other artifacts indicate subsistence shifts. The Locarno Beach tackle—small toggling harpoons and barbed antler points—suggests the exploitation of a wide array of marine habitats and a range of fish and sea mammals, perhaps with a focus on small-bodied ones. The net weights imply the use of gill nets for fishing. The appearance of the large harpoon heads during Marpole points to a shift to larger-bodied sea mammals and fish (see Lyman 1991 for the basis of this reasoning). Some authors see evidence in Marpole for a possible specialization in salmon fishing (e.g. Burley 1980; Matson and Coupland 1995; Mitchell 1971). If this is so, and the evidence is not at all strong, then one could speculate that nuts (or whatever plant foods were ground on those slabs) were sufficiently highly ranked that they continued to be exploited although diet width decreased. One could speculate further that Marpole had a subsistence base rather different from any historically known group on the Northwest Coast, and perhaps somewhat similar to that found in California, with its famous native economy based on salmon, deer, and acorns.

The Gulf of Georgia period appears to have been marked by a wide diet breadth, as indicated by the artifacts and associated faunal remains (Hanson 1991). However, the grinding slabs drop from the repertoire. This could reflect environmental change and a reduction in the range of the appropriate oaks (or other plant foods), or it could reflect shifts in foraging efficiencies for different resources in the diet. The former seems the more likely, but the changes in artifacts do not exclude the latter possibility. It is also interesting to recall that there is evidence of depletion of shellfish beds at the Hoko River Rockshelter during this time period (Croes and Hackenberger 1988). In any case, I offer these speculations to raise the possibility that our assumptions about Northwest Coast subsistence through time may be blinding us to alternatives.

Summary and Conclusions

I have argued elsewhere (Ames 1998; Ames and Maschner 1999) that Northwest economies could best be understood at two levels: a regional level and a local level. Some resources, such as salmon, can best be thought of as regional resources (resources that are essential to maintain high regional population levels), while others are entirely local (resources essential to maintaining high local population levels). In some places, regional and local resources are the same, but in other places not. I have also suggested a similar regional–local dynamic with regard to intensification as a process: production is increased across a region, but the particular mix of intensified resources, or even means of intensification, is entirely local. Thus we may see evidence of increased salmon production near the mouth of a river, but of herring in the next bay north. Or we might see a regional intensification of salmon production (increased levels of salmon production wherever possible), but intensification of other, so-called secondary resources everywhere else.

I have suggested here that most, if not all, the major animal resources exploited in the nineteenth century have been used on the coast for all of the last 10,000 years. This observation is not new with me. Intensification on the coast could not then proceed by adding new animal resources to the diet, but by increasing the efficiency of exploiting some, or by adding entirely new categories of resources. This has implications for the patterns of regional and local intensification discussed above. If, for example, a resource such as salmon was being exploited at maximum levels given available technology, then it could not be intensified. Intensification of overall food production would require increased harvests of other food resources. The technological and organizational problems in this situation might be how to intensify harvests of other resources without a parallel decline in salmon harvests. Some of the ways in which this bind might be solved have been discussed in this chapter, and include shifts in task organization.

There is one further implication of this that I wish to explore here. In a situation where salmon production is at maximum levels and salmon are the dominant resource, we would expect to see salmon dominate faunal remains. If intensification proceeds as described above (that is, of so-called secondary resources), then salmon might continue to dominate the faunal assemblages, especially if plant resources are those intensified. In other words, intensification might not show up in the faunal assemblages.

I have argued a number of points in this chapter. I end by stressing these: (1) finding evidence for intensification requires looking on both sides of the equation stated as *intensification = more food*. Archaeologists often look only for evidence for more food remains, or an increasing diversity of food remains. However, evidence for increased effort, or increasing efficiency of effort, is just as important. (2) Intensification includes an array of strategies, some of which, such as labor reorganization, may be difficult to see in the archaeological record; and (3) general models are useful for developing testable predictions of processes such as intensification. Evolutionary ecology is a powerful source for such models. Finally, I have implied several times in the foregoing that plant foods may have offered one of the few avenues on the coast for people to intensify food production, by providing the only class of "new" resources to be added to the diet, and ones that could be directly manipulated to increase production.

Notes

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1. Peasant economies very often provide useful analogies to Northwest Coast economies; however, such analogies require careful theoretical construction, which is far beyond the scope of the present chapter.

2. In a recent paper, Carlson (1998) argues a number of points: (1) that salmon were available in the coast's rivers at the end of the Pleistocene, and that (2) they were intensively exploited at least in some places prior to 6000 B.P. While his first point requires further empirical support, his second raises issues germane to this chapter. *Intensive* exploitation does not necessarily imply that it is the result of the process of intensification. In fact, intensive exploitation of salmon is predicted by Winterhalder and Goland's outcome 2, as discussed in the text. However, the following question arises: If salmon were already intensively exploited by the middle Holocene, then how was their production to be intensified? If they were harvesting salmon at the levels of Early Modern economies on the coast by the middle Holocene, then salmon could not have been intensified to meet the increased needs of what was clearly a growing population and the evolving social systems. Only two options seem to be available, if we accept Carlson's arguments: increase the efficiency of salmon harvesting and processing, or intensify the production of something else.

3. "K"-selected species are those that produce relatively few young, and invest heavily in them (e.g., humans). They often reproduce slowly. "R"-selected species produce enormous numbers of young, investing little in any individual offspring, but reproducing in great numbers.

4. High-ranking habitats would be those that were the least costly to exploit, given the available technology and labor. Any new resource habitats would necessarily then be those that were more costly to exploit, for whatever reason. Any additional habitats would be increasingly expensive to exploit since these would be the only ones left to add to the subsistence economy.

5. The term "Cascadia" refers to a region that includes both the Northwest Coast and the Columbia Plateau (Ames 1991b; Ames and Maschner 1999).