At the Malthusian ceiling: Subsistence and inequality at Bridge River, British Columbia

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A B S T R A C T

The Bridge River Village, located in the Middle Fraser Canyon of British Columbia, was established and grew to maximum size during the period of ca. 1800–1100 cal. B.P. Village expansion occurred in two distinct stages resulting in a stepped pattern of demographic growth. We suggest that this could reflect two distinctly different periods, the first (Bridge River 2) a relatively comfortable equilibrium with little subsistence stress; the second (Bridge River 3) a truly Malthusian ceiling associated with reduction in critical subsistence resources, social change, and eventual abandonment. In this paper we explore the interactions between resource productivity, food harvest and storage, animal husbandry, demographic growth, and socio-political change in the late Holocene Middle Fraser Canyon. The study provides us with the opportunity to compare and contrast histories of hunter–gatherer–fisher people with that of other complex hunter–gatherers and agriculturalists on similar demographic scales.

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Introduction

A fundamental problem in the archeology of village-scale societies (e.g. Bandy and Fox, 2010) concerns developing an understanding of the complex dynamics of village growth (and decline) and associated social changes, particularly in reference to subsistence production and storage. This has been a long-standing area of interest to archaeologists. Major strides were made during the 1980s with seminal works published by Hayden (1981), Testart (1982), and Ingold (1983). Hayden argued that the primary driver of change was technological innovation coupled with access to abundant resources appropriate for mass harvest and storage. To Hayden in 1981, mass harvest and storage permitted sedentism, and inequality in natural abundances led to social inequalities, an argument that was ultimately, very influential (e.g. Coupland, 1988; Matson, 1983). Testart flirted with technological innovation as prime mover but ultimately opted in favor an argument that favored storage-based economies as a pre-condition for growth, sedentism and subsequent social inequality. On the subject of emergent inequality, Testart opted for personal will of the individual players, thus avoiding deterministic arguments and setting the stage for subsequent models favoring the actions of individual agents with particular personality characteristics (Clark and Blake, 1994; Hayden, 1994). Ingold, in contrast, posed that it was not necessarily the fact of a new storage technology that pre-disposed a

society to growth and social change but the social uses of that technology. Ingold's arguments remain essential to scholars proposing more complex historical dynamics associated with socio-economic and political change (e.g. Wiessner, 2002). Critically, demography was essentially a dependent variable to these scholars who generally eschewed the population pressure and packing models that prevailed in many circles during this time (e.g. Binford, 1968; Cohen, 1981).

We have since learned that demographic models cannot be avoided if we are to fully understand social change over the long term. Theoretical modeling points to relationships between population size, health, land tenure, resource productivity, food storage and other technological innovations, and human social relationships (Lee, 1986; Lee et al., 2009; Wood, 1998). Understanding socio-economic and political implications of demographic change during periods of growth and equilibrium seems critical. Of particular importance are the dynamics of population, resource productivity, and social relationships during periods of population and resource equilibrium or in extreme cases, Malthusian ceilings (Lee, 1993; Lee et al., 2009; Puleston et al., 2012). Dynamics at Malthusian ceilings can be complex given the array of factors affecting production and maintenance of food supplies including spatial constraints on farming and/or foraging, resource structure, labor available, storage technologies, and spoilage and other loss factors. Neolithic archaeologists and demographers have engaged in an already significant amount of research designed to further our understanding of how these variables interact (e.g. Bocquet-Appel, 2002; Bocquet-Appel and Dubouloz, 2004; Bocquet-Appel and Naji,

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2006; Kuijt, 2000). Some of the strongest outcomes have been associated with research on demographics, food production and social complexity on Polynesian Islands (Kirch, 1984, 1997; Kirch et al., 2012; Kirch and Rallu, 2007 [and references therein]). Far fewer studies of this nature have focused on so-called complex hunter–gatherers where we recognize some analogous but also very different resource contingencies (e.g. Croes and Hackenberger, 1988; Goodale et al., 2008).

This study draws from contemporary demographic theory to offer new perspectives on population growth and decline, food harvest, storage, and emergent social complexity at the Bridge River site, a complex hunter–gatherer–fisher village dated ca. 1800–200 cal. B.P., located in the Middle Fraser Canyon of south-central British Columbia. Ancient inhabitants of Bridge River lived in large pithouses and engaged in a variety of forms of food storage that include both harvest and material storage and husbandry of one domesticated animal, the dog. The village was initiated under what appears to have been relatively egalitarian social relations (at least as measurable in the archeological record). But at some point it transitioned during a period of rapid population growth to a pattern of distinct inter-household inequality as measured with a variety of data. Given well dated household contexts with direct evidence for storage practices, this provides us with the opportunity to examine and to some degree attempt to disentangle relationships between demographics, some forms of food storage, and changing social dynamics.

Diets of Bridge River people were dominated by salmon and root foods and to a lesser degree, berries, deer, and other resources. Winter survival was predicated on extensive use of food storage. Drawing from a range of data sets, we argue that pit storage of salmon and other foods probably changed very little across the transition to social inequality. Food storage responded more to demography than social maneuvering. There is evidence however, that while approaches to harvested food storage changed little, the use of dogs as a husbanded resource may have changed quite significantly. Consequently, we draw from the zooarcheological record of Bridge River and other surrounding villages to create a model of dog keeping and ask how it changed in reference to emergent household wealth distinctions. Results of our zooarcheological studies are used to better understand social dynamics associated with occupations of Bridge River during two periods of demographic equilibrium, the first (ca. 1300–1600 cal. B.P.) of which appears to have been relatively stable without major food stress or social flux; the second (ca. 1300–1100 cal. B.P.) was more likely a true Malthusian ceiling with major impacts on socio-economic and political stability.

To accomplish these things we first establish the pattern of demographic growth and decline at Bridge River. We then present an exercise designed to illustrate the critical relationship between salmon productivity in the Middle-Fraser Canyon and its effects on the potential size of human populations. We review zooarcheological data in two areas: salmon and deer harvest, processing and consumption; and ownership and management of dogs. We then examine evidence for changes in approaches to food storage. Finally, we consider the wider implications of this research.

Demographic theory

Demography has played an important role in the histories of intermediate scale village societies around the world and Bridge River is no exception (Prentiss et al., 2008). In order to develop an understanding of demographic and socio-economic history at Bridge River we first outline a range of models designed to anticipate and explain variability in demographic history. We begin with patterns of population growth and follow with a consideration of population and cultural dynamics during periods of Malthusian equilibrium.

Kirch (1984) outlines a range of population growth scenarios, though not all are relevant beyond island situations (e.g. rapid extinction and exponential growth). Of direct relevance, however, for understanding Bridge River demographic history are the overshoot, oscillating and step models (Fig. 1). Each of the three scenarios shown in Fig. 1 assumes the basic logistic growth scenario that is effectively the standard Malthusian model (Lee, 1986; Malthus, 1976 [1798]) whereby increases in resources, whether independently (e.g. natural increase) or by technological means raises standards of living and results in population growth. However, growth eventually slows as population reaches equilibrium with the available resources. This Malthusian equilibrium or ceiling may carry with it a variety of implications for further growth or decline. If population growth is too fast and significantly overshoots equilibrium then it may crash (Fig. 1a), bringing population levels back well below carrying capacity defined in this approach as the resource limits available to support a given population. Other options include oscillation (Fig. 1b), as might occur for example when resources and associated populations fluctuate due to lagged linkages, and step (Fig. 1c), whereby resource productivity periodically rises leading to a stepped pattern of growth (Kirch, 1984; see also Pianka, 1974; Pieloe, 1977).

There is some debate over the ability of any human population to persist for a sustained period (e.g. over a century) at optimal equilibrium. Optimal population equilibrium has been defined as the size of the population that produces the largest surplus. However, it is also defined variously as the maximum population possible that does not degrade its associated resource base (Wood, 1998:120). Wood (1998), citing Casti (1990), is doubtful that either definition is adequately realistic for pre-industrial societies where anticipating future resource trends is not easy (and forecasting future economic swings is far from perfect even in today's western societies). On the other hand, for many hunter–gatherer societies with the ability to flexibly move between habitats while also regulating population, Wood's second definition (maximum population possible that does not degrade environment) may in fact be somewhat more realistic, all things equal (e.g. Howell, 1986). For territorially restricted, resource tethered, and high population density hunter–gatherer–fishers such as those of North America's Pacific Northwest, Wood's (1998) critiques probably have significantly greater relevance. If this is the case then we could expect a stronger role for more Malthusian processes in some contexts.
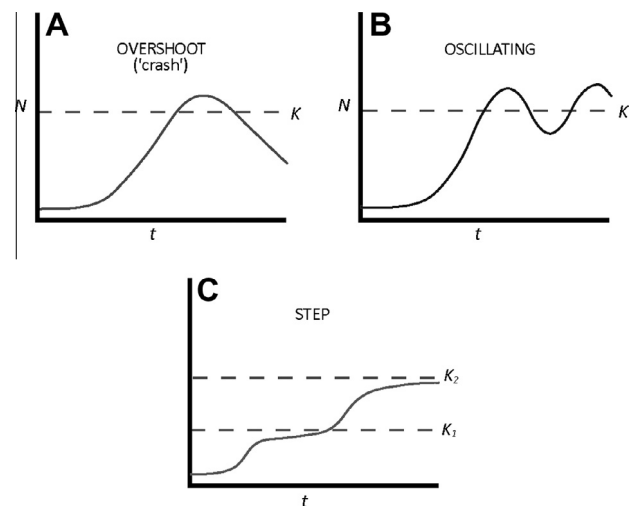

Fig. 1. Models of demographic growth and decline where *K* equals carrying capacity, *N* equals population size, and *t* equals time (redrafted from Kirch (1984)).

Mathematical modeling of subsistence economics and population dynamics among Neolithic scale societies at Malthusian equilibrium has yielded a range of conclusions (Lee, 1993; Lee and Tuljapurkar, 2008; Lee et al., 2009; Puleston and Tuljapurkar, 2008; Wood, 1998). Most notably, high crop yield and labor efficiency does favor high mean population sizes, but if there is low sensitivity to potential shortage it is possible that food ratios (food required for a population to meet its ideal requirements [Puleston et al., 2012]) will remain low as will more environmentally determined variances in returns (Lee et al., 2009). There are several major implications of this finding: first that increases in hunger and mortality in presumably most vulnerable age groups will increase as populations rise to an equilibrium point and second, that major crop fluctuations will potentially raise mean well being of a population while increasing rates of periodic famine and starvation. This counter-intuitive conclusion draws from the assumption that loss of young and old during down swings in crop production increases food access for all survivors and that resources recover their densities faster than human populations. But, if a food crisis persists for a longer period, losses could accrue in productive workers, which could lead to a significantly deepening crisis (Puleston and Tuljapurkar, 2008). Resolution of hunger issues can be accomplished in several ways. Constraints on access to food can be lifted by opening up of land associated with loss of people, thus permitting expansion of agricultural fields or foraging for non-domesticated resources. Technological innovations can permit improved subsistence efficiency, thus permitting production of more food in the same unit of space and/or time (this is the Boserup scenario [Wood, 1998]). Finally, natural resource abundance or conditions favoring crop production could simply improve. However, under the Malthusian model, sustained improvement in food access will inevitably lead to new population equilibria.

Winterhalder et al. (2012) point out that taxation (which can be a proxy for seed set-aside, spoilage and other resource loss) and storage introduce additional important variables. Their model suggests that taxation can have the same effect as other forms of loss, essentially keeping populations lower and generally better off. Storage can be used on an intra- or inter-annual basis with particularly important benefits in potentially raising the quantity of goods that can be lost (taxation, spoilage, etc.) and also alleviating the effects of bad years (that is if extra from previous years can be held over). An important implication is that under conditions of seasonal unpredictability, groups may purposefully over-produce and store to overcome the threat of potential loss. For Pacific Northwest people reliant on salmon (or other marine or anadromous food sources) storage from a particular harvest event would generally be limited to less than a year (e.g. Kennedy and Bouchard, 1992; Romanoff, 1992a), thereby limiting anticipatory storage under variable conditions. Alternatives for these groups include increasing harvest and storage of select high calorie plant foods such as geophytes (Lepofsky and Peacock, 2004) or generally expanding diet breadth (e.g. Broughton, 1994). An important social implication is that under expanding hunger of an extended Malthusian equilibrium, social groups who formerly shared food, might increasingly maintain private storage or share only when politically convenient (Boone, 1998; Hegmon, 1991). This could have the secondary but critical effect of altering long standing social relationships between groups.

Frames of reference: traditional subsistence and storage in the Middle Fraser Canyon

In this paper we seek to develop an understanding of the impacts of demographic growth on storage practices, foraging behavior, dog husbandry, and emergent social inequality at the Bridge River site. We are fortunate to have excellent ethnographic descriptions of traditional housepit occupation, food collecting, and storage practices in the Middle Fraser Canyon (Kennedy and Bouchard, 1978; Hayden, 1992 (and chapters therein); Prentiss and Kuijt, 2012; Teit, 1900, 1906). Mid-Fraser peoples employed an annual subsistence system predicated on delayed returns in a highly seasonal environment. In short, a highly active warm season was used to put up stores necessary for surviving a long cold season in sedentary winter villages. Storage facilities were created within and outside of large semi-subterranean pithouses.

Early spring was largely dedicated to immediate return hunting and fishing. Later spring activities included harvesting mid-elevation geophytes (edible roots) and deer hunting. Dried roots and smoked deer meat were transported to mid-summer fishing camps and to winter villages for later consumption. Mid- to late summer activities focused on intensive salmon harvest and processing for winter storage. Mid-summer was also critical for berry harvest and drying. Fall activities focused on higher altitude deer hunting, further root gathering, lithic procurement, and collection of a wide range of other plant and animal foods and materials in advance of the long winter. Dried salmon, deer, berries, and roots were critical winter subsistence items.

Storage technologies in the Mid-Fraser were varied and included cache pits, above ground facilities, baskets, and cords. Cache pits were lined with birch bark and layered with dried food items (e.g. plant materials, least oily fish [e.g. late-season sockeye salmon], etc.) and pine needles to help resist moisture and to repel vermin. Cache pits could be placed within or outside of houses and were typically converted to refuse receptacles when they had reached the end of their use-life. Ethnographies suggest that more oily fish (e.g. Chinook or "spring" salmon) were stored in above-ground receptacles. Roots were typically dried and strung on cords or sticks and hung on indoor storage racks or house rafters. Additional dried foods such as berries, bark, and other items could also be stored in baskets.

Ethnographies speak to variation in household access to critical food sources (Romanoff, 1992a, 1992b). Salmon fishing sites were effectively owned by individual families; those with highest rank held the best spots. Use of these places by non-owners required permission and this generally was granted but only after the owner family had derived all that was needed. Social control of access to other hunting and gathering locales may not have been as strict. Rather, ethnographies describe the effects of variability in individual performance (Romanoff, 1992a, 1992b). Essentially, households with poor hunters and lazy gatherers were significantly less well off materially and socially than others more entrepreneurial or better organized. Ethnographies are largely moot on the question of variability in wealth differentially manifested as equivalent variation in household storage capacity. Archaeologists working in the region (e.g. Hayden, 1997) have assumed that there was a relationship.

From an archeological standpoint, our best opportunity for measuring variability in storage comes with the frequent presence of large cache pits within house floors. Storage can also be examined through analysis of the zooarcheological record, particularly by looking at taxa found in winter houses, known to be available only during specific warm season periods (e.g. salmon, berries) or raised for later consumption (some dogs). Variation in numbers of household occupants is challenging to measure. However, correlations between cache pit volume and fire-cracked rock density have proven effective under the assumption that more persons require greater investment in pit storage and larger scale cooking operations requiring stone-boiling (Prentiss et al., 2012a; Prentiss and Kuijt, 2012). These measures are essential for defining variability in household demographic packing and its relationship to food storage, foraging, and animal husbandry.

The Bridge River site

The Bridge River site is one of several large winter villages (Fig. 2) in the Middle Fraser Canyon (Prentiss et al., 2008, 2012a; Prentiss and Kuijt, 2012). Archeological investigations since 2003 have focused on developing a detailed village-wide chronology of housepit occupations with the ultimate goal of understanding demographic growth, and socio-economic and political change. Most recent research suggests that the village first developed as a small group of houses about 1800 years ago. Growth occurred in two punctuations in which the number of likely simultaneously occupied houses rose from a maximum of seven in the Bridge River 1 (BR1, ca. 1800–1600 cal. B.P.), to about 17 in BR 2 (ca. 1600–1300 cal. B.P.), and finally to at least 30 in BR 3 times (ca. 1300–1000 cal. B.P.) (Fig. 3). Arrangement of houses was not random on the Bridge River terrace. Rather, during BR2 and BR3, occupants constructed houses placed in large circular arrangements implying the presence of social groups perhaps similar to that described in the ethnographies as "clans" (Teit, 1906). Finally, drawing from most recent excavation data (Fig. 4), we can argue that material

wealth-based inequality developed during the BR3 period (Prentiss et al., 2012a).

Material wealth-based inequality manifested in several ways. In brief, correlations between material-wealth indicators including prestige objects (e.g. stone beads, pendants, jade artifacts), prestige raw materials (e.g. nephrite jade, steatite, obsidian), non-local lithic raw materials, and ungulate prey items across multiple BR2 and BR3 housepit occupation floors suggested that significant wealth differences only developed within select BR3 houses (Prentiss et al., 2012a). Indeed only Housepit (HP) 24, occupied exclusively during BR3, stood out strongly over the other houses in terms of all measurements. These results are mirrored in the subsistence data discussed below.

An important part of the Prentiss et al. (2012a) study was an assessment of variability in cache pit volume and fire-cracked rock density. Cache pits are a good way to assess reliance on storage since it is impossible to recover other forms of storage (e.g. cords and baskets). Since cache pits were only sampled within test trenches, volume was calculated in reference to square meters excavated. Fire-cracked rocks (FCR) were counted (at Wentworth Scale cobble and pebble sizes) and density calculated in relation to cubic meters excavated per occupation component in each housepit. Quantitative analysis found that for all BR 2 and 3 housepit components cache pit volume correlated strongly with FCR density but not with any of the material-wealth indices (Prentiss et al., 2012a). This finding suggested that if FCR density was a consequence of cooking frequency and that derived from numbers of household occupants then cache pit volume was more correlated with demographics than wealth. One could counter that the highest numbers of people should also have been in the wealthiest and presumably largest households. However, house size does not correlate with either FCR density or cache pit volume.

Demographic change at Bridge River and the Middle Fraser Canyon

Ethnographies strongly imply that annual salmon numbers played a significant role in population sizes in the Middle Fraser context (e.g. Kennedy and Bouchard, 1992). Hayden (1992) asserts that while failures in salmon runs would have been disastrous to Mid-Fraser populations, normal salmon fluctuations would have had limited effect given their tremendous numbers even in weak years. Beyond generalized statements such as these we have little clarity regarding relationships between fisheries and Mid-Fraser demographics. As a first attempt to overcome this problem, we developed a simple simulation of fishing returns in good, medium, and poor years and used it to project numbers of consumers (Table 1).

As our ultimate goal is to better understand relationships between variation in population and resources we began our calculations with kilograms of fish estimated for good, medium and poor years in the Fraser River above the Thompson River confluence using data from Kew (1992). In order to offer a more extreme contrast between years we cut Kew's worst year by 50%. We then assumed that people worked 12 h per person day and as a group caught 10% of the total fish in the water during those fishing periods. Kennedy and Bouchard (1992) and Romanoff (1992a) describe a general pattern of intensive fishing whereby entire families worked the fishing rocks daily during the runs and returned home at night, though some could stay at the fishing site to guard against bears or human marauders. Given the quantities of fish in the Fraser River during pre-modern times, the 10% catch factor could be too high. However, it is currently impossible to know actual rates of success in pre-modern times. We also assumed a rate of loss at 10% assuming occasional problems with bears, insect infestations, and spoilage (Kennedy and Bouchard, 1992; Romanoff, 1992a). We calculated the edible portion of the catch at 62%
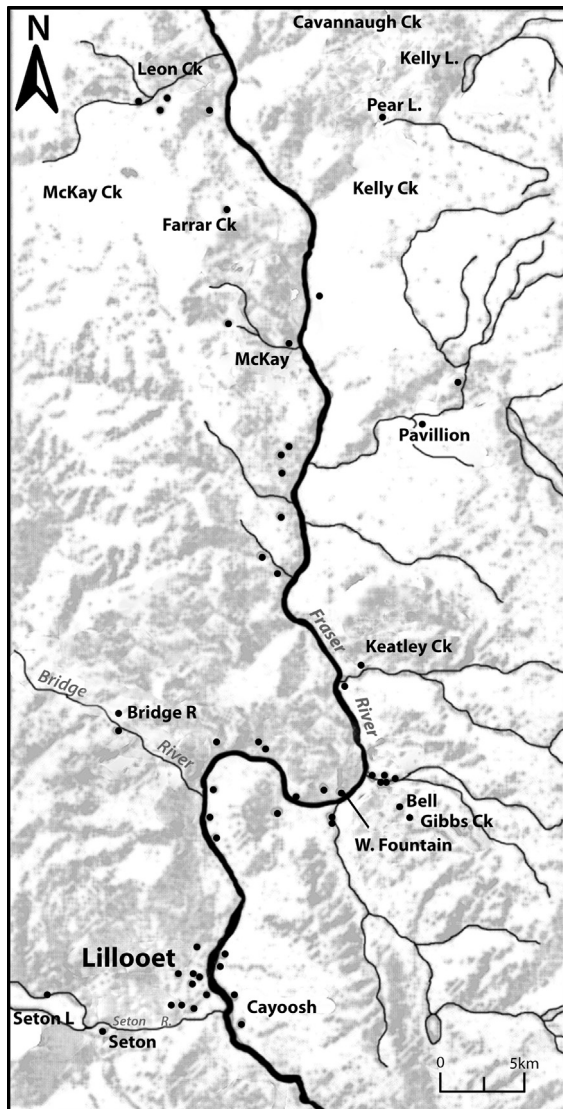

Fig. 2. Middle Fraser Canyon in the vicinity of Lillooet, British Columbia showing approximate locations of important sites (map by Eric Carlson, redrafted from Sheppard and Carlson (2010): Fig. 1).
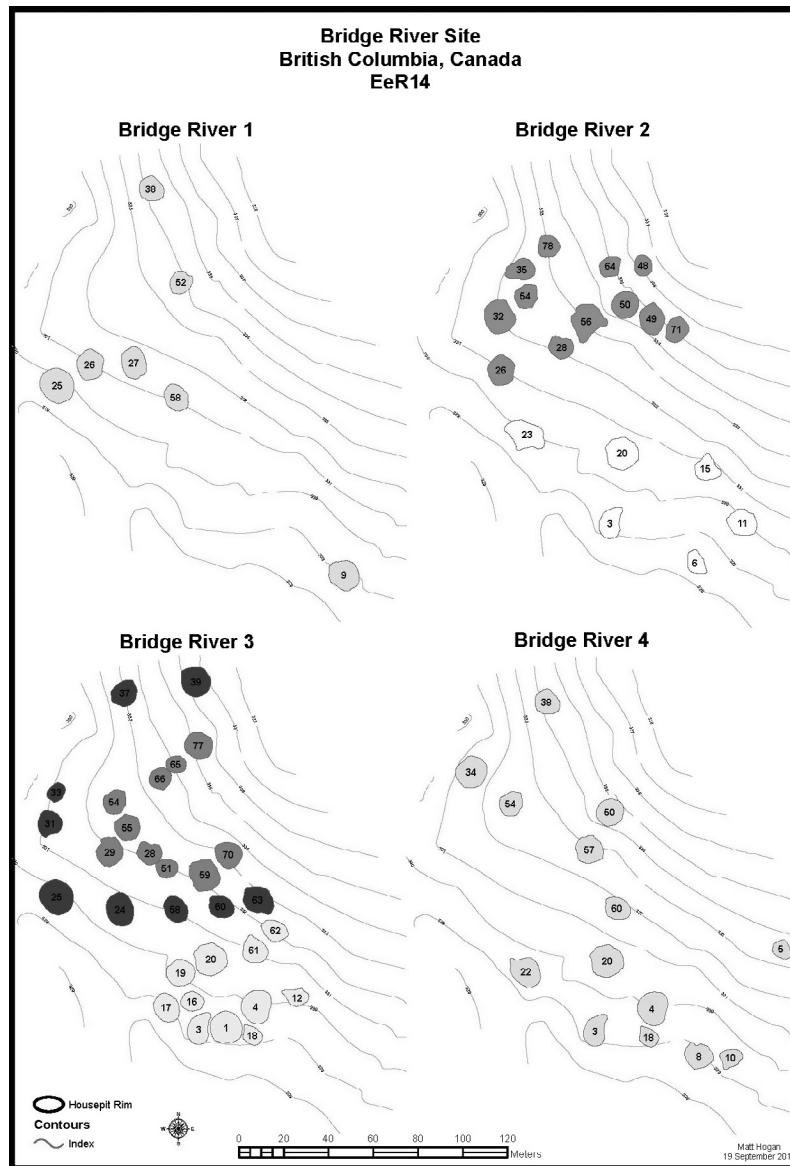
Fig. 3. Map of Bridge River site showing pattern of change in distribution of housepits over time (map by Matt Hogan).

drawing from our own experiments with salmon economic anatomy (Prentiss et al., 2012b). We calculated kilocalories (kcals) per kilogram (kg) using published assessments of caloric content of raw (uncooked) sockeye salmon fillets (http://calorielab.com/foods/salmon/57; accessed April 2012). Next we divided the total caloric output for good, medium and bad years by needs for an active individual person using a figure of 2600 kcal derived by calculating the approximate mean of male and female requirements cited by Lepofsky and Peacock (2004). Finally, we assumed that salmon were of fundamental importance to the diet (75% of total calories) during some segment of the year (Alexander, 1992; Kew, 1992; Romanoff, 1992a).

Alexander's (1992) ethnoarcheological model of the annual subsistence and mobility cycle in the Mid-Fraser suggests that stored salmon provided the primary caloric source during the months of December through February. Salmon were also the primary caloric source between mid-July and mid-August as this was peak fishing season, though as noted by Kennedy and Bouchard (1992) salmon fishing often continued into September. Minimally, therefore, we estimate that salmon probably provided 70–80% of calories for four months of the year. However, salmon were also consumed in lesser

quantities during other times of the year. Late sockeye and Coho runs favored salmon consumption in late August through September in some years. Spring (Chinook) salmon were available and popular during May, June, and early July. Stored salmon were consumed in November as winter households were established. Those unable to travel during the warm season (e.g. some elders and infirm persons), remained in the winter village and likely consumed salmon in varying quantities throughout the year. Consequently it is very hard to accurately estimate the average annual percentage contribution of salmon to individual caloric consumption. Therefore, we calculated population projections under three salmon consumption scenarios. We assumed a minimum need scenario whereby salmon contributed 75% of calories to the diet during only four months of the year. Given our ethnographic understanding of fishing and salmon's critical role in Mid-Fraser diets during winter and summer, this scenario is most likely too little. We calculated a maximum need scenario of 75% contribution for eight months of the year. This likely over-estimates as it would expect unrealistically long winter sedentism in pithouses and intense reliance on spring salmon in the early summer, an unlikely scenario given historically low numbers (compared to sockeye)
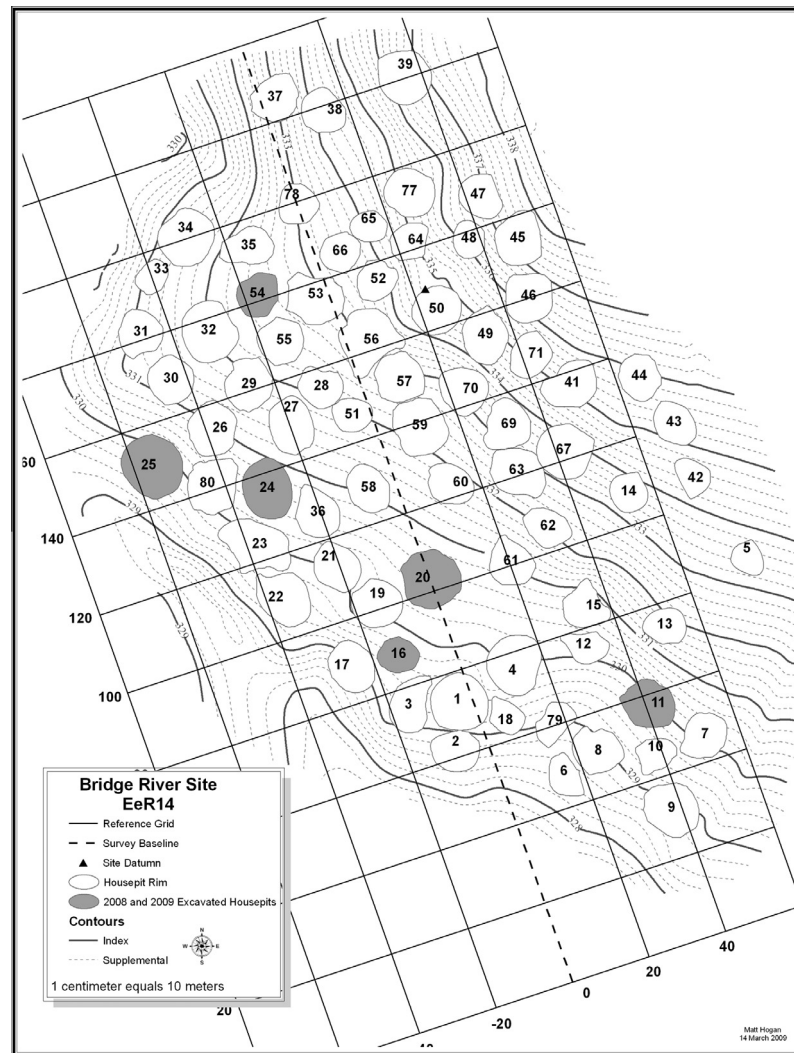
Fig. 4. Map of the Bridge River site showing housepits excavated in 2008 and 2009 (map by Matt Hogan).

Table 1
Projected population sizes in Middle Fraser Canyon based upon salmon consumption. Baseline data on salmon kilograms in good, medium and poor years are drawn from Kew (1992).

	Good	Medium	Poor
Total fish (kg)	78,668,000	34,226,000	10,081,000
Total 12 h work	39,334,000	17,113,000	5,040,500
10% Fish caught	3,933,400	1,711,300	504,050
Total 10% lost	3,540,060	1,540,170	453,645
62% Edible	2,194,837	954,905	281,260
1700 kcal per kg	3,731,223,240	1,623,339,180	478,141,830
2600 kcal per person	1,435,086	624,361	183,901
Maximum need (8 mos. @ 75%)	6966	3031	893
Intermediate need (6 mos. @ 75%)	10,475	4557	1342
Minimal need (4 mos. @ 75%)	21,104	9182	2704

in the Fraser system (Kew, 1992). Thus, we developed an intermediate scenario whereby salmon contributed 75% of calories for six months of the year. This permits us to anticipate intensive need for three to four months in winter and one month in summer along with varying use during other seasons.

Relying upon our intermediate scenario, our exercise (Table 1) suggests that in good years (and all other food resources held equal), populations in the Middle Fraser Canyon could be over 10,000 persons, but once salmon numbers drop in medium and poor years, predicted numbers of people drop to under 5000 and

1500 respectively. These results become more meaningful when projected against estimated Middle Fraser Canyon populations during pre-Colonial times. We estimated Mid-Fraser population sizes by adding up the total roof area (a proxy for floor area) per each housepit in all of the recorded Middle Fraser villages approximately between Leon and Cayoosh Creeks (Sheppard and Muir, 2010) and dividing that by a figure of two meters squared (Hayden, 1997). The 2 m² is probably too low, but the overall data set is also missing three destroyed major villages (Lillooet town site, Fountain, and Pavilion). Next, we made projections for growth

and decline over time. To do this we multiplied roof area calculations by percentages of total occupied houses during the life span of the Bridge River site during periods BR 1–3 as this is the only village with adequate dating to project demographic change. Thus, our estimates are built upon the assumption that growth and decline at Bridge River matches developments at other villages in the region. We feel this is justified, given approximately similar patterning in independent assessments of Mid-Fraser population dynamics based upon regional radiocarbon date frequencies (Lenert, 2001; Prentiss et al., 2007). Results suggest that around 1700 people could have inhabited the Mid-Fraser area in BR 1 times (ca. 1800–1600 cal. B.P.), followed by rapid growth to over 8000 by early BR 3 (ca. 1200–1300 cal. B.P.).

A series of independent studies of fisheries productivity from two oceanic cores spanning the past 5000 years in the Vancouver Island area (Hay et al., 2007; Patterson et al., 2005; Tunnicliffe et al., 2001; Wright et al., 2005) point to a clear pattern of weak production at ca. 2000 cal. B.P., rising to peak production at ca. 1200–1300 cal. B.P., and then rapidly declining to sub-average levels for several subsequent centuries. If we assume that salmon productivity is tied to wider oceanic regimes (e.g. Benson and Trites, 2002) then we can use these results to project variability in numbers of salmon, and consequently, people across these same time periods where Demographic periods 1–3 on Fig. 5 are equivalent to Bridge River periods 1–3 (Demographic period 4 is equivalent to immediate post-BR 3 or ca. 800–900 cal. B.P. and Demographic period 5 is somewhat later [ca. 600–700 cal. B.P.]). This becomes more interesting when we add estimated human populations for the Middle Fraser villages during these time frames. For this calculation we relied upon BR1–3 estimates in Table 2 for demographic periods 1–3. To anticipate period 4 we cut the peak population by 70% and for period 5, it was cut by 90%. This is approximately in line with prior estimates of demographic decline associated with the Mid-Fraser village abandonments (Hayden and Ryder, 1991; Kuijt, 2001; Lenert, 2001; Prentiss et al., 2007). If these projections and estimates approximate at least some degree of reality then fisheries productivity does a remarkably accurate job in predicting potential populations in the Middle Fraser Canyon.

Our next problem is to develop an understanding of how growth and decline occurred in the Middle Fraser. To accomplish this we return to the Bridge River site where to date we have run 91 radiocarbon dates on house floor materials and roof beams (Prentiss et al., 2008, 2010). Williams (2012) cautions, that for reconstruction of regional demographic histories spanning many thousands of years using cumulative probability distributions, it is critical to have at least 500 dates. However, given that we are looking at the history of a single site over a relatively short time span and that we have dated nearly all of the houses in the core portion of that site (Prentiss et al., 2008) with carefully chosen samples, we consider 91 dates an adequate initial source of information for modeling demography. The dating record from Bridge River permits us to ask questions regarding patterning in the demographic process, in particular to explore models outlined by Kirch (1984; e.g. overshot, oscillating, and step). We plotted cumulative probability distributions of the Bridge River radiocarbon record using CalPal-Hulu 2007 calibration data and the CalPal calibration program (Weninger and Jöris, 2003; Weninger et al., 2007). Results of this process (Fig. 6) reflect a similar outcome to our original studies (Prentiss et al., 2008) indicating a step pattern of growth at Bridge River. The graphic in Fig. 6 suggests three steps before site abandonment, corresponding to our previously identified BR 1–3 periods. We have very limited data on the small number of BR 1 houses, but fortunately, we do have adequate materials from BR 2 and 3 households to examine the prevailing economic and demographic conditions in these contexts, effectively what appear to be two demographic ceilings.

Subsistence and storage at Bridge River

Data on subsistence and storage at Bridge River confirm important differences in socio-economic conditions between the BR 2 and 3 demographic ceilings. We emphasize zooarcheological data as recovered botanical remains are still too sparse for adequate characterization. Salmon and to a much lesser degree, deer, were the keystone faunal resources used by Bridge River peoples (Prentiss et al., 2011). Variability in frequencies of these items is consequently useful for monitoring household economic well being when compared to estimates of household occupation densities. While we cannot measure actual numbers of household occupants it is possible to gain some understanding of relative density of occupants by comparing fire-cracked rock density and relative cache pit volume between houses and time periods (Prentiss et al., 2012a). Additional measures of deer processing intensity are also useful for assessing variability in potential access between houses and across major occupation periods (e.g. Broughton, 1994; Janetski, 1997).
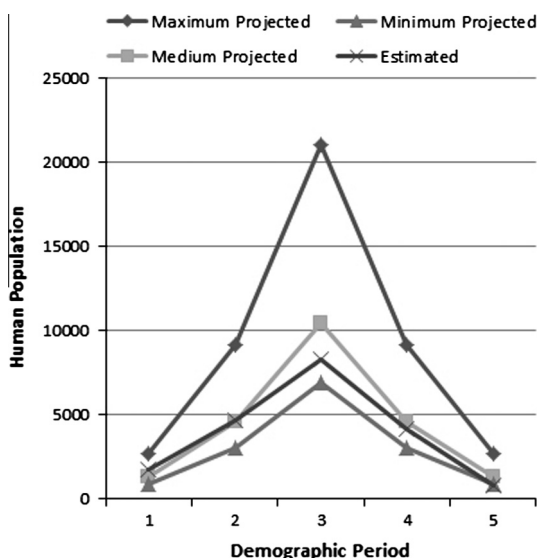
Fig. 5. Predicted and estimated populations in the Middle Fraser Canyon across five time periods.

Table 2
Estimated population sizes in Middle Fraser Canyon (roof area data from Sheppard and Muir (2010)).

| Site	Roof area	BR1 (.09)	BR2 (.22)	BR3 (.39)
Farrar Cr.	5240	472	1153	2043
McKay Cr.	2605	234	573	1016
Kelly Creek	8758	788	1927	3416
Keatley Cr.	8470	762	1863	3303
Bridge River	10,426	938	2294	4066
Bell	3072	276	676	1198
EdRl2	1199	108	264	468
Pine Mtn.	534	48	117	208
Latimer	480	43	106	187
EfRk6	366	33	81	143
EfRk107	354	32	78	138
EeRl221	219	20	48	85
EeRl75	214	19	47	83
EeRl220	197	18	43	77
EeRl145	175	16	39	68
EeRl135	114	10	25	44
Total		3517	9334	16,542
Persons Per 2 m^2		1759	4667	8271
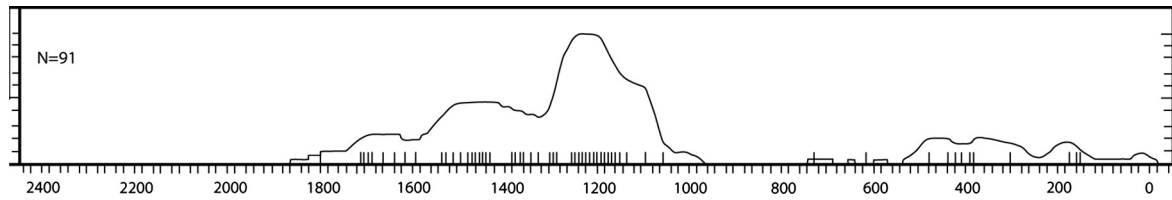
Fig. 6. Calpal graphic illustrating variability in radiocarbon dates at Bridge River and projections of potential occupation densities (redrawn from an original graphic by Lucy Harris).

As we are interested in variability in relative importance of salmon and deer across major occupation periods and between select houses we developed simple salmon and deer indices, each calculated at total NISP (taxonomically identifiable elements to level of genus) per cubic meter of sediment. We measured intensity of deer processing in two ways. It is well known in the Mid-Fraser, that hunters would make decisions regarding deer processing in the field based heavily on transport constraints and distance from the home base (Alexander, 1992; Tyhurst, 1992). In situations where deer were acquired at long distances or in particularly large quantities, field processing required disarticulation, meat stripping, grease extraction, and field smoking. When the latter operation was completed, meat, fat, and hides were transported back. It is also possible that under some conditions, important bones for marrow, grease and technologies (especially limbs) were also returned. We measured potential investment in field versus within-village processing with a simple processing index: NISP deer head and axial skeleton divided by total deer NISP for all taxonomically identifiable elements.

Mammal bones returned to the village were routinely processed for marrow and grease, which required significant destruction of elements. However, bone destruction was not always practiced to the same degree in every household as in the case of feasting (e.g. Kennedy and Bouchard, 1978) or within affluent houses with adequate supplies of carbohydrates and fats from other sources (Romanoff, 1992a). In order to simply measure variability in bone processing intensity we calculated a simple bone processing index by dividing total NISP mammal bone fragments at the 1–9 mm size grade by total NISP mammal bones (including all fragments), presuming that the contexts with most intensive bone processing would also generate the highest numbers of smallest bone fragments.

In order to assess subsistence variability between BR 2 and 3 contexts we examine village-wide signatures drawing from 2008 to 2009 excavation data (Table 3; Fig. 4). We then examined inter-household differentiation with two houses chosen from BR 2 and BR 3 groups. In each case we purposefully chose houses with extreme differences in size along with largest possible faunal assemblages in order to maximize the potential to recognize household differences. Thus, we chose Housepits 20 and 11 for BR 2 and Housepits 16 and 24 for BR 3. Given its large size and BR 3 date, Housepit 25 could have been a very good choice for this study. However, given a complete lack of storage features, a very large central fire pit, and great numbers of minimally butchered deer bones, we have reason to believe that the house may have been more often used for special events (e.g. feasts) than typical domestic activities.

Frequencies of salmon and deer remains decline between BR 2 and 3 despite stability in indicators of household occupation density (Fig. 7). Simultaneously, there is a reduction in head and axial parts of deer returning to the village and an increase in numbers of small bone fragments during BR 3 times (Fig. 8). These results suggest that both salmon and deer were less frequently harvested during BR 3 compared to BR 2. If this is the case then we would also expect to recognize a higher degree of inter-household variability in access to these resources between periods (e.g. Hegmon, 1991).

There is variation in relative numbers of salmon and deer remains between BR 2 Houses 11 and 20 (Fig. 9). However, this is best explained in reference to relative numbers of occupants. Housepit 20 likely had more occupants who generated more food remains entering into the archeological record compared to Housepit 11 (Fig. 9). There is no real difference between houses in terms of axial/head transport or bone processing intensity (Fig. 10). In contrast, BR 3 Housepit 24 has substantially more deer and slightly more salmon remains than similarly dated Housepit 16, despite the fact that indices of occupation density are slightly higher for Housepit 16 (Fig. 11). Further, indicators of deer element transport and processing in HP 16 and 24 contexts are inversely related to one another (Fig. 12). Clearly, Housepit 24 had significantly better access to deer than did occupants of Housepit 16.

These results indicate that despite general continuity in household occupation densities as indicated by FCR densities and relative cache pit volumes, access to critical subsistence resources, salmon and deer) declined, especially in less well-off households. Housepit 20, for example, a large house occupied in BR 2 and 3 times, also saw a major reduction in critical subsistence resources during BR 3 (Prentiss et al., 2012a). Given that inter-household differentiation in access to food appears to have become most obvious during BR 3 and that the village was abandoned at the end of this short period, it appears likely that subsistence stress became significant during this time. However, we cannot fully understand this process without a closer look at the dog remains from Bridge River and the Middle Fraser.

Dogs as food (among other things) at Bridge River

It is well known that Salishan peoples of the Pacific Northwest Coast and Plateau regions kept domesticated dogs (e.g. Crockford, 1997). Ethnographies and other studies point to a range of roles for dogs including hunting, transportation, protection and companionship, clothing (hides), weaving materials (hair), ritual, and food (e.g. Cail, 2011; Crellin, 1994; Solazzo et al., 2011; Teit, 1906). Dogs were kept by Mid-Fraser groups as a source of food for use under a variety of conditions (Cail, 2011; Crellin, 1994). Dog consumption occurred during special ceremonies and feasts as described in the journals of explorer Simon Fraser (Lamb, 1966). Dogs were also consumed as a backup food when other resources (e.g. salmon or deer) failed or stored supplies ran short (Crellin, 1994; Teit, 1906). Given their range of uses, dogs were clearly important social and subsistence resources for Mid-Fraser peoples and it is no surprise that dog remains occur frequently in the archeological record of this region (Cail, 2011; Langemann, 1987).

A relatively large sample of canid remains and coprolites were recovered from excavations at Bridge River in 2008 and 2009. Of the total 213 canid bones recovered at Bridge River, 179 (84%) came from two cache pits in Housepit 24; the other 16% derived from three other BR 2 and 3 housepit occupations. Coprolites were similarly clustered with 77% from cache pits (turned refuse pits) in Housepit 24 and the other 23% from BR2 and 3 refuse pits in nearby Housepit 54. These data suggest that occupants of HP 24 had a significant investment in dogs compared to other houses

Table 3
Bridge River site archeological data.

|	BR2	BR3	BR 3 Houses		BR 2 Houses	
			HP 16	HP 24	HP 11	HP 20
Excavated m³	4.35	10.29	1.82	1.76	2.77	.88
Cache pit volume[a]	1592	2625	704	833	638	927
Cache pit vol./m²	15.1	14.6	16.6	15.2	15	23.2
FCR count	5970	14,918	4078	3933	3219	2340
FCR/m³	1372	1450	2241	2103	1162	2659
Oncorhynchus sp. NISP	1949	1938	529	617	563	888
Oncorhynchus sp. NISP/m³	448	188	291	330	203	1009
Odocoileus sp. NISP	101	152	11	29	25	50
Odocoileus sp. NISP/m³	23.2	14.8	6	15.5	9	56.7
Fragmentation index	.31	.48	.66	.37	.27	.33
Axial + head NISP	65	69	3	18	14	27
Axial + head NISP/total NISP	.67	.47	.27	.62	.58	.6

[a] Expressed in thousands.
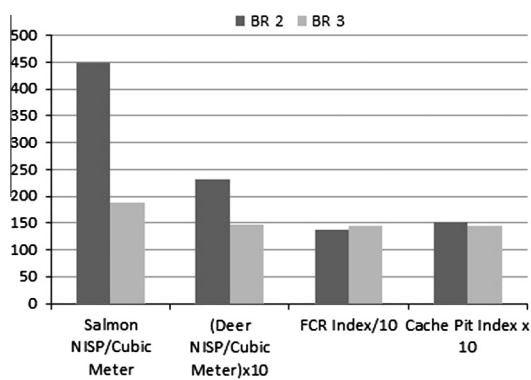
Fig. 7. Indicators of subsistence change and intra-household demographic stability between Bridge River 2 and 3 periods.
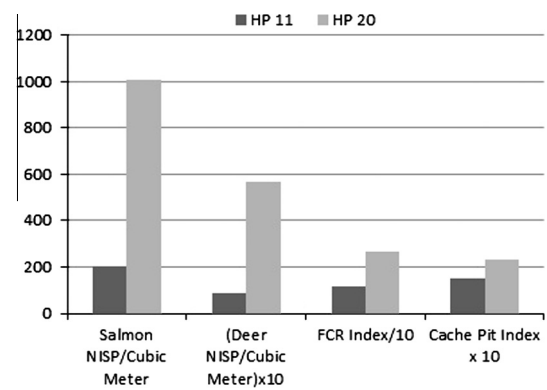

Fig. 9. Indicators of consistency in subsistence and demography between households during Bridge River 2 times.
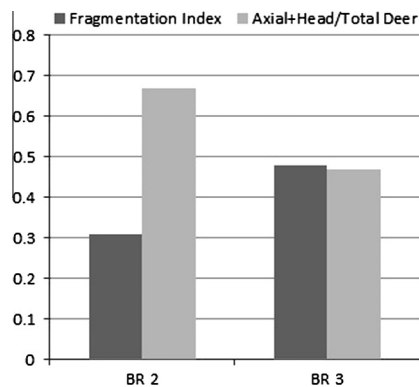

Fig. 8. Indices of change in deer processing between Bridge River 2 and 3 periods.
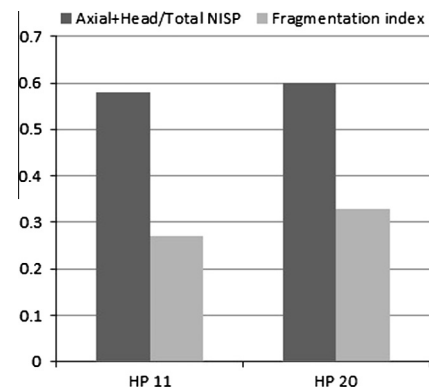

Fig. 10. Deer element processing indices for two housepits during Bridge River 2 period.

within the site. Perhaps not coincidentally this was also the wealthiest house in the village so far identified (Prentiss et al., 2012a).

The ancient DNA analysis derived from HP 24 coprolites suggests that there were two mtDNA lineages represented, similar to that seen in other Mid-Fraser villages and on the Northwest Coast (Yang et al., 2010). Isotopic analysis of dog remains and ancient DNA analysis of bones within coprolites confirm that HP 24 dog diets were dominated by sockeye salmon, likely similar to their human owners (Cail, 2011; Cail et al., 2010; Yang et al., 2010). Canid remains from HP 24 represent an MNI of two and consist of a single cranium (missing the maxilla and zygomatic areas), atlas and axis vertebrae, caudal vertebrae, rib portions, innominate, humerus,

femur, radius, ulna, tibia, fibula, and nearly complete representation of lower limb elements. A number of elements were found articulated including the atlas-axis, the right hip, and some paws. Both dogs were no older than three years old and at least one of them was female (Cail, 2011).

A variety of possible (e.g. Pechnikova et al., 2011) perimortem trauma were recognized including spiral fractures to both humeri, fracturing to the fourth right metacarpal, the right mandibular coronoid process, the ulna, and the pubic symphysis, and finally, likely cut marks to the medial aspect of the left mandible. Several of these elements also had evidence for carnivore gnawing. Preliminary assessment by Cail (2011) suggests the possibility of a scenario involving execution and post-mortem dismemberment. Minimally,
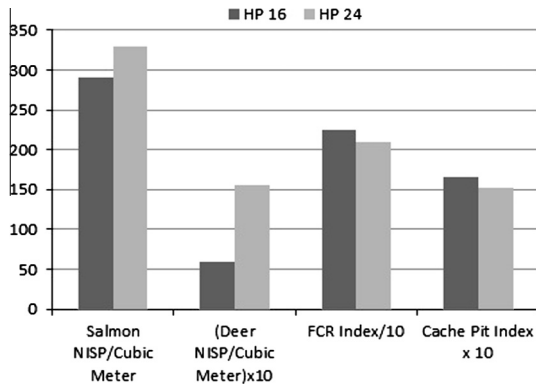
Fig. 11. Indicators of variability in subsistence and relative demographic consistency between households during Bridge River 3 times.
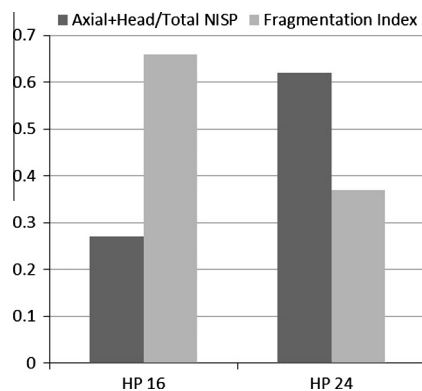

Fig. 12. Deer element processing indices for two housepits during Bridge River 3 period.

we can confidently say the dog remains from Housepit 24 resulted from death events closely spaced in time, followed by limited post-mortem processing by humans and subsequent ravaging by other dogs prior to deposition in two adjacent pits. There is no evidence for collection of marrow or bone grease as would be otherwise typical of medium mammal consumption in the Mid-Fraser villages.

All told, the Housepit 24 canid remains raise the possibility that household dogs were sometimes executed and butchered for immediate consumption as is consistent with ethnographic descriptions of Mid-Fraser traditional feasting (Kennedy and Bouchard, 1978; Lamb, 1966). Similar evidence was recovered from Housepit 7 at Keatley Creek from about the same date (ca. 1250 cal. B.P.) whereby remains consisting of cranial and lower limb parts from a young dog were discarded in an exterior fire pit along with disparate elements from bighorn sheep, mountain goat, beaver, and salmon (Prentiss et al., 2003). The combined evidence from Bridge River of concentrated numbers of canid remains and canid coprolites in one wealthy house implies that dogs may have been a managed food resource, perhaps sometimes consumed at special events. Further, given the relatively large number of deer elements in Housepit 24, dogs may also have been effective partners in the hunting process (e.g. Koster, 2008) giving this house added advantage over others less well organized (e.g. Housepits 16, 20, and 54).

Managing dogs in the Middle Fraser Canyon

If dogs were husbanded in a way perhaps analogous to that of some livestock herds then there should be recognizable signatures of this practice in the life histories of Bridge River dog populations (Cail, 2011). Reconstruction of life histories can be accomplished

using Life Tables (e.g. Lovejoy et al., 1977). While it is ideal to draw the target population from a single village, this is not possible in the Mid-Fraser context given small intra-village sample sizes. Consequently it was necessary to develop a life table drawing data on 30 dogs from six Mid-Fraser villages (including Bridge River and Keatley Creek) occupied during the general period of interest. Given the small sample size, conclusions are preliminary pending development of additional data (see Cail, 2011 for details of the analysis).

Four curves were defined illustrating aspects of the demography of prehistoric dog populations in the Mid-Fraser ca. 1000–1500. B.P. (Table 4; Fig. 13). The Death Curve (Fig. 13A) represents percentages of death at each age interval and suggests increased risk of death for dogs in the range of 8 months to two years. These data permit us to calculate a mean age at death of 2.62, a relatively young age compared to maximum age (about 10 years) implying a relatively high birth rate. Survivorship (Fig. 13B) starts at 100% since all individuals born are represented in the sample. The curve indicates increased mortality rates after one year of age and a brief reduction in rates at 6–8 years. Probability of Death (Fig. 13C) reflects the outcomes illustrated in the Death and Survivorship Curves. The probability of death rises after .5 years and achieves its maximum at about 3–4 years. Probability of death at 8+ is 100%. The Life Expectancy Curve (Fig. 13D) is approximately inverse to the Death Curve and indicates that if dogs survived past one year their life expectancy increased up to six years.

Although preliminary, these data suggest that dogs had a managed life cycle in the Mid-Fraser villages. It is clear that culling typically occurred between about .5 and 2 years and if the dogs survived this period they had the potential to live much longer lives of up to 6–10 years. This implies two roles for dogs: one as a food source as in the possible scenario at Housepit 24; the other as long-lived household companions and workers. Data are insufficient at this point to evaluate the role of sex-based decisions in dog culling. Crockford (1997) recognizes similar life histories among Makah and Coast Salish dog populations that also include a skew towards older males over older females suggesting that older females were culled to limit populations. It is interesting in this context that at least one of the HP 24 butchered dogs was likely female.

Did storage practices change at Bridge River?

So far, we have outlined several potential sources of insight into relationships between demographics, subsistence, and social change at Bridge River. However, we have not formally reviewed the evidence for variability in storage practices and considered

Table 4
Mid-Fraser dog life table matrix.

X	Dx	dx	lx	qx	Lx	Tx	ex	cx
0	3	0.1000	1.0000	0.1000	0.2375	2.3292	2.3292	0.2375
0.25	4	0.1333	0.9000	0.1481	0.2083	2.0917	2.3241	0.2315
0.5	0	0.0000	0.7667	0.0000	0.3833	1.8833	2.4565	0.5000
1	8	0.2667	0.7667	0.3478	0.3167	1.5000	1.9565	0.4130
1.5	4	0.1333	0.5000	0.2667	0.2167	1.1833	2.3667	0.4333
2	6	0.2000	0.3667	0.5455	0.5333	0.9667	2.6364	1.4545
4	3	0.1000	0.1667	0.6000	0.2333	0.4333	2.6000	1.4000
6	0	0.0000	0.0667	0.0000	0.1333	0.2000	3.0000	2.0000
8+	2	0.0667	0.0667	1.0000	0.0667	0.0667	1.0000	1.0000
10	0	0.0000	0.0000	0.0000	0.0000	0.0000	3.0000	0.0000
	30				2.3292			7.6699

Age (X); number of individuals at these ages (Dx); age specific probability at death (dx); total years lived (lx); age specific probability at death (qx); total years lived (Lx); total years to be lived (Tx); life expectancy (ex); proportion of the population alive in the age intervals (cx).
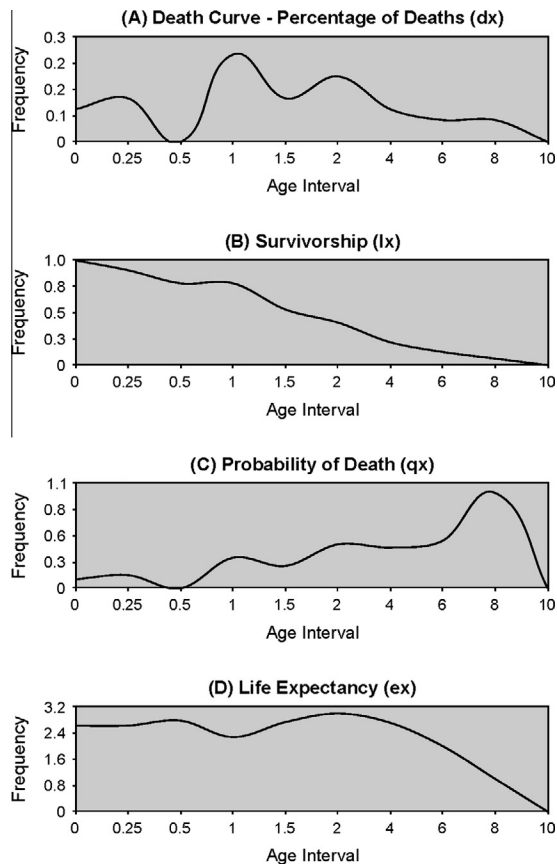
Fig. 13. Mid-Fraser dog-life table curves.

collections of salmon heads, and a healthy resident population of dogs dining on salmon in Housepit 24 probably implies a household with abundant access to critical protein and fat/carbohydrate sources. In contrast, Housepit 16 had virtually no salmon head parts, a few heavily processed deer bones and a similarly low number of canid remains implying a household struggling to supply critical nutrients to its members. Not surprisingly, Housepit 16 was abandoned early enough in the BR3 period that a large meat/fish roasting oven was constructed in its collapsed roof deposits, likely by an adjacent household.

Dogs had long been kept in Bridge River households, albeit at low numbers, until BR 3 times. If our life history graphs are accurate and if only select BR 3 houses could afford larger populations of dogs, husbandry of dogs emerged as a viable socio-economic strategy for providing a ready supply of special food for feasts, as an aid in hunting, and as a beast of burden for transporting other subsistence items in abundant quantity to feed the household and guests in wealthier pithouses. This opens up the possibility that groups of dogs may have been investments in and of themselves and that they could have even been provided to other houses as loans and gifts much like pigs in New Guinea (e.g. Wiessner, 2002).

Discussion

Demography and Bridge River

Scholars of human demography draw a distinction between benign or optimal population-resource equilibria and true Malthusian equilibria or ceilings (Wood, 1998). At the optimal ceiling we recognize stable periods of maximum population where resource base is not degraded. We pointed out that while this state may not have been common in many contexts; there could have been exceptions as in the case of stable hunter–gatherer societies where mobility and birth control were options for coping with fluctuating access to food resources. There have been occasionally documented examples of this in agricultural contexts as in the case of the Polynesian Island, Tikopia, where demographic stability was made possible without significant economic misery via an agricultural system that did not degrade the land base and an enforced system of population leveling via celibacy, abortion, infanticide, and emigration (Green and Green, 2007; Kirch, 1997). In significant contrast, truly Malthusian ceilings are associated with situations where population growth is less specifically "managed" and access to food declines for many or all. It is not hard to find examples of this scenario, particularly in the literature of Polynesia and other island contexts (e.g. Mangaia [Kirch, 1997]; see also Kennett et al., 2009; Winterhalder et al., 2010) and indicators can include decline in critical foods relative to population density, expansion of storage as an attempt to overcome expected shortage, altered food sharing arrangements, increased violence, and potentially, investment in technologies to overcome shortage. Theoretical demographers note that loss of non-workers (e.g. very young children and the most elderly and infirm) can ease food-associated misery via access to more food resources. But, continued demographic loss of prime aged adults can be catastrophic over the longer term, though it is possible that truly large scale reduction could open land and ease subsistence restrictions in important ways for survivors.

Our analysis of radiocarbon dates at Bridge River suggested that the village experienced two periods of demographic equilibrium. The first, associated with the BR 2 period, featured the establishment of up to 17 occupied houses arranged in two groups, though only the northern group formed an obviously semi-circular arrangement implying some kind of integrated social group.

their relationships with demographic factors and social change. Critical points are as follows: First, there is virtually no evidence for variability in storage capacity, measured as cache pit volume, correlating with access to wealth items. Rather, cache pit volume is more likely associated with numbers of household occupants. Wealthy (HP 24) and relatively poor (HP 16) houses have virtually identical scores on cache pit volume and FCR density (Table 3; Fig. 11). Drawing from Winterhalder et al. (2012), we recognize that our measures of storage volume are likely of maximum capacity and that inter-annual storage mass (and the group it could have supported) may have varied to some unknown degree. Second, faunal remains indicate that all households had access to both fish and ungulates. However, by BR 3 times, houses with reduced access to artifacts considered to be potential wealth markers (Prentiss et al., 2012a) also had reduced access to ungulates and when these resources did become available, apparently invested greater labor in fat processing. This could imply additional shortages in fats and/or carbohydrates. Interestingly, it is only Housepit 24 that has large numbers of salmon head elements clustered in a single cache/refuse pit on its single floor that we now think is linked to feasting (Prentiss et al., 2012b). Third, evidence from canid remains suggests that dogs may have been a managed resource in which larger numbers of dogs were kept by wealthier households in BR3 times (e.g. HP 24 [Prentiss et al., 2012a]) and sometimes killed and consumed during specific events.

There is no evidence for change in storage technology or development of new domesticated food sources during the transition to wealth-based inequality. Rather, house groups made use of existing technologies to better themselves or at least attempt to maintain parity. Some things did change however. Access to some crucial food sources for some was reduced while there was improvement for others. Minimally processed deer bones,

Subsistence data suggest a close relationship between household occupational density and corresponding densities of food remains as measured by frequencies of salmon and deer bones. Processing indices do not implicate a high degree of food stress; deer appear to have been routinely acquired at distances close enough to the village that entire (or nearly so) animals could be transported for within-village processing and salmon appear to have been abundant. There is little in the record of artifact types and lithic raw materials to suggest significant inter-household differentiation (Prentiss et al., 2012a). Populations approximately doubled at the advent of BR 3, manifested in two arc-like or ring shaped arrangements of houses. During the occupation span of BR 3, some houses were abandoned and reused as roasting oven features (e.g. Housepit 16) and by the end of BR 3 the entire village was abandoned. Current data on BR 3 subsistence and demographics suggests densely packed houses (much like BR 2), but with declining access to the keystone food sources, salmon and deer. Despite a general pattern of subsistence reductions, some households developed distinctive patterns of affluence as at Housepit 24 where we uncovered markers of material wealth (frequent beads, nephrite tools, etc.), a large collection of deer remains, abundant salmon, a cache pit filled with salmon heads and other indicators of feasting.

While per-capita investment in storage facilities did not apparently change across the BR 2 to 3 transition, there was a shift in the use of dogs. By BR 3 times it is clear that select affluent houses had the capability of husbanding larger numbers of dogs than other households. The Housepit 24 data indicate that some young dogs were killed and consumed possibly on special occasions. All together, these data suggest that during BR 3, dogs had become investments in several ways. Ethnographies tell us that Mid-Fraser people used dogs when hunting (Alexander, 1992) and recent ethnoarcheological research elsewhere informs us that dogs can increase the likelihood of hunting success associated with medium to larger sized game (Koster, 2008). Dogs were also very useful as pack animals for hauling meat and plant foods for foraging locales (Alexander, 1992; Crellin, 1994). Some dogs were raised as fur bearers by Salish speaking groups (Solazzo et al., 2011) and stone spindle whorls found at Bridge River could endorse this view. Finally, dogs could be consumed either in feasting contexts or as back-up when other foods failed. In essence, dogs helped to insure hunting and gathering success and in and of themselves, were a form of food storage much like other examples of animal husbandry. However, while management of comparatively large packs of dogs by select houses may have brought short term success, it was apparently not a strategy that could change the downward subsistence and demographic slide associated with late BR 3. We suggest that the cost of managing large numbers of dogs may simply have been too high, as current evidence suggests that dogs ate salmon (Yang et al., 2010) and a household had to have enough salmon to feed its own members throughout the year (including poor salmon productivity years) and still have enough to cover the dogs as well. For most BR 3 households, this was likely impossible, particularly in late winter (e.g. Alexander, 1992:157).

All data considered, BR 2 may reflect a short-lived optimum, though it is also possible that just prior to the BR 3 population jump there could have been aspects of a Malthusian ceiling. Radiocarbon date modeling indicates a reduction in occupation rates between ca. 1425 and 1300 cal. B.P. (Fig. 6). Unfortunately, we do not have adequate data at this time to explore this possibility. However, it is abundantly clear to us that once Bridge River populations hit the BR 3 peak and began to decline, the village had entered into a true Malthusian ceiling. The jump to BR 3 population levels does not appear to have been triggered by a Boserup (1965) style pattern of subsistence intensification brought on by technological change or shifts in land use. The only changes in foraging we can recognize are longer distance travel to obtain some foods (e.g.

deer) and this occurred as a process during BR 3 not as the cause of BR 3 patterns. This leaves us with the possibility that the spike in populations at ca. 1250–1300 cal. B.P. were associated with an equivalent jump in food resources, especially anadromous salmon, and this may have been directly related to a similar short-lived spike in marine productivity that was followed by centuries of sub-average production (Finney et al., 2002; Tunnicliffe et al., 2001). We propose that the abandonment of Bridge River and subsequent abandonments of the other Mid-Fraser villages was the result of a run-away demographic cycle. Burgeoning Mid-Fraser populations at ca. 1200–1300 cal. B.P. may have overshot productivity of their environment associated with a simultaneous decline in salmon numbers causing an initial series of demographic losses that compounded with each poor salmon year. Drawing data from the Keatley Creek site and nearby Hat Creek Valley, Kuijt and Prentiss (2004; see also Prentiss et al., 2007) argue that rapidly rising populations could have over-exploited geophyte and deer populations causing local groups to work hard to maintain parity via landscape extensification. The eventual outcome was a substantial dispersal and/or loss of Mid-Fraser populations and an opportunity for survivors to eventually rebuild under conditions of reduced demographic constraints. However, this would take some time as salmon numbers likely remained annually unpredictable and generally low throughout the Medieval Warm period (Finney et al., 2002). Interestingly, numbers of root roasting ovens in the nearby Upper Hat Creek Valley rise precipitously during the demographic low following the abandonment of the large villages (Lepofsky and Peacock, 2004) implicating the continued presence of small groups intensifying a different resource during the period of weak salmon returns.

One byproduct of the ceiling was the development of wealth-based inequality. It is clear that the pattern of inequality was not triggered by any major technological changes or expansions in per capita storage. Rather, it appears to have come as a consequence of households changing the rules of food sharing and consumption under stressful conditions. It is possible that there may have been a very short-lived period of unprecedented good times at the BR 2 to 3 transition period. These conditions permitted rapid demographic growth and fissioning in houses. New houses were established while older social and kinship-based groupings were likely maintained. Thus, the BR 3 village was a larger and more formalized version of the earlier one in BR 2 times. Within this framework, new houses came into being with varying degrees of incipient advantage or disadvantage based upon social relationships established by their immediate ancestors (e.g. Teit, 1906). When salmon and deer numbers declined across the region, households did what they had to do to insure survival. This probably meant drawing upon those established networks, closing off some open access places for hunting and fishing, and signaling success with events such as feasts partially as a means of attracting workers as a way to overcome losses in bad years (e.g. Ames, 2006).

Wider implications

Gaining a precise understanding of relationships between food production, storage, consumption needs, surplus, and social change is clearly a challenging enterprise. Archaeologists working in the Middle Fraser have operated from a set of general assumptions regarding seasonal access to storable food resources and their potential to support large numbers of people in all but the most catastrophic years (e.g. Hayden, 1992). However, when we begin to break down these assumptions for purposes of modeling subsistence and demographics the path to knowledge becomes somewhat foggy. For our purposes, we had to make a number of assumptions regarding returns and subsistence needs associated with Mid-Fraser salmon. It is difficult to estimate the percentage

of fish harvested in a given seasonal cycle and it is perhaps just as hard to determine how much could have been lost to bears, insects, spoilage, raiding, and other factors before consumption. While we will probably never know actual percentages of fish harvested from rivers of the Pacific Northwest, we could develop better estimates of food loss with well designed actualistic experiments.

These issues aside, our simple modeling exercise and subsequent archeological analysis offers a number of implications for understanding emergence and decline of village scale societies and associated social transformations. Our study supported a number of predictions drawn from theoretical demographic models, namely that population rise is correlated with increasing subsistence resource productivity, short-lived demographic optima can be achieved, and true Malthusian ceilings do result from population/resource imbalance, potentially within one to two generations. Further, many predicted characteristics of a society at the Malthusian ceiling are recognized, though not all so far. Decline in food relative to household occupation density is clearly evident as is change in differential household wealth and uses of food. In contrast, there is virtually no evidence that households engaged in any formal expansions in storage facilities to offset anticipated short periods. It is possible that storage of plant foods such as processed berries and geophytes could have expanded in weak salmon years as these were generally not kept in pits but in boxes and strung on sticks and strings, which would not be recognizable in archeological contexts (Lepofsky and Peacock, 2004; Turner, 1992). However, even if geophyte and berry storage could be expanded, it would not likely have offered enough extra food to compensate for catastrophically low salmon returns in societies so dependent upon this resource. Catastrophic salmon returns during ceiling periods could also have triggered raiding and other forms of violence but there is very little direct evidence for an expansion in violence or warfare in the Mid-Fraser during BR 3 times (but see Sakaguchi et al., 2008).

We have argued that wealth-based social inequality developed as a by-product of competition between networked households once population size peaked during the BR 2 to 3 transition period. It was probably facilitated by groups laying claim to rights of first access to portions of foraging and fishing landscapes and then maintaining the labor force to efficiently exploit those resources before others were permitted access. It was clearly not facilitated by any centralized expansion or control of storage facilities or innovations in the nature of storage. Thus, this study backs findings of some other scholars working on Neolithic societies elsewhere in the world (e.g. Barier, 2011; Kuijt et al., 2011) that it is control or at least manipulation of production that is most important in the development of social inequalities. This is perhaps best reflected in our canid data whereby it is clear that newly wealthy households could maintain larger numbers of dogs in contrast to most other households that evidently had few to none.

Our conclusion that overt competition and subsequent archeologically-measurable inequality occur within Malthusian ceiling periods provides insight to help us better understand other sequences in the North Pacific region. Archaeologists of the Northwest Coast would significantly benefit from a formal analysis of Marpole and early Gulf of Georgia phase demographics and social change as it is evident that patterns of village growth and decline played a role in the establishment of hereditary inequalities during the period of ca. 2000–1000 cal. B.P. (Lepofsky et al., 2005; Matson and Coupland, 1995). Likewise, the late Kachemak phase of the Gulf of Alaska (Fitzhugh, 2003), dated to ca. 1500–800 cal. B.P., would be better understood with a formal analysis of demographics, resource conditions, violence, and social change. We do not think it coincidental that Mid-Fraser socio-economic, political and demographic change occurred in these same time frames, especially given their common reliance on salmon populations,

winter storage practices, and kin-based social alliances. It may well be that socio-economic flux and demographic declines recognized in both the former cases were directly associated with dynamics of Malthusian ceilings.

References

Alexander, D., 1992. Prehistoric land use in the mid-Fraser area based on ethnographic data. In: Hayden, B. (Ed.), A Complex Culture of the British Columbia Plateau. University of British Columbia Press, Vancouver, pp. 99–176.

Ames, K.M., 2006. Thinking about household archaeology on the northwest coast. In: Sobel, E.A., Gahr, D.A.T., Ames, K.M. (Eds.), Household Archaeology on the Northwest Coast. International Monographs in Prehistory Archaeological Series, vol. 16, Ann Arbor, pp. 16–36.

Bandy, M.S., Fox, J.R. (Eds.), 2010. Becoming Villagers: Comparing Early Village Societies. University of Arizona Press, Tucson.

Barier, C.R., 2011. Storage and relative surplus at the Mississippian site of Moundville. Journal of Anthropological Archaeology 30, 206–219.

Benson, A.J., Trites, A.W., 2002. Ecological effects of regime shifts in the Bering Sea and Eastern Pacific Ocean. Fish and Fisheries 3, 95–113.

Binford, L.R., 1968. Post-Pleistocene adaptations. In: Binford, S.R., Binford, L.R. (Eds.), New Perspectives in Archeology. Aldine Publishing Co., Chicago, pp. 313–341.

Bocquet-Appel, J.-P., 2002. The paleoanthropological traces of the neolithic demographic transition. Current Anthropology 43, 638–650.

Bocquet-Appel, J.-P., Dubouloz, J., 2004. Expected paleoanthropological and archaeological signal from a neolithic demographic transition on a worldwide scale. Neolithic Studies 10, Documenta Prehistorica 31, 25–33.

Bocquet-Appel, J.-P., Naji, S., 2006. Testing the hypothesis of a worldwide Neolithic demographic transition: corroboration from American Cemeteries. Current Anthropology 47, 341–366.

Boone, J.L., 1998. The evolution of magnanimity: when it is better to give than to receive? Human Nature 9, 1–21.

Boserup, E., 1965. The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure. Aldine, Chicago.

Broughton, J.M., 1994. Late Holocene resource intensification in the Sacramento River Valley: the vertebrate evidence. Journal of Archaeological Science 21, 501–514.

Cail, H.S., 2011. Feasting on Fido: Cultural Implications of Eating Dogs at Bridge River. M.A. Thesis, Department of Anthropology, The University of Montana, Missoula.

Cail, H.S., Prentiss, A.M., Richards, M.P., 2010. Cultural implications of the dog remains at the Bridge River site: Taphonomic and isotopic analyses. Poster presented at the 75th Meeting of the Society for American Archaeology, St. Louis MO.

Casti, J.L., 1990. Searching for Certainty: What Scientists Know about the Future. W. Morrow, New York.

Clark, J., Blake, T.M., 1994. The power of prestige: competitive generosity and the emergence of rank societies in Lowland Mesoamerica. In: Brumfiel, E., Fox, J. (Eds.), Factional Competition and Political Development in the New World. Cambridge University Press, Cambridge, pp. 17–30.

Cohen, N., 1981. Pacific Coast Foragers: Affluent or Overcrowded. Senri Ethnological Studies 9, 275–295.

Coupland, G.G., 1988. Prehistoric Cultural Change at Kitselas Canyon. Canadian Museum of Civilization, Mercury Series, Archaeological Survey of Canada Paper No. 138, Ottawa.

Crellin, D.F., 1994. Is there a Dog in the House: The Cultural Significance of Prehistoric Domesticated Dogs in the Mid-Fraser River Region of British Columbia. M.A. Thesis, Department of Archaeology, Simon Fraser University, Burnaby, B.C.

Crockford, S.J., 1997. The Osteometry of Makah and Coast Salish Dogs. Archaeology Press, Simon Fraser University, Burnaby, BC.

Croes, D.R., Hackenberger, S., 1988. Hoko river archaeological complex: modeling prehistoric northwest coast economic evolution. In: Isaac, B.L. (Ed.), Research in Economic Anthropology: Prehistoric Economies of the Pacific Northwest Coast. JAI Press, Greenwich, CT, pp. 19–86.

Finney, B.P., Gregory-Eaves, I., Douglas, M.S.V., Smol, J.P., 2002. Fisheries productivity in the Northeastern Pacific ocean over the past 2200 years. Nature 416, 729–733.

Fitzhugh, B., 2003. The Evolution of Complex Hunter–Gatherers: Archaeological Evidence from the North Pacific. Kluwer/Plenum, New York.

Goodale, N.B., Kuijt, I., Prentiss, A.M., 2008. Demography of prehistoric fishing–hunting people: a case study of the upper Columbia area. In: Bocquet-Appel (Ed.), Recent Advances in Paleodemography: Data, Techniques, and Patterns. Springer-Verlag, New York, pp. 179–207.

Green, V.J., Green, R.C., 2007. An accent on atolls in approaches to population histories of remote Oceania. In: Kirch, P.V., Rallu, J.-L. (Eds.), The Growth and Collapse of Pacific Island Societies. University of Hawai'I Press, Honolulu, pp. 232–256.

Hay, M.B., Dallimore, A., Thomson, R.E., Calvert, S.E., Pienetz, R., 2007. Siliceous microfossil record of late Holocene oceanography and climate along the west coast of Vancouver Island, British Columbia (Canada). Quaternary Research 67, 33–49.

Hayden, B., 1981. Research and development in the stone age: technological transitions among hunter–gatherers. Current Anthropology 22, 519–548.

Hayden, B., 1992. Introduction: ecology and culture. In: Hayden, B. (Ed.), A Complex Culture of the British Columbia Plateau: Traditional Stal'at'imx Resource Use. University of British Columbia Press, Vancouver, pp. 3–46.

Hayden, B., 1994. Competition, labor, and complex hunter–gatherers. In: Burch, E.S., Ellana, L.J. (Eds.), Key Issues in Hunter Gatherer Research. Berg Press, Oxford, pp. 223–239.

Hayden, B., 1997. The Pithouses of Keatley Creek. Harcourt Brace College Publishers, Fort Worth.

Hayden, B., Ryder, J., 1991. Prehistoric cultural collapse in the Lillooet area. American Antiquity 56, 50–65.

Hegmon, M., 1991. The risks of sharing and sharing as risk reduction: interhousehold food sharing in egalitarian societies. In: Gregg, S.A. (Ed.), Between Bands and States. Center for Archaeological Investigations, Occasional Paper No. 6, Southern Illinois University, pp. 309–329.

Howell, N., 1986. Feedbacks and buffers in relation to scarcity and abundance: studies of hunter–gatherer populations. In: Coleman, D., Schofield, R. (Eds.), The State of Population Theory: Forward from Malthus. Basil Blackwell, New York, pp. 156–187.

Ingold, T., 1983. The significance of storage in hunting societies. Man 18, 553–571.

Janetski, J.C., 1997. Fremont hunting and resource intensification in the eastern Great Basin. Journal of Archaeological Science 24, 1075–1088.

Kennedy, D.I.D., Bouchard, R., 1978. Fraser river Lillooet: an ethnographic summary. In: Stryd, A., Lawhead, S. (Eds.), Reports of the Lillooet Archaeological Project. Number 1. Introduction and Setting, National Museum of Man, Mercury Series, Archaeological Survey of Canada Paper No. 73, Ottawa, pp. 22–55.

Kennedy, D.I.D., Bouchard, R., 1992. Stl'átl'imx (Fraser River Lillooet) fishing. In: Hayden, B. (Ed.), A Complex Culture of the British Columbia Plateau. University of British Columbia Press, Vancouver, pp. 266–354.

Kennett, D., Winterhalder, B., Bartruff, J., Erlandson, J.M., 2009. An ecological model for the emergence of institutionalized social hierarchies on California's Northern Channel Islands. In: Shennan, S. (Ed.), Pattern and Process in Cultural Evolution. University of California Press, Berkeley, pp. 297–314.

Kew, M., 1992. Salmon availability, technology, and cultural adaptation in the Fraser River watershed. In: Hayden, B. (Ed.), A Complex Culture of the British Columbia Plateau. University of British Columbia Press, Vancouver, pp. 177–221.

Kirch, P.V., 1984. The Evolution of Polynesian Chiefdoms. Cambridge University Press, Cambridge.

Kirch, P.V., 1997. Microcosmic histories: island perspectives on "Global" change. American Anthropologist 99, 30–42.

Kirch, P.V., Rallu, J.-L., 2007. The Growth and Collapse of Island Societies: Archaeological and Demographic Perspectives. University of Hawai'I Press, Honolulu.

Kirch, P.V., Asner, G., Chadwick, O.A., Field, J., Ladefoged, Lee., Ladefoged, Lee, C., Puleston, C., Tuljapurkar, S., Vitousek, P.M., 2012. Building and testing models of long-term agricultural intensification and population dynamics: a case study from the Leeward Kohala Field System, Hawai'i. Ecological Modelling 227, 18–28.

Koster, J., 2008. Hunting with dogs in Nicaragua: an optimal foraging approach. Current Anthropology 49, 935–944.

Kuijt, I., 2000. People and space in early agricultural villages: exploring daily lives, community size, and architecture in the late Pre-Pottery Neolithic. Journal of Anthropological Archaeology 19, 75–102.

Kuijt, I., 2001. Reconsidering the cause of cultural collapse in the Lillooet area of British Columbia: a geoarchaeological perspective. American Antiquity 66, 692–703.

Kuijt, I., Prentiss, W.C., 2004. Villages on the edge: Pithouses, cultural change, and the abandonment of aggregate Pithouse villages. In: Prentiss, W.C., Kuijt, I. (Eds.), Complex Hunter–Gatherers: Evolution and Organization of Prehistoric Communities on the Plateau of Northwestern North America. University of Utah Press, Salt Lake City, pp. 155–170.

Kuijt, I., Guerrero, E., Molist, M., Anfruns, J., 2011. The changing Neolithic household: household autonomy and social segmentation, Tell Halula, Syria. Journal of Anthropological Archaeology 30, 502–522.

Lamb, W.K. (Ed.), 1966. Simon Fraser: Letters and Journals, 1806–1808. MacMillan, Toronto.

Langemann, E.G., 1987. Zooarchaeology of the Lillooet region, British Columbia. M.A. Thesis, Department of Archaeology, Simon Fraser University, Burnaby, B.C.

Lee, R.D., 1986. Malthus and Boserup: a dynamic synthesis. In: Coleman, D., Schofield, R. (Eds.), The State of Population Theory: Forward from Malthus. Basil Blackwell, New York, pp. 96–130.

Lee, R.D., 1993. Accidental and systematic change in population history: homeostasis in a stochastic setting. Explorations in Economic History 30, 1–30.

Lee, C.T., Tuljapurkar, S., 2008. Population and prehistory I: food dependent population growth in constant environments. Theoretical Population Biology 73, 473–482.

Lee, C.T., Puleston, C.O., Tuljapurkar, S., 2009. Population and prehistory III: food-dependent demography in variable environments. Theoretical Population Biology 76, 179–188.

Lenert, M., 2001. Calibrated radiocarbon dates and culture change: Implications for socio-complexity in the mid-Fraser region, British Columbia. Northwest Anthropological Research Notes 35, 211–228.

Lepofsky, D., Peacock, S.L., 2004. A question of intensity: exploring the role of plant foods in northern plateau prehistory. In: Prentiss, W.C., Kuijt, I. (Eds.), Complex Hunter–Gatherers: Evolution and Organization of Prehistoric Communities on the Plateau of Northwestern North America. University of Utah Press, Salt Lake City, pp. 115–139.

Lepofsky, D., Hallett, D., Lertzman, K.P., Mathewes, R., 2005. Climate change and culture change on the southern coast of British Columbia 2400–1200 B.P. American Antiquity 70, 267–294.

Lovejoy, C.O., Meindi, R.S., Pryzbeck, T.R., Barton, T.S., Heiple, K.G., Kotting, D., 1977. The paleodemography of the Libben site; Ottawa County, Ohio. Science 198, 291–293.

Malthus, T.R., 1976 (1778). An Essay on the Principle of Population. W.W. Norton and Co., New York.

Matson, R.G., 1983. Intensification and the development of cultural complexity: the northwest versus northeast coast. In: Nash, R. (Ed.), The Evolution of Maritime Cultures on the Northeast and Northwest Coasts, Simon Fraser University Department of Archaeology Publication No. 11, Burnaby.

Matson, R.G., Coupland, G., 1995. The Prehistory of the Northwest Coast. Academic Press, San Diego.

Patterson, R.T., Prokoph, A., Kumar, A., Chang, A.S., Roe, H.M., 2005. Late holocene variability in pelagic fish scales and Dinoflagellate cysts along the west coast of Vancouver Island, NE Pacific Ocean. Marine Micropaleontology 55, 183–204.

Pechnikova, M., Porta, D., Cattaneo, C., 2011. Distinguishing between Perimortem and Postmortem fractures: are Osteons any help? International Journal of Legal Medicine 125, 591–595.

Pianka, E., 1974. Evolutionary Ecology. Harper and Row, New York.

Pieloe, E.C., 1977. Mathematical Ecology. Wiley Interscience, New York.

Prentiss, A.M., Kuijt, I., 2012. People of the Middle Fraser Canyon: An Archaeological History. University of British Columbia Press, Vancouver.

Prentiss, W.C., Lenert, M., Foor, T.A., Goodale, N.B., Schlegel, T., 2003. Calibrated radiocarbon dating at Keatley Creek: the chronology of occupation at a complex hunter–gatherer community. American Antiquity 68, 719–735.

Prentiss, A.M., Lyons, L., Harris, L.E., Burns, M.R.P., Godin, T.M., 2007. The emergence of status inequality in intermediate scale societies: a demographic and socio-economic history of the Keatley Creek site, British Columbia. Journal of Anthropological Archaeology 26, 299–327.

Prentiss, A.M., Cross, G., Foor, T.A., Markle, D., Hogan, M., Clarke, D.S., 2008. Evolution of a late prehistoric winter village on the interior plateau of British Columbia: geophysical investigations, radiocarbon dating, and spatial analysis of the bridge river site. American Antiquity 73, 59–82.

Prentiss, A.M., Smith, L., Reininghaus, L., Schirack, M., Wanzenried, M., Ward, O., 2010. Report of the 2009 University of Montana Investigations at the Bridge River Site (EeRl4). Report on File, National Science Foundation and Bridge River Band, Lillooet, B.C. <http://www.cas.umt.edu/casweb/for_faculty/FacultyDetails.cfm?id=518> (accessed February 2013).

Prentiss, A.M., Chatters, J.C., Lyons, N., Harris, L.E., 2011. Archaeology of the middle Fraser Canyon, British Columbia: changing perspectives on paleoecology and emergent cultural complexity. Canadian Journal of Archaeology 35, 143–174.

Prentiss, A.M., Foor, T.A., Cross, G., Harris, L.E., Wanzenried, M., 2012a. The cultural evolution of material wealth based inequality at Bridge River, British Columbia. American Antiquity 77, 542–565.

Prentiss, A.M., Smith, L., Barnett, K., Walsh, M., Carlson, E., 2012. Assessing variability in salmon processing, storage, and consumption at Bridge River, British Columbia. Paper presented at the 77th Annual Meeting of the Society for American Archaeology, Memphis.

Puleston, C.O., Tuljapurkar, S., 2008. Population and prehistory II: space limited human populations in constant environments. Theoretical Population Biology 74, 147–160.

Puleston, C., Tuljapurkar, S., Winterhalder, B., 2012. Population Ecology and Prehistory I: Abrupt Imposition of Malthusian Equilibrium in a Natural Fertility, Agrarian Society. Manuscript in possession of authors.

Romanoff, S., 1992a. Fraser Lillooet salmon fishing. In: Hayden, B. (Ed.), A Complex Culture of the British Columbia Plateau. University of British Columbia Press, Vancouver, pp. 222–265.

Romanoff, S., 1992b. The cultural ecology of hunting and potlatches among the Lillooet Indians. In: Hayden, B. (Ed.), A Complex Culture of the British Columbia Plateau. University of British Columbia Press, Vancouver, pp. 470–505.

Sakaguchi, T., Morin, J., Dickie, R., 2008. Defensibility of large prehistoric sites in the Mid-Fraser region on the Canadian Plateau. Journal of Archaeological Science 37, 1171–1185.

Sheppard, J., Muir, R., 2010. "Oh I've seen one way bigger than that!" current research on Housepit settlement patterns in the Mid-Fraser Region of B.C. The Midden 42, 3–8.

Solazzo, C., Heald, S., Ballard, M.W., Ashforth, D.A., DePriest, P.T., Koestler, R.J., Collins, M.J., 2011. Proteomics and Coast Salish blankets: a tale of shaggy dogs. Antiquity 85, 1418–1432.

Teit, J., 1900. The Thompson Indians of British Columbia. Memoirs of the American Museum of Natural History, Jesup North Pacific Expedition 1, 63–392.

Teit, J., 1906. The Lillooet Indians. Memoirs of the American Museum of Natural History, Jesup North Pacific Expedition 2, 193–300.

Testart, A., 1982. The significance of food storage among hunter–gatherers: residence patterns, population densities, and social inequalities. Current Anthropology 23, 523–538.

Tunnicliffe, V., O'Connell, J.M., McQuoid, M.R., 2001. A Holocene record of marine fish remains from the Northeastern Pacific. Marine Geology 174, 197–210.

Turner, N.J., 1992. Plant resources of the Stl'átl'imx (Fraser River Lillooet) people: a window into the past. In: Hayden, B. (Ed.), A Complex Culture of the British Columbia Plateau. University of British Columbia Press, Vancouver, pp. 405–469.

Tyhurst, R., 1992. Traditional and contemporary land and resource use by Ts'kwalaxw and Xaxli'p bands. In: Hayden, B. (Ed.), A Complex Culture of the British Columbia Plateau: Traditional Stal'at'imx Resource Use. University of British Columbia Press, Vancouver, pp. 355–404.

Weninger, B., Jöris, O., 2003. A ¹⁴C calibration curve for the last 60 ka: the Greenland-Hulu U/Th timescale and its impact on understanding the Middle to Upper Paleolithic transition in Western Eurasia. Journal of Human Evolution 55, 772–781.

Weninger, B., Danzeglocke, U., Jöris, O., 2007. Comparison of Dating Results achieved using Different Radiocarbon-Age Calibration Curves and Data. <http://www.calpal.de/calpal/files/CalCurveComparisons.pdf>.

Wiessner, P., 2002. The vines of complexity: egalitarian structures and the institutionalization of inequality among the Enga. Current Anthropology 43, 233–270.

Williams, A.N., 2012. The use of summed radiocarbon probability distributions in archaeology: a review of methods. Journal of Archaeological Science 39, 578–589.

Winterhalder, B., Kennett, D.J., Grote, M.N., Bartruff, J., 2010. Ideal free settlement of California's Northern Channel Islands. Journal of Anthropological Archaeology 29, 469–490.

Winterhalder, B., Puleston, C., Ross, C., 2012. Household-level Storage and Population-Level Consequences in a Temperate Zone, Agrarian Production System. Amerind Seminar Paper.

Wood, J.W., 1998. A theory of preindustrial population dynamics: demography, economy, and well-being in Malthusian systems. Current Anthropology 39, 99–136.

Wright, C.A., Dallimore, A., Thomson, R.E., Patterson, R.T., Ware, D.M., 2005. Late Holocene Paleofish populations in Effingham Inlet, British Columbia, Canada. Palaeogeography, Palaeoclimatology, and Palaeoecology 224, 367–384.

Yang, D., Speller, C.F., Prentiss, A., 2010. Ancient DNA analysis of the canine bones and coprolites from the Bridge River site, British Columbia. Poster presented at 75th Annual Meeting of the Society for American Archaeology, St. Louis.