The Bitterroot Socio-Natural Model: Applying Bunkhouse Creek Archaeological Project Data to Test Resilience

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Abstract

The Bitterroot Socio-Natural Model employs an agent-based model to explore resilient behaviors as manifested in two differing social systems who have occupied the Bitterroot Mountain landscape of the Northern Rockies in Montana. The Bitterroot socio-natural model is developed from a synthesis of resilience theory literature combined with an archaeological investigation of the Bunkhouse Creek Logging Camp site, which provides examples of pre-contact and historical social systems. The model tests how resilient behaviors of social systems contribute to the sustainability of both culture and the environment in the face of socio-natural perturbations. Results from the computer simulations show that equitable distribution of resources contributes most effectively to sustainability when the scale and scope of distribution is increased. Moreover, the Bitterroot socio-natural model outcomes suggest a social system has scaffolding against environmental shocks if it has manifested behaviors that respect carrying capacities of the natural system, population regulation, and more egalitarian approaches. The outcomes from the Bitterroot socio-natural model inform a framework for sustainable development by demonstrating the relationships between resilient behaviors in counteracting socio-natural perturbations.

[Keywords: resilient behaviors, sustainability, archaeology, pre-contact, historic, agent-based model]
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CHAPTER ONE

“One of the first challenges of conceptualizing sustainable futures will be to distinguish those features of social systems and human interactions with the environment that can be altered to achieve more desirable social and ecological outcomes, and those that are so much a product of history, human development, and biological, social, and cultural evolution that we must accept their undesirable constraints in fashioning our visions of the future.”

- National Research Council 1999

“Archaeology as an argument for the future – to reveal alternative realities that have worked, could have worked, do work and can work.”

– Barbara Little

INTRODUCTION

This thesis presents the utility of combining archaeological investigations with agent-based modeling for use in the applied field of global change archaeology. The first section summarizes interdisciplinary research completed for the Bunkhouse Creek archaeological investigation which provides examples of pre-contact and historical social systems existing in the Bitterroot Range of the Northern Rockies in Montana. The second section describes how the Bitterroot socio-natural agent-based model was developed from the interdisciplinary data provided by the Bunkhouse Creek project and a synthesis of resilience theory literature with the goal of testing relationships between resilient behaviors in counteracting socio-natural perturbations. The final section describes the methods for programming the Bitterroot socio-natural model in NetLogo language and discusses how the computer simulation outcomes inform a framework for sustainable development.

Research Questions

Archaeology has function to inform contemporary global issues through its discovery of the past. Specifically, archaeology has function to inform some of today’s tough and topical questions, mainly: How can we sustain? As we approach a supposed population “carrying
capacity” for the world, can we to again push past Malthusian limits and maintain our levels of comfort? Can we sustain both our social structure as well as a correct ecological balance? Now, these are not questions we can answer absolutely, but we can explore how resilient behaviors effect the likelihood of sustainability, an increasingly pressing current societal concern that makes the list for the United Nations’ Millennium Development Goals.

Archaeological investigations reveal ‘scenarios of resilience’ in various societal structures; resilience here meaning the capacity of a socio-natural system to absorb or withstand perturbations and other stressors such that the system essentially maintains its structure and functions (Gunderson & Holling 2002; Holling 1973; Hopkins 2009; Walker et al. 2004). In these scenarios, can we find certain behaviors of socio-natural systems that foster resilience? Previous research on complex adaptive systems such as the socio-natural system, suggest that resiliency is key to sustainable development - the ability to meet our needs without compromising the ability of future generations to meet their needs (Gunderson & Holling 2002; Adger & Kelly 1999; Adger 2000; Delacourt 2004; Deppish & Hasibovic 2011; Keck & Sakdapolrak 2013; Kirch 2005, 2007; Redman 2005; and van der Leeuw & Redman 2002; WCED 1987). Comparing these various ‘scenarios of resilience’ against one another, as well as against scenarios that do not show resilience, many scholars have come to the same conclusion: *resilient social structures display certain behaviors*. Researchers examining socio-natural systems see resiliency manifest itself in behaviors that favor diversity (of resources and use), demographic regulation (migration and population pressure), innovation (investment in social capital), common benefit, and decentralized organization (bottom-up approach) (Adger 2008; Berkes and Folke 1998; Biggs et al. 2012; Bodley 2012; Kirch 2007; Van der Leeuw 1992).
Now the question becomes: *What are the conditions under which the consequences of having different types of social ‘design’ (i.e. social structure) effect the designs’ capacity for resilience* (Gilbert 2008)? Put another way and borrowing from Elinor Ostrom’s questions for a resilient social-ecological framework, *what patterns of interactions and outcomes are likely to result for using one set of rules for the governance and use of a particular resource system and its units and users in a particular social system* (2009)? *Can we find if there are thresholds for resilient behaviors in the context of differing social systems?* Threshold here meaning ‘limits of an equilibrium range where the system can flip from one state to another’ (Gunderson & Holling 2002). The overall goal being to test what works when and what doesn’t, to add to a database, not to predict a panacea (Ostrom 2007; Resiliencealliance.org).

These are questions that can be illuminated through the combination of archaeological investigation and agent based modeling computer simulation, a useful tool in analysis of complex systems such as socio-natural systems. Archaeological investigation paired with current agent-based modeling computer technology can allow us to model ‘scenarios of resilience’ in many interesting ways, we can explore how within different societal structures resilient behaviors could play out in future trajectories. This type of interdisciplinary experimentation and research are necessary to explore answers to that tough and topical question: How can we sustain?

The Bitterroot socio-natural modeling experiment presented in this paper seeks to test the resilient behaviors as presented in differing social systems. The Bitterroot model has the capability to test many of those resilient behaviors at once. The Bitterroot model does not project predictions but experiments. This model asks: *Do differing social structures have differing capacities for resilience based on their differing manifestations of resilient behavior?*
**Nature of the project**

The Bunkhouse Creek archaeological investigation provided the impetus for this research in resilience theory and socio-natural agent based modeling. As a study area, Bunkhouse Creek provides great ground for testing the above research questions through the contrasting of two distinct social systems use of the same landscape. Excavation of the Bunkhouse Creek historic logging camp allowed an opportunity to investigate how resource extraction (land use) and its resultant landscape modification in the post-contact period (industrial economy) effected the ecosystem in contrast to resource extraction practices of the pre-contact period (hunter-gatherer economy) in the Bitterroot Mountain Range of the Northern Rockies. These elements unique to the Bunkhouse Creek study area provide an opportunity to evaluate two systemically different social systems’ attitudes toward nature and how those attitudes guide actions that effect ecological and social resiliency (Redman 2004). Empirical data collected on each systems’ social structure and natural environment was then converted and programmed into an agent-based computer model, with the intent of recreating their spatiotemporal histories (Dean et al. 1998). These “histories” were projected beyond the time period that has been reliably and validly recreated (Dean 1998; Kohler & Van der Leeuw 2007). This experiment of projecting forward tests multiple hypotheses as it allows analysis of the resulting resilient parameters of behavior.

Applying resiliency as the theoretical framework for analysis, the project investigates what role resource extraction has played in long term ecological effects on the area as well as how differing social systems direct the choice of resource extraction. Specifically, the Bunkhouse Creek project aimed to identify which social behaviors and decision making processes contribute to the resiliency and expectant sustainability of both culture and environment.
**Location of the Site**

The project area is located in the southwest Bitterroot National Forest, the traditional territory of an Interior Salish tribe, the Bitterroot Salish. Bunkhouse Creek Logging Camp, site 24RA0798 is located in the Bitterroot Mountain Range of Montana. Site 24RA0798 sits at UTM 11N 713264 5100946 and can be found on the Darby Quad Map: R3W T21N Sections 7 & 8. It is one mile south of Lake Como and approximately three and a half miles northwest of Darby, MT. The historic logging site and its adjacent landscape, are an area of known continuous use for at least the past 300 years (Bigart 2010; Frison 1978; Malouf C. 1969, 1974; Malouf R. 1979; McLeod & Melton 1986; Salish-Pend d’Oreille 2005; Teit 1927; Turney-High 1937; Wolf 1974).

![Figure 1. Location of the Bunkhouse Creek logging camp with detail map inset](image)

**Previous work**

Ethnographic research as well as previous site inventories conducted by EthosTech and the United States Forest Service, archaeological investigations, and paleoecological examinations have been conducted in the vicinity, establishing a sound basis for project research.
(Lake Como Survey 1992; McLeod & Melton 1986; Mehringer et al. 1977; Karsian 1995; Power et al. 2006; Ronan 1890; Salish-Pend d’Oreille 2005; Smith 1999; Teit 1927; Turney-High 1937; Williams 2006; Wolf 1974). While these past studies have been individually archaeological and ecological, the recent Bunkhouse Creek project synthesized these various forms of data as well as added to the human behavioral and environmental record through its excavations, palynological analyses, and dendrochronological analyses. Similar place-base studies have been conducted, the Bunkhouse Creek Project will be the first for the Rocky Mountain region (Adger 2000; Crumley 1994; Grimm et al. 2008; Kirch 2007; Kohler & Van der Leeuw 2007; Redman 1999; Redman et al. 2004).

The 2014 Bunkhouse Creek archaeological investigation expands on previous work at the site, informing the Bitterroot National Forest’s historic logging district boundaries and its public interpretation of the district, adding to the overall heritage story of the Bitterroot National Forest. Furthermore, as stated above, this area has not been subject to a joint socio-natural diachronic study, as presented here. By administering this type of study, this region provides empirical data to support the modeling efforts that seek to answer the above research questions regarding resilient behaviors.

**Physical Environment**

“Valley which we found more bountifully versified with Small open plain covered with a great variety of Sweet cented plants, flowers, and grass.”

– William Clark

The Bitterroot Mountain Range, part of the Northern Rocky Mountains, stretches through the southwest portion of Montana and eastern portions of Idaho. The Bitterroot Valley to its east provides a drastic elevation change from the Bitterroot Range and its western border of the Sapphire Range. The Bunkhouse Creek Logging camp, site 24RA0798, is situated at an elevation
of 4600 ft. on an eastward facing slope in the Bitterroot Mountain Range just north of Darby, Montana.

The Bunkhouse Creek project area is located in a coniferous and temperate area, receiving mild winters and warm summers. Vegetation found here consists of Ponderosa Pine (Pinus ponderosa), Douglas fir (Pseudotsuga menzeisii), and other subalpine species. Kinnickinnick (Arctostaphylos uva-ursi), huckleberries (Vaccinium), twinflower (Linnaea), and bear grass (Xerophyllum tenax) are also present (Pfister et al. 1977, Jack Losensky personal communication).

The closest water source is a small creek, Bunkhouse Creek. One mile north is Lake Como, once a seasonal lake area whose marshy lands produced a camas bounty (Mary Williams personal communication). Lake Como was dammed in 1909 by the Bitterroot Irrigation Company in order to support logging practices and the growing local infrastructure (Lake Como Survey 1992).

Hydrology, geology and vegetation of the Bunkhouse Creek project area supports a range of wildlife, including: black bear (Ursus americanus), elk (Cervus canadensis), moose (Alces alces), mountain lion (Puma concolor), bighorn sheep (Cervus canadensis), white-tail (Odocoileus virginianus) and mule deer (Odocoileus hemionus) as well as various other small mammals and avian species (McLeod & Melton 1986, Merhinger et al. 1997, Como Lake Project 1992).

The Bitterroot Range’s varied topography supports diverse flora and fauna. Such bounty also supports social systems. In the last 200 years, two social systems have taken advantage of the verdant landscape in differing ways.
“At the center of tribal cultures lay a deeply ingrained ethic of reciprocity between people, and between people and the land. We lived by a shared sense of what was appropriate and right in our relations with each other and with the earth. Over such a vast tenure on the land, the Sélis and Qlispé doubtless experienced historical changes that are beyond our knowledge today, including changes in climate, fluctuations in the availability of various foods, and the inevitable ups and downs in relations between tribal nations. But for a very long time, our way of life, rooted in our spiritual relationship with our environment and careful stewardship of our resources, provided a dependable sustenance to countless generations.”

- Confederated Salish and Kootenai Tribes

Since time immemorial, Salish speaking peoples traditional lands have included the Bitterroot Mountains and valley (Salish et al. 2005). The earliest written accounts of the Bitterroot Salish, once given the misnomer of the Flatheads by early fur traders and explorers, claim the tribe used the present day Stevensville area as a large single winter camp.

Archaeological and ethnographic evidence confirms occupation of the Bitterroot Mountains and valley since the retreat of Glacial Lake Missoula and continuously thereafter (Griswold and Larom 1954; Malouf 1969; McLeod and Melton 1986; Salish et al. 2005; Teit 1927; Ward 1973).

Since the warming trend of the Holocene around 12,000 years ago, this Salish speaking hunter-gatherer group managed to adapt to the changing environment in which they lived. Yet, their social system structure does not appear to alter itself much. Ethnographic accounts confirm the Bitterroot Salish were pushed to depend on this specific area of the Bitterroot Mountains more heavily in later years due to pressure from Plains tribes, namely the Blackfoot (Hungrywolf 1974; Ronan 1890; Salish et al. 2005; Teit 1927; Turney-High 1937). This ethnographic evidence as well as archaeological evidence reveals the pre-contact Bitterroot Salish to have a seasonally migrating, hunter-gatherer society that had no central organization other than a head chief and an assistant chief for each separate band of the tribe (Frison 1978; MacDonald 2012;
At its core, the Bitterroot Salish tribe’s social organization was non-hierarchical. No known privileged classes existed, with the exception of war parties and braves. (Teit 1927). Each tribe formed a unit – members tied together by blood or mutual interests, methods of making a living, common country, and dialect. Each tribe consisted of a number of bands, each making headquarters in some definite locality, composed of families more or less closely related by blood (Teit 1927). Band members looked to the guidance of one individual, often but not always hereditarily appointed (Hungrywolf 1974; Ronan 1890; Salish et al. 2005; Teit 1927; Turney-High 1937) This head chief was in charge of disciplinary matters, living arrangements, sanitation, and peace-making ceremonies (see above references). Sub-chiefs or small chiefs were often consulted in related matters (Hungrywolf 1974; Teit 1927). These chiefs did not comprise an elite class and only periodically would they meet to discuss the tribe as a whole. Rules of this cooperative system mostly governed settlement formations and their protection, sanitation procedures, and horse care.

Resources were shared among camp members, no matter who was the most successful in the communal hunting and gathering (Salish et al. 2005). Furthermore, intertribal exchange allowed the Salish access to food and resources that were abundant in other territories. As all tribes of this region did not practice agriculture, this structure of exchange further supported these independent tribes in their subsistence.

The season cycle of life practiced by the Salish was intentional to avoid pressure on the landscape, just as it was intentional to take only what was needed. The Salish year began with the winter solstice during the time of living on stored food and wintering west of the divide.
As the season changed to spring, the harvesting of plants began. Each plant was gathered at a specific time: ‘Indian potatoes’ (claytonia laceolata) in April, Bitterroots (lewisia rediviva) in mid-May, wild carrots (perideridia giardneri) in mid-summer, and camas (camassia quamash) in early August (Hungrywolf 1974). Each animal was also hunted at specific times: birds in the spring, buffalo in summer and fall, and elk and deer after buffalo hunts (Hungrywolf 1974). Killed animals were then processed wholly, every part having a use. Effort was made to avoid waste in all things. Value and respect for the landscape, plants, and animals guided Salish social structure (Salish et al. 2005).

When European settlers entered the Bitterroot Mountains in the late 19th and early 20th centuries (Anaconda Forest Product Records 1890; Flanagan 2003; Richey 1998; Smith 1999; Toole 1984; Williams 2000), not only did the settlers more prominently and permanently populate the areas that were traditionally winter villages for the Bitterroot Salish, they brought with them the capitalist system of social organization. This system puts the means of production and distribution of wealth in the hands of individuals, embedding a society stratified by class.

Population pressure increased these changes as Euro American settlers continuously flooded the area. With them they brought new rules, laws of living and a new worldview. These were agriculturalists, herders, and ranchers. Their ways of living did not include seasonal migration, it was sedentary. Resources were not treated the same, nor were traditional ones used. Foreign and exotic species were brought in for sustenance. Both effected the landscape in insidious ways. Euro Americans brought with them the idea of engineering the landscape to suit their needs rather than themselves adjusting.

By 1855, the U.S. government saw the presence of the Salish in the Bitterroot as an impediment to more settlers moving into the area, though for years Salish and settlers lived
together without issue. Even when Salish worldview differed from western ideas, “a common sight among the Flathead People for many generations were traditional spirits combined with modern ways, people chose and lived by the best of both (Hungrywolf 1974).” Certain modern conveniences – such as guns, kettles, and agriculture - were adopted and incorporated. Even with this shift in resource availability, Bitterroot Salish social structure was not altered. Yet, a treaty was drawn up between Governor Stevens and Chief Victor in which the Salish were asked to move out of the Bitterroot Valley, trading twenty-three thousand acres for two thousand, and onto the reservation. Quickly this act was forgotten and things persisted for another 40 years. In 1891, the chief of the time, Charlo, reluctantly led his people north of Missoula to the Flathead Reservation. Once the Salish were forced to move to the reservation by the new colonial government, certain resource gathering methods could not be practiced as they were no longer granted access to their traditional lands, lands that soon no longer held traditional resources due to the engineering of the landscape.

Conveniently about this same time, logging interests began surveying the Bitterroot forest for merchantable timber. Anaconda Copper Mining Company’s (ACMC) business was booming, and their mines needed timber to support their ever-expanding and prosperous adits. The company started clear-cutting the area, vastly altering the Salish traditional landscape in short order. ACMC’s avaricious approach to logging was thwarted in 1905 when the United States Forest Service (USFS) took over for the General Land Office in managing the Bitterroot National Reserve, soon changed to National Forest (Sherman 1906, Toole 1984).

The national head of the USFS, Gifford Pinchot, had a vision of sustainable forestry that did not align with the heavily capitalist interests of the Anaconda Copper Mining Company (Sherman 1906). While this may have saved the forests from clear cutting, USFS management
hurt it in other ways. One such way was the suppressing of fire. Salish traditional ecological knowledge held that setting periodic fires, especially in the fall, promised good grazing for horses and wild game, allowed certain berries to grow more bountifully the next season, and kept undergrowth to a minimum, resulting in aesthetically pleasing open forests, easier hunting, easier travel and a decreased likelihood of large disastrous fires (Salish et al. 2005).

**Previous Archaeological Research at the Site**

There has been previous archaeological testing at site 24RA0798. The site was first found in the 1970s by now retired forest ecologist Jack Losensky during an ecological evaluation for logging operations. Many years later, it was preliminarily surveyed by both Losensky and the current Heritage Program Manager and Tribal Relations Coordinator for the Bitterroot National Forest, Mary Williams. Williams and Losensky’s survey located a wagon road, skid road, possible scaler’s cabin, can dump, cookhouse and blacksmith’s shop (Williams 2006). Williams’ work at site 24RA0798 consisted of National Historic Preservation Act (Section 110(a) (2)) and National Forest Management Act recording. A survey and surface collection were conducted; a site form and map were produced; artifacts were analyzed. Williams’ recording and analysis provided preliminary information for the dating of the site, the layout of the site, and the possible identification of the former management company of the logging camp.

In 2006, the Bunkhouse Creek site received some can dump testing by University of Montana Anthropology student Ben Woody. His work consisted of surface collection and subsurface testing in the can dump feature. Woody’s mapping and artifact collection contribute to this project’s artifact analysis. Following this work, Williams nominated site 24RA0798 for the National Register as it contributes to the historic logging district in the Bitterroot Mountains as being a part of the first timber sale in Region One, an enterprise that defined late 19th and early
20th century Montana culture and economy. It was determined eligible for the National Register of Historic Places in 2007, even though this site has been lacking the proper funds to supply a more comprehensive investigation.

Pertinent to the landscape analysis of this dataset are what type of sites are located nearby. These immediate area sites are important to note as proof the region has served prominently over hundreds of years for its resources, not only for the social system which utilized site 24RA0798 (Bunkhouse Creek Logging Camp), but for a differing social system, the Salish. Prehistoric occupation sites exist on the shores of Lake Como, located one mile as the crow flies north of site 24RA0798 (Como Lake Project 1992, McLeod & Melton 1986). Unfortunately, they are no longer accessible as dam operations in 1909 changed access to these sites by flooding them with the expansion of the seasonal lake. Proof of prehistoric occupation and land use demonstrates the shift in resource dependence over time and is discussed in detail in a subsequent section.
CHAPTER TWO

LITERARY REVIEW

Publications that deal with research questions at various sites

Beyond these regionally archaeological works, other publications have also dealt with similar research questions as posed here. Global Change Archaeology scholars are focused on examining what behaviors and combination thereof foster resilience in socio-natural systems. Donald Hardesty defines “the emerging field” as an area of research that “seeks to document and apply historical knowledge of past human–environmental interactions to the understanding of contemporary environmental problems and management and planning for future sustainability (2007).” Charles Redman has compiled a book Human Impact on Ancient Environments (1999) and contributed to the book The Archaeology of Environmental Change: Socionatural Legacies of Degradation and Resilience (2009) both present diachronic, empirical case studies of socio-natural interactions which uncover practices both exploitative and sustainable (Fisher et al. 2009). Numerous other researchers have explored this interdisciplinary field that complies data from multiple soft and hard sciences and whose aims are closely related to those of historical ecology, political ecology, and applied anthropology. Research most significant to these questions include the works of Patrick Kirch, Elinor Ostrom, and W. Neil Adger to name a few.

Patrick V. Kirch’s extensive experience in the Pacific comparing the evolution of different island systems has revealed much about which social behaviors cultivate longevity in the socio-natural system (Kirch 2005, 2007, 1997, 1997; Kirch et al. 2012). His 2007 work, Three Islands and an Archipelago: Reciprocal Interactions between Humans and Island Ecosystems in Polynesia, identifies key aspects of sustainability. Kirch has found the following
contribute to this longevity: (1) population control via migratory patterns or strict control over reproduction, (2) respect for the common benefit via equitable distribution of wealth and resources (lack of stratification), (3) prevention of resource depression via diversification in reliance and use, (4) investment in social capital via the absence of stratification allowing equal opportunities for all to innovate, and (5) self-regulation again via the absence of stratification requiring a centralized homogenous authority.

Adger found similar conclusions in the mangroves of Vietnam (2000). In this alternate geographical area, he underscores the recursive relationship between social and natural resilience as the two are linked through a social system’s dependence on ecosystem services and how that social system conceives of the ability of the ecosystem to rejuvenate its resources. Thus, “resilience of the social system is related to the resilience of the ecological system on which the social system depends (Adger 2000).” He then goes on to identify some contributing social behaviors to the resilience of these inextricably linked socio-natural systems including: (1) equitable distribution of resources leads to stable economic growth; interestingly it leads to as well as results from (2) investment in human capital, (3) migration spreads risk by providing for (4) diversification and the reduction in resource dependency.

Elinor Ostrom worked on producing a general social-ecological system (SES) analysis framework which offers standards for quantifying a complex adaptive system’s capacity for resilience. Ostrom identified relevant variables for measuring how a social structure manages its resources. Variables that align with other scholars findings include: (1) the number of users of a resource or the size of the population, (2) investment in norms and social capital which enforces reciprocity rules and trust leading to (3) collective-choice rules and shared management, (4)
shared common knowledge of a resource system and how their actions affect each other, and (5) importance of resource to users, either through livelihood dependence or value (Ostrom 2007).

Anderies et al. compared multiple case studies from around the globe and concluded that certain “messages…can help improve policy and management” (Anderies et al 2006; Van der Leeuw et al. 2011). These “messages” include: (1) inclusiveness (neither ecosystems nor social systems can be managed in isolation), (2) breadth of scope (include multiple scales, multiple temporalities from very rapid to very slow), (3) diversity (as opposed to efficiency, even at cost, because in the long term it facilitates change), and (4) dynamic management and adaptive governance (rather than top-down management) (Van der Leeuw et al. 2011).

The ARCHAEOMEDES Project: Understanding the Natural and Anthropogenic Causes of Land Degradation and Desertification in the Mediterranean Basin, ran by Sander Van der Leeuw in the Mediterranean, found that (1) as long as people migrated seasonally, the pressure on the landscape was little, (2) humans soon became the overriding force (population pressure), (3) which affected the speed of ecological recovery (dependence on resource), and lead to a breakdown of social systems, expanding the spatial scope of their impact, thus effectively reducing landscape resilience (Bodley 2012; Van der Leeuw 1992). Moreover, the project discovered the most rapid change occurred during the Industrial Revolution of the 1890s and the change to dependence on globalization.

Carole Crumley’s seminal work in Burgundy, France corroborates the relevance of certain resilient behaviors. Through historical ecology analysis, her team found that (1) population increase affects both environment and social structure and (2) the best way to counteract negative consequences that could arise is to foster economic variability, insuring flexibility (diverse resource use) (Crumley 1987).
The Archaeology of Environmental Change: Socionatural Legacies Degradation and Resilience presents case studies from multiple times and places. Charles Redman is one contributor that found indicators of collapse of Hohokam culture to include: (1) increasing population, (2) increasing aggregation (more and varied distinct groups acting independently rather than collectively) and (3) increasing hierarchical sociopolitical organizations (top-down, less egalitarian). The increasing stratification led to excessive resource exploitation to support the distinction of elite classes and such practices proved antithetical to the resilience of the social structure and environment (Fisher et al. 2009).

In the same volume, Vernon L. Scarborough investigates landscape engineering’s role in ancient Mesoamerican society’s collapse. His work suggests that (1) “technotasking” or innovation does work to help sustain the population in a longer term, but warns that there are still limits unknown to us for such an economic pathway as past examples have ended in collapse. Alternately, his work suggests that a (2) “labortasking” pathway leads to community coordination of its diverse needs, enhancing its flexibility to deal with external environmental stressors (Fisher et al. 2009). Other contributors to the book come to similar findings regarding the impact of (1) stratified structures and (2) resource dependence on resilience as found by Redman and Scarborough.

The above scholars’ studies reveal what behaviors foster resiliency in multiple social structures from about the world. From those works, three resilient behaviors can reasonably be synthesized: (1) equitable distribution of wealth and resources to provide for common benefit that counteracts stratification, (2) demographic regulation with possible seasonal migration to avoid resource depression, and (3) diverse utilization of resources to inhibit resource depression and resource dependence.
Resilience Theory

Using a resiliency framework within the context of global change archaeology offers an approach to understanding and managing an intractable system toward sustainability. As there is no true homeostasis for earth’s socio-natural systems, resilience theory helps us “to understand not only how societies generate, acknowledge and are impacted by stressors,” but also to understand which general social structure practices allow us to maintain the self-organizing capacity of a system, or resilience (Walker, Johnson). Resilience is the capacity of a socio-natural system to absorb or withstand perturbations and other stressors such that the system essentially maintains its structure and functions (Gunderson & Holling 2002; Holling 1973; Hopkins 2009; Walker et al. 2004). Lack of resilience is indicated by a socio-natural system’s inability to respond to or rebound from constant dynamic conditions, like gradual changes or large perturbations, that occur in nature (i.e. drought) and society (i.e. disease) (Resilience Alliance).

One of the main elements in resilience theory is the concept of a threshold – the limit a system can reach before the functioning of the socio-natural system experiences a regime shift. A regime shift occurs when certain thresholds are passed and an abrupt response occurs resulting in a “large, persistent change in the structure and function of social-ecological systems, with substantive impacts on the suite of ecosystem services provided by these systems (Regimeshift.org).”

The space between thresholds provides an equilibrium. In fact, this space or latitude between thresholds houses multi-stable states - a fluctuating equilibrium (Holing 1998, Walker
Picture a skateboarder on a halfpipe (Figure 2). The skateboarder is the socio-natural system, the coping of on either side of the halfpipe are the thresholds, and the halfpipe itself represents the latitude of the system. As the skateboarder moves between the copings, he is experiencing multi-stable states of equilibrium. When the skateboarder stops on one of the decks, passing a threshold, he is experiencing a regime shift, a new way of functioning, in this case transferring from skating to standing still.

Figure 2. Socio-natural system resilience components

Our ever increasing human presence results in ever increasing social engineering of the natural system. Thus, social structure practices have become a leading factor in the capability of a socio-natural system for resilience. Behaviors of the social system that guide its equilibrium and generate latitude between thresholds can be called resilient behaviors. As described above, a synthesis of empirical studies uncovered some possible societal resilient behaviors. Framing thinking about socio-natural systems within resilience theory allows comparative exploration of what combinations of resilient behaviors keep these socio-natural systems within a certain latitude before a threshold is reached and the system shifts or reorganizes into a differently functioning regime.
CHAPTER TWO

ARCHAEOLOGICAL METHODS

An Agent-Based Modeling Computer Simulation was developed to illuminate resilient behaviors pertinent to sustainable practice in order to answer the research question: \textit{Do differing social structures have differing capacities for resilience based on their differing manifestations of resilient behavior?} An agent-based model can provide for analysis of anthropogenic behaviors that contribute or detract from the resilience of the socio-natural with representational programming of real-word socio-natural variables (Dean et al. 1998; Kohler & Van der Leeuw 2007). Several methods were utilized to provide inputs for the agent based modeling.

First, a social structure baseline was constructed using past archaeological, environmental, and textual evidence. This required interdisciplinary testing (archaeological and ecological) of site 24RA0798 as well as utilization of existing data which included historical texts and ethnographies. The evidence was then synthesized from these multiple sources to provide data to formalize the agent and environmental states and their rules for behavior in the modeling system. Finally, once the model was programmed, it ran numerous times under varied conditions. The exact method for agent-based model programming and the analysis of its results will be discussed in detail. However, it is necessary to first discuss the methods undertaken to establish a social structure baseline.

In order to program agent rules in a computer model, some type of real-world phenomena must be used as a reference pattern or a “target” social reality (Gilbert 2008). This target supplies a measure of validity for the computer model, considered a “middle range” model –
meaning while it does not *exactly* reproduce the social structures and environment that existed in the regional landscape of the Bitterroot Mountains, it does replicate the main characteristics of these social structures (Gilbert 2008). A reference pattern for the social structures and their accompanying resource extraction in the Bitterroot region was created by synthesizing several methods: archaeological investigation, pollen analysis, archival and historical document research, ethnographic readings, and the study of secondary sources.

**Background Research**

The real impetus for this research came in the form of an offer from the USFS to excavate a historic logging campsite. Background research conducted for field work planning helped to construct the aims of the excavation and increase its interdisciplinary scope. Original research design intended to reconstruct land use and resource extraction in this known continued use area of the Bitterroot National Forest in order to examine how the landscape and hence the ecosystem were modified over the last three hundred years by anthropogenic activity. Previous site reports, archives, and historical documents were studied for information pertaining not only to the Bunkhouse Creek Logging Camp, but also for information focused on pre-contact human use of the Bitterroot Mountains and the surrounding landscape.

Collection of this information began with site reports provided by the Bitterroot National Forest Supervisor Office in Hamilton, Montana. Research permission was granted by the Cultural Heritage Manager and Tribal Relations Coordinator, Mary Williams. A USGS topographical map recorded all discovered sites in the area, an excellent visual to establish location and type of site. Of twenty-seven sites in the vicinity of Bunkhouse Creek Logging Camp and the Lake Como area just to its north, eighteen are pre-contact sites. The pre-contact site types include lithic scatters, occupation sites, a rock carin, and a scarred tree. The remaining
nine sites are historic and are related to logging practices and other landscape altering activities, such as the damming of Lake Como. These archaeological site reports provide tangible evidence of Salish use of the area in addition to documenting the shift in land use once European settlers arrived.

Additionally, general local histories, in the form of ethnographic reports as well as historical documents related to area logging practices were studied. The Confederated Salish and Kootenai Tribes (CSKT) and its Elders Advisory Council penned an authoritative history: The Salish People and the Lewis and Clark Expedition, elucidates cultural practices, social structure, and values which confirms the archaeological evidence of the enduring presence of the Salish on this landscape (Salish et al. 2005). Other accounts by Bitterroot Salish tribal members, including Adolf Hungrywolf and Agnes Vanderberg, extend firsthand knowledge of Salish social structure and land use (Hungrywolf 1974, Vanderberg 1995). Furthermore, anthropologists and ethnographers working around the turn of century, most notably James Teit for this region, complied several ethnographies on the Bitterroot Salish which supplement direct knowledge about a culture with an oral tradition (Fahey 1974; Ronan 1890; Teit 1927; Turney-High 1937; ).

Written histories about this region must acknowledge the presence and influence of the Anaconda Copper Mining Company (ACMC) in shaping the newly formed state of Montana. To support their mining operations, ACMC clear cut timber across the state before USFS enforcement. In the 1890s, the barely ten year old company started prospecting for timber in the Bitterroot Mountains. Mary Williams of the USFS supplied documentation the first timber sale for Region One which occurred between the USFS and ACMC. This sale was for the Lick Creek area in the Bitterroot National Forest, just north of Lake Como. Subsequent revisions to this permit included the addition of the project area, Bunkhouse Creek, just south of Lake Como.
Thus, Anaconda Forest Products Records 1890-1971 Collection MSS057 located in the archives of the University of Montana was accessed and studied for information relating to Bunkhouse Creek Logging Camp. While there are mentions of Bunkhouse Creek in the USFS/ACMC timber permit and its revisions, no descriptions about the camp have been discovered.

**Archaeological Excavation**

Due to the lack of literary evidence for Bunkhouse Creek Logging Camp, an archaeological excavation was undertaken to evaluate the site; the aims being to determine the operator of the camp and its extent. The excavation was also an opportunity to examine ecological change over time, but that will be discussed in a subsequent section.

Previous field work at site 24RA0798 had uncovered a general layout for the site, yet Bunkhouse Creek Logging camp had not been systematically surveyed. The first days of field work in the 2014 season consisted of the field crew (Britt Schlosshardt, Cathy Jo Beecher, Jack Losensky and Kent Miller) walking transects between boundaries of the site provided by Forest Service Road 550A and Bunkhouse Creek itself while using a metal detector to pin flag any subsurface hits as well as surface finds and possible features. The boundaries were determined and confirmed by lack of concentrated finds and features outside of these boundaries. Photography of possible features also occurred at this time. Further survey was undertaken later that week beyond the boundaries of the site with the help of Cathy Jo Beecher and Jack Losensky.
Figure 3. Site overview map
Additionally, GPS readings were taken at all surface finds and features using Avenza, a free application for smart phones which works with Google Earth. These readings provided initial visuals for the layout of the site. More accurate mapping was completed with the expertise of Kent Miller, using a Leica Theodolite in conjunction with Tripod Data Systems. Final maps were produced by Kent Miller using AutoCAD software (see Appendix 2).

Once the extent of the Bunkhouse campsite was reasonably determined, shovel testing was undertaken at various features in order to further discern what those features were as well plan the location for excavation units. Shovel tests occurred at the scaler’s cabin, the skid road, the can dump, the cookhouse, the wagon road, the blacksmith shop, the possible privy, and the camping terraces.

All seven shovel tests were based on metal detected “hot spots” in these features. A 50cm x 50cm area was excavated at each shovel test. Soil changes were recorded using a Munsell Soil Color Chart. Artifacts and, in certain cases organic matter, were collected from these test areas. Evidence of fire (i.e. charcoal and burnt pine needles) and its depth was noted. The topography
of the area confined shovel testing to a forty centimeter depth; most shovel tests averaged around thirty centimeters.

Photo 2. Cookhouse excavation unit
Photo 3. Can dump excavation unit
Two units were opened during the course of the 2014 field season in well determined features: the cookhouse and the can dump. In each feature, 2 x 2 meter squares were plotted as the excavation called for locating historical artifacts of a certain period as requested by contract with USFS, thus a horizontal expanse for testing versus more vertical testing for time change was needed. Additionally, site 24RA0798 is not known for Native American repetitive habitation but the surrounding mountain area is known for Native American occupation, hunting, and gathering use. Excavation of units deeper than historical context finds was undertaken to discern environmental change. Soil samples from these layers provided chronological depth for pollen analysis.

Excavation of each unit was undertaken using the following procedures. The two 2 x 2
meter squares were plotted and mapped against control points provided by Kent Miller (see Appendix 2). Photographs and unit maps were produced of pre-excavated units and continually produced at ten centimeter intervals until lack of finds or topography halted progress. Sediment from each layer was screened through ¼ mesh, finds were collected, sorted by material, and bagged within each of these ten centimeter intervals. Soil samples were collected from each unit at five centimeter intervals in order to provide nuanced pollen analysis samples considering the shallow depth of the units. This pollen sampling strategy followed procedures recommended by Jan Gish at site 48YE381 (Gish 2013). Additionally, several macrobotanical specimens were collected for analysis. Once excavation of a unit was completed, the unit was backfilled using the excavated soil to prevent disturbance by possible recreationists in the Bitterroot National Forest. Time and labor constraints prevented further excavation in the 2014 field season, but contract goals were met.

**Pollen and Macrobotanical Analysis**

Four soil samples and two macrobotanical specimens from the excavation units were submitted for analysis in order to discern environmental change over time. These samples were sent to Jan Gish after processing was completed at the University Of Texas A&M. Though the Bunkhouse Creek project did not secure adequate funding for radiocarbon testing to absolutely date pollen analysis results, the diagnostic artifacts found in the unit relatively date the soil samples submitted for analysis. The results showed little environmental change (see Appendix 1 for detailed results).

Pollen analysis confirms the abundance of ponderosa pine and other pine species in this area both historically and in modern times. “The 3.5 percent value of fir pollen in the surface sample, on the other hand, implies only minor local presence of fir trees, despite classification of
the modern plant community as a grand fir series. Similarly then, the 3.5 to 5.5 percent values in the subsurface samples could reflect substantial presence of fir trees in historic times as well. Conifer regeneration through the Historic period has often favored Douglas-fir over ponderosa pine (Gish Appendix 1, USDA Forest Service 2008: 3.3-16).” These dynamics are not evident in the pollen records, probably in part due to the underrepresentation of Douglas-fir pollen in the forest soils.” Fire suppression has long assumed to be the cause of Douglas-fir’s appropriation of this forest habitat, but these results are indicating that Douglas-fir presence may have decreased from historic to present times, at least in this specific forest area. Additionally, several taxon found confirm the riparian nature of the site in historic times.

Macrobotanical analysis revealed Douglas-fir and spruce wood charcoal in the excavation units. This fuel could signify either a forest fire or a cooking space. Some non-botanical specimens were also analyzed. “The fragments mostly were black or brownish in color, glossy or dull, brittle/friable, usually globular, but also layered, in part. None were metallic. It is possible these materials are volcanic or perhaps some type of slag (Gish see appe).”

**Artifact Analysis**

Collection and cataloguing of artifacts followed both USFS and UM standards. Each artifact collected was recorded in a database (available upon request). The database provides information on where the artifact was found, what material it is, what its dimensions and weight are, and when possible describes its function and the time period for the artifact. That information was then analyzed against historical research. The results are discussed in a subsequent section.
CHAPTER FOUR

EXCAVATION RESULTS

Survey, mapping, and excavation performed at site 24RA0798 confirmed the site’s use for logging activities in the early 1900s. The pedestrian systematic survey conducted found that this occupation and timber processing area was concentrated to a ten acre expanse. Within these ten acres numerous features and a total of 578 were found and recorded (see Appendix 2). Two hundred and forty-six metal-detected and pin flagged spots were also mapped with the expertise of USFS Surveyor Kent Miller (Figure 3). Furthermore, many diagnostic artifacts found corroborate the assumed early 20th century use of the site (Figure 4).

Figure 4. Dating Analysis of Diagnostic Artifacts

<table>
<thead>
<tr>
<th>Description</th>
<th>Count</th>
<th>Time Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire nails</td>
<td>62</td>
<td>1890-Present</td>
</tr>
<tr>
<td>Square-top nails</td>
<td>4</td>
<td>1835-Present</td>
</tr>
<tr>
<td>Beer bottle fragments</td>
<td>25</td>
<td>1881-1905</td>
</tr>
<tr>
<td>Citrate of Magnesium bottle</td>
<td>1</td>
<td>1880-1915</td>
</tr>
<tr>
<td>Sawyer’s saw bottle</td>
<td>1</td>
<td>1906-1922</td>
</tr>
<tr>
<td>Whiskey bottle</td>
<td>1</td>
<td>1878-1919</td>
</tr>
<tr>
<td>Wine bottle</td>
<td>1</td>
<td>1900s</td>
</tr>
<tr>
<td>Hole-and-cap can fragments</td>
<td>7</td>
<td>1810-1820</td>
</tr>
<tr>
<td>Amethyst glass fragments</td>
<td>94</td>
<td>1885-1920</td>
</tr>
<tr>
<td>Saw file</td>
<td>1</td>
<td>1840-1930</td>
</tr>
<tr>
<td>Copenhagen tins</td>
<td>3</td>
<td>1906-1935</td>
</tr>
<tr>
<td>Prescription bottle</td>
<td>1</td>
<td>1876-1910</td>
</tr>
<tr>
<td>Stoneware</td>
<td>1</td>
<td>1877-Present</td>
</tr>
<tr>
<td>Rivet buttons</td>
<td>11</td>
<td>1894</td>
</tr>
<tr>
<td>Hole-in-cap can</td>
<td>3</td>
<td>1820-1930</td>
</tr>
<tr>
<td>.22 caliber cartridges</td>
<td>3</td>
<td>1885</td>
</tr>
<tr>
<td>Serving spoon</td>
<td>1</td>
<td>1900</td>
</tr>
<tr>
<td>Center clip for wagon</td>
<td>1</td>
<td>1920</td>
</tr>
<tr>
<td>Atkins Victor crosscut saw</td>
<td>2</td>
<td>1920</td>
</tr>
<tr>
<td>Barrel tie</td>
<td>1</td>
<td>1854</td>
</tr>
<tr>
<td>“Go-Devil” Logging Sled</td>
<td>1</td>
<td>Late 1800s-1900s</td>
</tr>
</tbody>
</table>
Figure 5. Cookhouse detail map


**Cookhouse Feature**

Just north of the ridge that leads to Bunkhouse Creek lies a terraced area measuring approximately 25 by 20 feet (Figure 5). Previous field work conducted by Mary Williams first alleged this area as a cookhouse due to apparent linear earth features as well as the find of a salt shaker top (Photo 7). Additionally, its proximity to the can dump suggests this was the main area where food was processed and served. The 2014 field season aimed to confirm this assumption through excavation of a 2 x 2 meter square. In the course of the excavation, artifacts of various materials were uncovered (database available upon request, see numbers 19-31, 85).

The excavation of the cookhouse unit neither refuted nor undeniably confirmed this feature’s use as a kitchen and mess hall area. The above indicators hold true and the artifacts found in the excavation unit (described below) as well as the 36 metal detected finds and “hot spots” surrounding this feature point to this feature’s use as a possible social gathering place, a possible food storage area, as well as a possible structural area.

**Flora Finds**

Eleven charcoal pieces were found in the cookhouse excavation unit suggesting two possibilities: that they are remnants of a forest fire or that they are remnants of a cooking area that used wood fuel. The latter would support the cookhouse assumption, but dating of the charcoal would be necessary to determine this more completely.

**Metal Finds**

Metal artifacts unearthed include: two hole-in-cap cans, fifteen wire nails of various pennyweights, two fragments of small gauge bailing wire, one .22 caliber spent cartridge, one tobacco tab, and one Copenhagen can.
These artifacts span a range of functions, complicating interpretation of this feature. While the cans, tobacco items, and the wire nails suggest food storage, social gathering, and a building structure respectively, the scant presence of each does not overwhelmingly clarify the cookhouse features’ function. The lack of artifacts supports site 24RA0798 use as a temporary logging camp. Background research found that the USFS required ACMC to remove all timber refuse, structures, and equipment shortly after the timber contract was fulfilled (ACMC Forest Products Records).

Glass Finds

Glass artifacts collected from this excavation unit include: twenty-five slightly amethyst glass fragments of varying thickness, as well as sixty-seven fragments of a prescription bottle. Manganese was added to glass as a stabilizing and clarifying agent between roughly 1885 and
1920 which when exposed to sunlight overtime, gave glass a purple tint. (SHA Bottle Identification). The amethyst glass fragments then support site 24RA0798’s early 20th century use. The prescription bottle is a household item and very well could have been kept at the “store” or commissary of the camp which “carries necessaries required by the woodsmen, such as shoes, clothing, tobacco and a few drugs (Bryant 1913).” Alternately, this prescription bottle could have been a personal item randomly discarded after use.

![Photo 9. Prescription bottle](image)

Just outside the cookhouse foundation perimeter wire and board have been attached to a tree. Two nails fasten the broken board to the tree just above its base; approximately five feet above this, the wire has been bored into the tree. The function of this artifact has yet to be determined, though one hypothesis is that it part of a camp communication system.
Can Dump Feature

The Can Dump feature (Figure 5) is located just south of the cookhouse on a slope that leads to Bunkhouse Creek. This feature is approximately fifty by fifty feet, but the heaviest concentration of this waste area occurs in a twenty-five by twenty-five foot area. A can dump sample explored the density of a 1 x 1 meter expanse. In total there were 221 one complete cans, three bones, one shoe fragment, and one shell. When these numbers are extrapolated to the heavily concentrated area (25ft x 25ft), the result of over fifteen hundred cans points to a significant occupation of the site.

During the 2014 field season a 2 x 2 meter unit was excavated on the slope north of this heavy concentration area. Different from the cookhouse excavation unit, artifact finds were focused in the zero to ten centimeter depth. Only two were unearthed in the 10 to 20 centimeter depth (database available upon request, see numbers 36-61, 77). However, the variety and volume of pieces excavated from the can dump unit support the idea that the waste area for the
camp began at the top of the slope leading down to Bunkhouse Creek; throwing refuse over the side of the hill where it was out of sight was convenient and weathering processes helped it coalesce closer to the creek.

**Footwear**

Previous fieldwork and the can dump statistic discovered one “caulked” shoe sole and one shoe fragment from a heel. The construction and handmade modification indicate an early 20th century date as well as logging activity.

*Photo 12. Caulked shoe sole*

**Faunal Finds**

Faunal finds from the can dump excavation unit include: one possible stifle joint of bovine femur, the other a possible section of the ilium. Previous field work and the can dump statistic located four additional bone fragments. These finds corroborate this features’ function as a waste area for food processing.
Unidentified Finds

Unidentified finds include: eleven pieces of leathery material, five pieces of pearlescent material, and one two pronged artifact.

Metal Finds

The range of metal artifacts located in the can dump excavation unit support this feature’s classification and include: fifty wire nails of various pennyweights, five .22 caliber cartridges, five metal fasteners (metal hardware), one fragment of a Copenhagen tin, eleven rivet buttons, thirty-nine can fragments, one cap, one fork, and one spoon. Previous field work and the sampling of the can dump uncovered numerous cans, one of which is a hole-and-cap can, an
interesting outlier to the time period as these were manufactured between 1810 and 1820. Additionally three metal bar-clip draught horseshoes of differing dimensions were collected. The shoes are of the general use type with built up heel and toe which suggests the shoes were not used for winter logging.

![Image of wire nails](Photo 17. Wire nails)

![Image of .22 caliber cartridge](Photo 18. .22 caliber cartridge)

![Image of hole-and-cap can](Photo 19. Hole-and-cap can)

![Image of horseshoes](Photo 20. Horseshoes)

**Glass and Ceramic Finds**

Contributing to the bulk of finds from the excavation unit were one hundred and fifteen glass fragments, including one possible extract or prescription bottle, and twenty four white glazed ceramic pieces of possible earthenware hotel ware.
Previous fieldwork collected several diagnostic glass artifacts: a green glass hand-blown beer bottle fragment on the base of which the marker’s mark reads "SB & GCO. 16" for Streator Bottle and Glass Company located in Streator, Illinois (1881-1905), one slightly amethyst Citrate of Magnesia bottle fragment manufactured by Illinois Glass Company (1880-1915), a complete brandy finished bottle with a wire wrapped just under lip of the indicates it once was attached to sawyer or hung nearby containing saw lube, a body fragment of a whiskey liquor bottle embossed with "Bonnie Louisville KY" (1878), six fragments of green wine bottle including a Bordeaux style base kick-up, twenty-four brown glass fragments including the crown cap finish neck piece that is typical for beer bottles, and finally one "Georgia green" bottle base with a slight push up suggesting a soda or mineral water bottle. These finds support the can dump feature’s classification, indicate logging activity, and suggest that site 24RA0798 was not an ACMC run logging camp. ACMC ran “dry” camps and the unconcealed presence of beer, wine, and whiskey bottles points no prohibitions against drinking in the camp (Mary Williams personal communication).
Scaler’s Cabin Feature

The scaler’s cabin is located east of the can dump and just north of Bunkhouse Creek (Figure 6). This feature gets its name from researching Forest Ranger Nathaniel E. “Than” Wilkerson’s diary, in which he discusses the existence of scalers cabins; scalers are those with the job of determining log volume. Than Wilkerson was one of the Bitterroot National Reserve’s and the Bitterroot National Forest’s first Rangers (Williams, USFS). In his diary, Than describes USFS cabins built apart from logging company living quarters. This cabin is separated from the camping terrace feature by several acres and finds itself very near a road feature. Only five logs in the southwest corner of the cabin remain. These logs have been axe cut into a V-notch and some contain square head nails. A complete cabin outline and a depression for an entryway in the east is visible in dirt berms extending from with the log remains. This seventeen foot by
twelve foot rectangular structure is almost perfectly aligned with the cardinal directions (see Photos).

Additionally, several surface finds discovered just outside the perimeter of the cabin: one spoon, five hole-in-cap cans, one large square can, eight unknown metal detected hot spots as well as a large metal tub modified at the base with many holes, suggest that this space was a separate living area.

Pedestrian survey discovered a separate possible feature west of the scaler’s cabin but no determination on its function has been made (Losensky 2014). This possible feature consists of one board of treated milled wood, a fragment of coiled wire three centimeters in diameter, and a possible terrace area extending south from a ridge to the north.
Photo 27. Coiled wire

Photo 28. Milled wood
Figure 6. Scaler's cabin detail map
Skid Road Feature

Also west of the scaler’s cabin, the skid road feature runs about one hundred and twenty-four feet southwest to northeast between Bunkhouse Creek and forest service road 550A (Figure 6). It measures roughly four to five feet in width, standard railroad gauge width, but its grade of about ten percent is much too steep for a railroad track. Average railroad grade tops out at less than three percent, although, private logging company railroads did push grade limits into the fifth percentile (Forest service web). Pedestrian survey discovered this feature possibly extends further southwest and further northeast on a course to meet with the wagon road feature; closer investigation of the landscape is needed to confirm this finding. However, ACMC records search show that a Mr. William Toole and a Mr. D.V. Bean were buying up land in Township 3 Range 21 for ACMC as early as 1892 (MSS Collection 057). Then, almost a full year before the March 21, 1907 ACMC and USFS Lick Creek timber sale was signed, ACMC instigated a three year contract with a Mr. G.D. Goeriz “to build up, keep, maintain, construct, run conduct and operate railroads, tracks, and spurs for logging purposes for the hauling and transport of saw logs, camp supplies and building of wagon roads” of Township 3 Range 21 Sections 3, 4, 5, 6, 7, 8, and 9 (MSS Collection 057). This skid road feature crosses sections 7 and 8. Furthermore, ACMC granted Goeriz “the right off setting, operating, running, and conducting a sawmill at any place or site owned by [ACMC] of the N ½ of the NE ¼ or SE ¼ of NE ¼ or the NE ¼ of SE ¼ of Sec. 8 T3N R21W (MSS Collection 057).”
Few artifacts were discovered nearby including: one hole-cap-can, one piece of bailing wire, five cables, and one unknown metal detected “hot spot”. The presence of the cables suggests that yarding or power skidding of logs could have occurred on this road feature, though one cable’s diameter of 3/8ths inch does not equal the standard size used in early 20th century logging and could be a remnant of logging completed in the 1970s (Bryant 1913, Jack Losensky personal communication)

**Wagon Road Feature**

The wagon road feature extends 371 feet through the center of site 24RA0798 (Figure 3) following “requirements for a camp site for snow logging” as described by Ralph C. Bryant in his seminal book Logging: The Principles and General Methods of Operation in the United States (1913). “The camp should be located so that the main haul or two-sled road will run through the camp lot on its way to the landing (Bryant 1913).”
Photo 30. Oxen pulling an eight-wheeled “Lindsey” wagon. (Photo courtesy of samlindsey.com)

Similar to the skid road feature, the wagon road’s width is approximately five feet and has a grade of ten percent, thus it also meets standard railroad gauge width but exceeds normal railroad grade percentage. Still, it falls within sections 7 and 8 of T3N R21W and could be a candidate for Goeriz’s railroad contract with ACMC (MSS Collection 057). The southwest terminus of the wagon road feature is the southwest corner of site 24RA0798, just before the terrain slopes down into Bunkhouse Creek. The northeast terminus extends past forest service road 550A into the NW ¼ of section 8 and has been Kelly-humped before reuniting with the winding 550A road. There is an offshoot, heading northwest from the wagon road, to the Blacksmith shop feature. Access to and from the “Smithy” further signals this wagon road feature as the center of camp in logging operations. Seven metal detected hits are in the vicinity of the wagon road but are unknown as excavation was not undertaken in this area.

Privy Feature

The privy feature is southeast of the blacksmith shop on the opposite side of the wagon road (Figure 7). A shovel test in the center of an approximately three foot deep, square-shaped depression discovered one fragment of a Copenhagen tin. At ground level, the metal detector hit
“hot spots” at two corners of the square. Trowel tests at the northeast and southeast corners revealed four wire cut nails, indicating a structure possibly once stood above the depression. Moreover, the possible privy feature is isolated away from a water source, the cookhouse, and the camp terraces. Further investigation of this feature is needed to more completely support the latrine function.
Figure 7. Blacksmith shop detail map
**Blacksmith Shop Feature**

Northwest of the privy, at the end of the wagon road offshoot, lies the blacksmith shop feature, an approximately twenty foot by fifteen foot terraced area (Figure 7). While the average size for a blacksmith shop in a camp of sixty men is slightly larger than this (27ft x 27ft), natural processes have been at work at site 24RA0798 for over one-hundred years, contributing to indistinct feature outlines (Bryant 1913). Furthermore, no written records have been located referencing the amount of men camped here, thus this additional logging tract of the Lick Creek timber sale very likely had a smaller sized camp than the main camp near Lick Creek to the north.

The blacksmith shop was where “horses were shod, sleds and other equipment were made and repaired and similar work done (Bryant 1913).” Surface finds in and around this feature include: ten barrel ties, five cans, four band clamp pieces, one standard oil axel grease can lid, one center clip for a wagon, two broken metal bars, four unidentified but possible metal pins, several coal pieces, a Disston brand (1840-1950s) saw file, one possible metal hasp or clasp, four possible metal chain links, one ring for a neck yoke, one possible head hoop or chime fragment of a barrel, one unidentified piece of metal hardware, two pieces of leather tack, two halves of a slightly amethyst bottle neck with a brandy finish, twelve plate head horse shoe nails, one possible plow ski for a logging sled, two log dogs, and two wheel axel hubs. This volume of surface finds relating to various repair work as well as the presence of coal, indicating a forge, substantiate the blacksmith shop hypothesis.
Photo 31. Disston saw file  

Photo 32. Center clip  

Photo 33. Phila barrel tie  

Photo 34. Plate head horse shoe nails
Figure 8. Camping terrace detail map
Camping Terrace Feature

A well-trodden foot path inclines west from the north side of the blacksmith shop feature to the south side of two possible camping terraces (Figure 8). Camping terrace “A”, the northwest terrace, measures approximately eighteen feet by fifteen feet. Camping terrace “B”, to the southeast, measures approximately twenty-three feet by twenty-one feet. As an average bunkhouse size of thirty-five by thirty-seven feet sleeps sixty men, these camping terraces suggest: two smaller bunkhouses, a camp of a smaller size, or terraces of an alternate use (Bryant 1913).

An excavation unit was not opened in this feature but a shovel test discovered some bailing wire three centimeters down in terrace “B” and survey with the metal detector signaled seven more “hot spots”. Surface finds in this feature and the surrounding area include: several glass fragments, one can, one metal rod, bailing wire, two large stakes, two barrel ties, one cable fragment and one choker cable. Additionally, an outlying boot fragment was discovered northwest of terrace “A”. These artifacts, beyond the stakes and possible use of bailing wire to dry clothes, do not explicitly indicate a bunkhouse feature (Bryant 1913). Future excavation could reveal more telling artifacts such as personal items or building materials, though due to
timber sale contract obligations requiring removal of buildings, the flat terraced areas may be the
only remnants of these structures (ACMC).

**Barn Terrace Feature**

Just to the southwest of the camping terrace feature on the opposite side of the foot path is the possible barn terrace (Figure 8). This feature is signified by one north-south running linear feature measuring eighteen feet with a large flat expanse extending east. While one measurement cannot indicate the exact floor plan for the feature, it should be noted that a camp housing “twenty-five to thirty-five horses” averages two stables forty by forty feet (Bryant 1913).

![Photo 37. Leather tack](image1)

![Photo 38. Leather belt or strap](image2)

![Photo 39. Wire at base of tree](image3)

![Photo 40. Mass of bailing wire](image4)
Again, an excavation unit was not opened in this feature but future subsurface testing is suggested as twenty-one “hot spots” were discovered in and around it using metal detection. Surface finds in this area include: a large mass of bailing wire located near the distinctive linear feature, four additional fragments of bailing wire, one fragment of a leather belt or strap, two leather fragments of possible tack, one barrel tie, one choker cable and one metal can. The leather tack, masses of bailing wire, and the flat expanse itself are potential indicators for a barn feature.

Discovered between the camping terrace feature and the barn terrace feature is Bailing wire wrapped around the base of two trees which are located directly across the foot path from one another. Perhaps the wire is the remnant of a fence meant to contain livestock, but more investigation of this area would be needed to confirm this supposition.

**Conclusions and Recommendations**

While the testing and analysis of site 24RA0798 could not definitively answer certain questions about who ran the camp, a subcontractor or ACMC itself, results thoroughly confirmed its function as a substantailly important logging camp. This is an significant finding for the first timber sale of the region and a significant marker in Montana history and heritage. Further investigation into who operated the camp should be completed by continued records research and further excavation of site 24RA0798.

Ecological testing results provided no significant evidence of differing amounts or types of pollen at the Bunkhouse Creek logging camp over the last 100 years, suggesting the impact of historic logging has not had a noticeable effect on the modern ecology of the area. Lack of environmental change is a positive finding and points to a resilient intervention by a social
instituion, USFS. Still, more chronologically in depth ecological landscape analysis, including liminology and more extensive records research, should be included in future work.

The methods of research undertaken in investigation of site 24RA0798 contribute to the understanding of early 20th century logging practices, its role in Montana’s history and economic evolution, and how this economic transition brought on by European settlement greatly contrasted from the native inhabitants way of life. It is important to continue pairing this type of work with agent-based modeling as the resulting simulations of these established societal behaviors can help us experiment for unexpected and unintended consequences. Additionally, this process promotes interdisciplinary collaboration.
CHAPTER FIVE

“The goal of agent-based modeling is to create agents and rules that will generate a target behavior. Sometimes the rules are not well known, or you just want to explore the system’s behavior. In that case ABM can be used to help you better understand a phenomenon through experimentation with rules and properties.”

- Uri Wilkensky

“We cannot solve our problems with the same thinking we used when we created them.”

– Albert Einstein

AGENT-BASED MODELING METHODS

The results of the Bunkhouse Creek archaeological project data can be used as a ‘reference pattern’ to create an agent-based model that tests the strengths and weaknesses of pre-contact and historical social systems’ manifestations of resilient behaviors against socio-natural perturbations. Computer simulations of baseline behaviors recreated from Bunkhouse data are expected to model the ‘real world’ scenario of an abrupt shift in social system dominance when the European system is introduced to the existing Salish social system. Using data collected from the Bunkhouse Creek archaeological project to recreate the Salish and European social systems within a computer simulation allows experimentation with abstract scenarios. Results from these abstract simulations inform a framework for sustainable development.

Agent-Based Modeling in Archaeology

Various scholars have already seen the utility of collating archaeological and environmental knowledge with computer simulation to investigate social systems and their interactions. Global case studies with various applications are available. The Model Based Archaeology of Socionatural Systems edited by Timothy Kohler and Sander van der Leeuw compiles case studies which in ecologists and social scientists collaborative efforts produce “specific, generally quantitative models that provide partial descriptions of socio-natural systems
of interest that are then examined against those systems (Kohler & van der Leeuw 2007, Berger et al.).” Contributions to this volume which specifically use agent-based modeling include the work of Tony J. Wilkinson et al., and Timothy Kohler et al.

Kohler et al.’s study is based in the Mesa Verde region. Their aim was to build a regionally nuanced agent-based model to examine the “causal structure” for a seven hundred year span of “settlement ecodynamics” (Kohler). The project takes several steps to achieve this goal, beginning with the compilation of historical and reconstructed ecological data with the archaeological record and ending with the translation of this data into an agent-based computer simulation. In initial runs, the model result’s lack of fit with the archaeological record allowed Kohler et al. to discern the effect of closed versus open systems on settlement success. This “informative failure” is a unique consequence of agent-based modeling as “departures of real human behavior from the expectations of a model identify potential causal variables not included in the model or specify new evidence to be sought in the archaeological record (Dean et al.).” Follow-up experiments are forth coming.

Utilizing archaeology and agent-based modeling to examine ancient Mesopotamian settlement systems, Wilkinson et al. uncovered one main social behavior that contributes to resiliency (2007, 2008). By modeling the socio-natural system, introducing both environmental and social stressors, and then testing for the social structure’s sensitivity to change, the project discovered exchange and production modification can lessen the impact of unpredictable environmental stressors. Future work by Wilkinson et al. hopes to establish a trajectory for their study community.

A 1998 seminal study Understanding Anazazi Culture Change by Dean et al. “[evaluated] the principles and procedures embodied in the Sugarscape model [created by Joshua
Epstein and Robert Axtell] and [explored] the ways in which bottom-up agent-based computer simulations can illuminate human behavior in a real world setting (1998, Axtell et al. 2002).” As done in the previous studies discussed, archaeological information from the Long House Valley in Arizona was paired with a rich landscape reconstruction in an agent-based modeling platform. The validity of the model was tested by how well model runs fit with the archaeological record. While in some cases the fit with the “real-world target” was surprisingly accurate, in others it differed. Overall, Dean et al. emphasized how both outcomes, a fit or a lack of one, assist in “[identifying] rules of agent behavior that account for those dynamics (1998).”

In Crabtree and Kohler’s Ecological Modeling Special Issue: Modeling across Millennia, the MedLanD project studied the effects of agro-pastoral land use on two areas in the Mediterranean region (Barton et al. 2012). Using the archaeological record and paleoclimate reconstruction “to test and refine” an agent-based model, the project discovered interesting information about the socio-natural system’s recursive relationship, specifically the relation between climate’s influence on landscape change.

A 2011 paper by Van der Leeuw et al. calls for moving “Toward an Integrated History to Guide the Future.” Several case studies of agent-based modeling, developed from a range of ecological and archaeological data, are presented which highlight the need for cross-scale (panarchical) study of socio-natural interactions. Integrating different scales will “yield new insights” to shape a future with greater potential for sustainability.

These papers present a common theme of pairing archaeology with agent-based modeling to not specifically predict the future, but to project scenarios for the future. These social simulation scholars take advantage of agent-based modeling’s interdisciplinary platform to
analyze the complexities of socio-natural systems. It is a test bed to explore alternatives and possibilities, to illuminate the previously unthought-of and unseen.

**Overview**

*Purpose*

The purpose of the Bitterroot Socio-Natural model is to test which social behaviors contribute to the resiliency of both culture and environment utilizing comparison between two differing social systems. The socio-natural dataset determined through archaeological and historical research completed at the Bunkhouse Creek Logging Camp site (24RA0798) paired with a review of resilience theory literature in archaeology provide a reference pattern for testing resilient behaviors as found in two differing social systems, the Bitterroot Salish, and incoming European settler population. Using Netlogo programming language, rules are imposed for both social systems in a closed and structured environment with stochastic demographic processes. (Senior et al. 2013; Wilensky 1999).

NetLogo is an agent-based modeling programming language developed by Uri Wilensky for simulating complex phenomena. This language uses “computational representations” rather than “advanced mathematical techniques that are tractable and allow us to calculate answers (Wilkensky & Rand 2015).” NetLogo is a free, open source program which encourages collaboration among programmers and therefore enriches the interdisciplinary aspect of this project (available at ccl.northwestern.edu/netlogo).

*Entities, States, Variables and Scales*

To test the research question - *Do differing social structures have differing capacities for resilience based on their differing manifestations of resilient behavior?* - a model must have the capacity to test two social systems at the same time as well as separately. NetLogo allows this
using ‘breeds’. Thus two different breeds are programmed into the model, A-persons and B-persons. A-persons are intended to be the Bitterroot Salish population and B-persons are intended to be the incoming European population based on the reference pattern provided by the Bunkhouse Creek project.

The Bitterroot Socio-Natural model is made up of these two breeds of agents who interact with the environment and other agents. Demographic regulation and population trends are based on stochastically determined mortality and reproduction rates (Senior et al. 2013). Reproduction occurs asexually and within certain age parameters (Epstein and Axtell 1996). The environment is made up of 1089 patches with a wrapping world. Each patch is a square shaped cell “endowed with varying amounts of a generic resource, and patch richness (as determined by carrying capacity of a patch and growth rate) is assigned at the start of the simulation (Kohler and van der Leeuw 2007).” Time passes in ticks in NetLogo. For this model one tick or iteration represents one year. Every model runs for one-thousand iterations or until population collapse. Population collapse is defined as no more individuals.

**Differences in Individual Rules**

The individuals of different breeds possess different land-use, common benefit, and movement rules. For the A-person breed these rules are based socio-natural variables or testable elements of the Bitterroot Salish social system and include: (1) equitable distribution of wealth and resources to provide for common benefit (2) demographic regulation with possible seasonal migration to prevent resource depression (3) utilization of diverse resources to prevent resource depression. The differing elements of the incoming European population social system (B-person breed) include: (1) unequitable distribution of wealth and resources altering levels of benefit (2)
sedentariness and sharp shifts in population (3) skewed resource dependence that effects biodiversity.

*Process Overview and Scheduling*

At every iteration all individuals (1) move, (2) harvest, (3) share, (4) randomly reproduce based on number of possible offspring, (5) age, and (6) randomly die (see Figure 9).

**Figure 9. Schematic of events**

**Design Concepts**

*Emergence*

The Bitterroot socio-natural model is interested in certain response variables. These include: (1) How long a population sustains before collapse, if collapse occurs, (2) how stable population levels are, (3) how much resource is maintained in the world, and (4) how equitably resources are shared.
Sensing

All individuals are able to determine the amount of resource on each patch which effects its suitability for harvest by that individual’s breed rule.

Interaction

Individuals of each breed are able to share with those of their own breed within a certain proximity.

Observations

Several measurements are taken at each iteration of a simulation run. These include: (1) distribution of resource calculated with Lorenz Curve and Gini Index graphs, (2) total populations for each ‘breed’, and (3) percent of resource available in the world. Steady or slightly fluxing population and resource levels indicate stability and reflect the socio-natural systems’ resiliency. Observations are recorded with real time graphing as well as in Excel spreadsheets. A model run terminates after 1000 iterations or population collapse. Experimental parameter settings are recorded at the start while any changes to setting mid-run are recorded at the time of introduction.

Details

Initialization

At initialization, the number of individuals for each breed are set by the slider mechanism and are randomly dispersed within the world. The age is set to zero. Both ‘breeds’ have the same properties of age, max-age and amount of starting resource.

```turtle
 turtles-own [ resource ;; the amount of resource an agent has age ;; the current age of this person (in ticks) max-age ;; the age at which this person will die of natural causes ]
```

Figure 10. Code for turtle properties
Trial runs (discussed in Chapter Six) established baselines for each breeds baseline parameter settings.

**Sub-models**

At each iteration seven events occur in the order described in Figure.

(1) **Movement/ Migration vs. Sedentariness**

The code for modeling migration or sedentariness constrains distance an agent can move to find the patch with the most amount of grass. Each social system has a different range. The Salish movement rule allows the A-person breed to target any patch in the world with the most grass. The European movement rule only allows the B-person breed to target the four surrounding patches. Thus the A-persons have a larger harvest range to replicate the migratory, seasonal lifestyle of the Salish tribe. More complex movement rules should be incorporated in future models and this will be discussed in a subsequent section.

```
to move ;; how to model migration with vision (high vision for migrators/lower for non?));; make quadrants with different growback rates for seasons?
  ifelse breed = apersons
    [ move-apersons ][
      if breed = bpersons
        [ move-bpersons ]
    end
end

to move-apersons
  let target max-one-of patches [ grass-amount ]
  face target
  move-to target
  set resource resource - 1
end

to move-bpersons
  let target max-one-of neighbors4 [ grass-amount ]
  face target
  move-to target
  set resource resource - 1
end
```

*Figure 11. Code for movement*
(2) Harvest/ Diverse utilization of resource vs. resource dependence

The harvest rates are modeled off of the Cooperation model found in NetLogo’s model library. Under this model, each breed harvests differently. The A-persons only harvest patches within their targeted movement range that have a grass-amount, or resource level, above five. Once on a patch with a resource level above five, an A-agent then harvests fifty percent of that patch. The B-person breed harvests any patch with a resource level above zero and harvests one-hundred percent of it.

As with all other code in this program, adjusting parameters for harvest levels requires only a simple change in one line of code, allowing the model a level of flexibility in its attempt to reference the Bitterroot Salish and the incoming European populations. Additionally, this flexibility allows users to change the parameters ‘mid-run’, representing an environmental or social stressor, and therefore testing the resiliency of the socio-natural system (Wilkinson et al. 2007).

```plaintext
to harvest
  ifelse breed = apersons
    [ harvest-apersons][
      if breed = bpersons
        [ harvest-bpersons ] ]
  end

to harvest-apersons ;; eat-cooperative from cooperation model and GL
  if grass-amount > 5
    [ let harvest-amount grass-amount * 0.50
      set grass-amount grass-amount - harvest-amount
      set resource resource + harvest-amount ]
    recolor-grass
  end

to harvest-bpersons ;; eat-greedy from cooperation model and GL
  if grass-amount > 0 [ 
    let harvest-amount grass-amount * 1
    set grass-amount grass-amount - harvest-amount
    set resource resource + harvest-amount ]
    recolor-grass
  end
```

*Figure 12. Code for land-use*
(3) Common Benefit/ Equitable distribution vs. unequitable

For both social systems, or ‘breeds’, the agent-based model reflects the resilient behavior of common benefit through the distribution of resources, or sharing (Adger 2000, Kirch 2007). Again, the agent’s ability to share is programmed using a slider; the interface mechanism changes sharing values with a sliding scale. Additionally, a parameter controlling who each agent shares with is programmed into the model. For the A-person breed, the Bitterroot Salish social structure, an agent shares with those of its breed within a patch radius of three. For the B-person breed, the European social structure, an agent shares with those of its breed within a patch radius of one. While the code that determines who an agent shares with does not use a slider to test heterogeneous inputs, the code only requires alteration in one location (see the Cooperation, Altruism and Diffused/ Direct network models available at ccl.northwestern.edu/netlogo).

```plaintext
; modified from diffusion on a directed network model
let recipients apersons in-radius 3 ;; larger radius to suggest more egalitarian, but what if no one from breed in radius? directed link network a better guarantee
if any? recipients [ ask recipients [ set resource resource + ( apersons-share-amount / count recipients ) ] ]
set resource resource - apersons-share-amount
end

to share-bpersons ;; modified from diffusion on a directed network model
let recipients bpersons in-radius 1
if any? recipients [ ask recipients [ set resource resource + ( bpersons-share-amount / count recipients ) ] ]
set resource resource - bpersons-share-amount
end
```

Figure 13. Code for Common Benefit
(4) Reproduction

An agent will produce a random amount of offspring greater than or equal to 0, but strictly less than the number chosen on the number-offspring slider on the interface. Thus for an agent to possibly reproduce, the slider must be set to at least two. When an agent reproduces, their resource level is divided by the number-offspring selected on the slider. These programming procedures allow easy adjustment of the amount of offspring. Many parameters can be explored, such as “varied forms of cultural regulation” present in a society (Kirch 2007).

```plaintext
Figure 14. Code for reproduction rates
```

to reproduce;;certain age and amount of resource range needed for reproduction; also add sex and neighbor component?
    ifelse breed = apersons [ reproduce-apersons ]
    [ if breed = bpersons [ reproduce-bpersons ] ]
end

to reproduce-apersons ;; must modify reproduction - look at % reproduction in wolf sheep predation model
    if age >= 15 and age <= 40 ;; and last_reproduced < current_tick - 4
        [ set resource resource / apersons-number-offspring
          hatch random (apersons-number-offspring) [ setup-apersons ] ]
    end

to reproduce-bpersons
    if age >= 15 and age <= 40 ;; and (last_reproduced < current_tick - 4)
        [ set resource resource / bpersons-number-offspring
          hatch random (bpersons-number-offspring) [ setup-bpersons ]]
    end
```

(5) Age

Both breeds have a randomly determined death age on or before the max-age of one-hundred is reached. This code is programmed into each breeds’ setup procedure as:

```plaintext
set max-age random-float 100
```

Figure 15. Code for max-age
This line of programming replicates the indiscriminateness of death in a simplistically accurate way, only dependent on a max-age of 100, an age ceiling that easily can be adjusted and altered.

(6) *Die*

Individual age is represented by the number of iterations an individual has existed within the world. Individuals of both breeds die randomly before max-age of 100 or when their resource level is less than zero.

(7) *Grass Regrowth*

This model endows patches with a carrying capacity (max-grass amount) of ten and a growth rate of 0.1 (Wilensky 2015).

```
to regrow-grass
  ask patches [ 
    set grass-amount grass-amount + 0.1
    if grass-amount > 10 [ 
      set grass-amount 10
    ]
  ]
```

*Figure 16. Code for resource growth rate, a patch procedure “Go”*
CHAPTER SIX

“Simulation needs to be a theory-guided enterprise and the results of simulation will of be the development of further theory, rather than the prediction of specific outcomes.”

- Nigel Gilbert and Klaus Troitzsch

THE BITTERROOT SOCIO-NATURAL MODEL

Following coding, multiple simulations were run with varying input parameters and the Bitterroot socio-natural model outputs observed (Bratley, Fox and Schrage 1987). The resulting emergent phenomena, the aggregate or macro system behavior not programmed into the code, was analyzed for causal relationships between resilient behavior and sustainability (Gilbert and Terna 1999, Wilensky 2015, Epistein & Axtell 1997). Each breed representative of a social system was tested individually to establish a baseline, then the two breed’s baselines were run at the same time in an attempt to replicate a historically accurate admixture of Europeans and Bitterroot Salish. Aggregate behaviors of population and resource were evaluated over time by preforming a sensitivity analysis and robustness check for each behavior and its effect on the longevity of a socio-natural system in the face of social and ecological stressors, or isolating the effect of a resilient behavior on the sustainability of the socio-natural system (Axtell et al. 2002, Wilensky 2015, Wilkinson 2007, Gilbert 2008).

The Bitterroot socio-natural model adheres to one of the core principals of agent-based modeling, which is to start with a simple model and increase complexity as need be; a simpler model is easier to verify (Wilensky 2015, Wilkinson et al. 2007). The Bitterroot model can be refined to make the cultural parameters more specific, but a level of generality more easily allows isolation of causal relationships between resilient behaviors and sustainability, the utility of which is demonstrated in the subsequent analysis.
Thus far it appears the agents of the differing social systems have been coded with properties that replicate in a general sense the real world target phenomena. The reflection of the real world target “face” validating the Bitterroot socio-natural model. “We then examine the behavior of the model and compare it with observations of the social world. If the output from the model and the data collected from the social world are sufficiently similar, we use this as evidence in favor of the validity of the model (or use a lack of similarity as evidence for disconfirmation) (Gilbert & Terna 1999).” Building on the data collection started with the excavation of the Bunkhouse Creek Project, a facsimile model and a more empirical validation of that facsimile can be achieved (Axtell et al. 2002, Dean et al. 2000, Gilbert 2008, Wilensky 2015).

Apparent from preliminary simulations, the Bitterroot socio-natural model produces massive amounts of data. With so many testable parameters, the Bitterroot model takes advantage of NetLogo’s Behavior Space feature to systematically organize run outputs into a referential spreadsheet. Behavior Space enables runs of a “specific a subset of values from the ranges of each slider, it will run the model with each possible combination of those values and, during each model run, record the results (Wilensky 2015).” Behavior space’s parameter sweep presents data in such a way that “you will be able to see relationships form between different sliders and the behavior of the system (Wilkensky 2015).”

Yet, Behavior space, by itself, does not allow adjustment of parameters mid-run, which is necessary to simulate environmental and social perturbations’ influence on the socio-natural system’s resiliency (Wilkinson 2007, 2008). Thus, sustainable parameters disentangled from Behavior Space data inform each social system’s baseline modeling. Then further testing of a
socio-natural system’s sustainability is conducted by exposing each social system to each other, as well as to other stressors.

Several measurements are taken at each tick of the model clock during a simulation run. These include: (1) distribution of resource calculated with Lorenz Curve and Gini Index graphs, (2) total populations for each ‘breed’, and (3) percent of resource available in the world. Steady or slightly fluxing population and resource levels indicate stability and reflect the socio-natural systems’ resiliency.

In this preliminary stage, simulations have been run “purposively to inspect combinations that we think are particularly interesting or that are close to regions where major changes in the simulation’s behavior are expected (phase changes, regime shifts)”, and those simulations have already managed to illuminate some interesting causal relationships between resilient behaviors and stressors (Bitterroot Socio-Natural Model available upon request).

“We shaped our world in ways less obvious and less intrusive than did the agricultural and urban societies to which the expedition members belonged, which exerted more direct control over the plants and animals they relied upon for food.”

- Confederated Salish and Kootenai Tribes

**Parameter Testing and Sensitivity**

Ethnographic and archaeological data reveals the pre-contact Bitterroot Salish to have a seasonally migrating, non-hierarchical, hunter-gatherer society (Frison 1978; Malouf C. 1969, 1974; Malouf R. 1979; McLeod& Melton 1986; Ronan 1890; Salish-Pend d’Oreille 2005; Teit 1927; Turney-High 1937; Wolf 1974). This established Native American tribe experienced an abrupt influx of European presence. Therefore, to account for this abrupt influx, parameters for a sustainable Native population must be modeled. For the Salish population, the A-person breed, a fairly arbitrary initial-population was selected. The population selection (497 agents) was based on a Behavior Space sweep, in which 90% of runs with varied population levels displayed
longevity for the Salish social system. Additionally, the Behavior Space parameter sweep revealed sharing to have a positive effect on population robustness. Thus, the A-person share slider was set at five, half their starting resource amount, intending to represent a generous, yet reasonable distribution of resource. Another component of resource distribution limits the sharing distance: A-persons share within a radius of three, to reflect their cooperative system. The offspring slider was set at three, meaning at random some agents reproduce between 0 - 2 children (Epstein and Axtell 1996). Also, A-person agents have free reign to move about the world targeting the patch with the most grass, meant to represent a migratory lifestyle. Their harvest rate of 50% before targeting a new patch is meant to represent traditional ecological knowledge of the landscape.

Introducing varied perturbations, excluding obvious socio-natural system devastations of no reproduction and no food growth, did not result in a complete collapse. Stressors were introduced by adjusting the parameters of grow-back, sharing, and offspring in various ways, and the A-person test model with the parameters of proved a suitable baseline.

Some behaviors discovered during this ‘stress ‘test’ confirm the model is simulating the real world; decreasing grow-back decreases population and a decrease in offspring produced an obvious drop in population. Other macro-level behaviors revealed interesting relationships to be further explored. For example, the interplay of share-amount and share-radius leads to questions of how much to share and with how many? A high level of both in combination is initially decreasing the population to manifest egalitarian resource distribution.

By default the European social structure, the B-person breed, is also modeled to be a sustainable reflection of its sedentary, stratified, and agricultural characteristics. Here again, the breed parameters are based off the historic and archaeological record. A low population (65
agents) was chosen to model initial European influx, to represent a trickle of settlers before the mid to late 1800s immigration assault on the region. To reflect the European stratified society, the B-person breed share-amount must be lower than that of the A-person breed and the B-person breed’s sharing radius is smaller than that of the A-breed. In an attempt to reproduce the sedentariness of the European agricultural lifestyle, the B-persons were given a smaller range of movement between “fertile” patches. Finally, to reflect lack of traditional ecological knowledge, the B-person harvest was set at 100% for any patch with more than zero resource. A Behavior space parameter sweep proved this combination of parameters to be 94% sustainable.

Again, a sensitivity analysis was run for the B-persons population. Once each baseline proved to reasonably sustain individually against perturbations, a combination model was setup to run both those sustainable examples at the same time.

Results

Baseline Combination Run

The Bitterroot socio-natural model attempts to recreate the reality of the European influx using known history about the European effect on the Native American population. An admixture of B-persons (European) with A-persons (Salish) in the Bitterroot model should cause an impact or disturbance on A-persons social ‘infrastructure’, as to replicate no longer being able to practice their traditional ways in their traditional lands (Adger 2000). The Bitterroot socio-natural model validates this hypothesis when incorporating a smaller B-person population with a medium-sized A-person population: the smaller B-person population dominates the landscape, reducing the available grass-amount to levels not supported by the A-person harvest rule.

How quickly the smaller B-person population harvest rule effects the combination model run is impressive. A parameter sweep shows that generally in about fifty ticks of the model run
clock, the A-person population drops to zero and the resource is depressed to extremely minimal levels. Yet, at this extremely minimal resource level, about 1-10% of total possible resource, the B-person population maintains but high levels of population flux.

Figure 16. Baseline Run

**Run Variant 1: Less Offspring**

This scenario variant introduces a social change by altering the number of offspring an agent has the possibility to produce to only one. This alteration does not change the outcome for the Salish representation; the A-person population is still reduced to zero in generally fifty ticks. After the plummet of the A-person population, the B-person population does differ from the baseline combination run (above) in that the reduction of offspring results in steadier resource, resource amount per agent, and population levels. The steadier outputs confirm Kirch’s, among others’, conclusion that a “key aspect” to sustainability is “a deeply ingrained sense of population regulation (2007).”
Run Variant 2: Differing the Share-amount

In this variant, the Bitterroot socio-natural model introduced a social change by adjusting the distribution of resource for each population. The A-persons share-amount and share-radius are both increased to ten based on the sensitivity analysis results of previous parameter sweeps, which suggest that conjunctionally increased share parameters support the longevity and robustness of a socio-natural system, while lowered sharing parameters result in more resource and population level fluctuations. The A-person population maintains its presence in the admixed world much longer before failure, yet the continued survival of the B-person population occurs amid rapid changes of population and resource levels.
Run Variant 3: Differing Grow-back rates

Another baseline variant introduces the environmental stressor of a reduced resource grow-back rate. Using baseline parameters, and reducing only grow-back rates (0.1 to 0.05), not much changes compared to the baseline combination run of the Bitterroot socio-natural model. The Salish representation is still reduced to zero and the European representation still manages past 1000 ticks in a highly fluctuating manner.

A grow-back variant was run again, only lowering the rate even more extremely, to 0.01. This run resulted in both populations dying out. This points to an ecological disturbance threshold for the European representation as well as continues to confirm the B-person harvest rate (consumption rate) as detrimental to the resource which effects their own survival.

Figure 19. Grow-back at 0.01 variant

Run Variant 4: Differing share-amount and grow-back rates in combination

This Bitterroot socio-natural model variant combines the two above variants of sharing and grow-back: the sharing parameters of the share variant above are placed on both populations, then the grow-back rate is reduced. Results of the 0.05 grow-back rate run show the Salish representation out lasted the European representation and survived past 1000 ticks, suggesting
increased distribution of resource parameters and knowledge of landscape through harvest rates support their survival.

Figure 20. Combination increased sharing and reduced grow-back of 0.05 variant

When the grow-back rate is lowered more extremely to 0.01, the A-person population again outlasted the B-persons. Yet, after an attempted A-person population increase in the marginal resource environment, the A-person population failed, suggesting a threshold for the length of time a population can survive in a marginal environment.
CHAPTER SEVEN

“This may be because the principal value of simulation in the social sciences is for theory development rather than for prediction.”

- Nigel Gilbert and Pietro Terna 1999

“I believe we can as individuals and maybe even as organized groups, most effectively work….even when not explicitly part of any movement, but when simply aware of similar goals at a local scale.”

- Barbara Little 2009

DISCUSSION AND CONCLUSIONS

The Bunkhouse Creek archaeological project produced an interdisciplinary chronology of socio-natural systems which served as a ‘reference pattern’ for the Bitterroot socio-natural computer simulations. Integrating archeological data with agent-based modeling enables experimentation with abstract scenarios informed by real world data but that exceed a known outcome. Although the Bitterroot socio-natural model results are limited, the model achieved its aim with its ability to extend beyond a known outcome and isolate resilient behavior aspects of a socio-natural system. Results from this social simulation approach inform contemporary social issues, specifically sustainable development. Archaeology’s role in the social simulation approach is fundamental as it uniquely provides the necessary applicable examples for experimentation. Furthermore, agent-based modeling demonstrates its value for theory advancement.

The Bitterroot socio-natural model is an agent-based model that tests a social structures’ resiliency through measured runs and whose results offer new analytical possibilities in an effort to answer the research question: Do differing social structures have differing capacities for resilience based on their differing manifestations of resilient behavior? The Bitterroot model is a ‘face-validated’ general template (middle-range) model programmed from a synthesis of “documented historical knowledge of past human-environment interactions” and resilient
behaviors exposed through resilience theory research on complex socio-natural systems (Hardesty 2007; Kirch 2007). The above Bitterroot socio-natural model variants are just a sampling of simulations explored, yet these initial Bitterroot simulation outcomes provide insight into the relationships between resilient behaviors and socio-natural stressors. Moreover, variant run results have acted as a level of confirmation for resilience theory findings by Kirch (2007), Adger (2000), Ostrom (2007), Van der Leeuw (1992), and Wilkinson (2007), among others. Because the Bitterroot socio-natural model can accept so many possible alterations and refinements, the continued testing of resilient behaviors will take invested research of specific parameter combinations.

The Bitterroot model experiments with a combination of resilient behaviors in the face of stressors and the outcomes of the simulations inform a framework for sustainable development (Fisher et al. 2009, Holling 1998). The following are outcomes from the Bitterroot socio-natural model simulations to be considered in planning for sustainability. First, a social system can manage to maintain in the very marginal environment it has created, but the tradeoff for high consumption levels forces a decrease in population size so the system can persist on the remaining resources. Awareness of the recursive relationship between humans and the environment appears to more stably sustain a social system (Salish et al. 2005).

Next, simulations of differing offspring numbers support scholars’ findings on the regulation of population contributing to the robustness of the socio-natural system, as lower populations inherently use less resources (Kirch, Adger). Additionally, simulation outcomes suggest sharing as a form of population regulation. Equitable distribution of resources contributes most effectively to sustainability when the scale and scope of distribution is increased.
Finally, the Bitterroot socio-natural model outcomes suggest a social system has scaffolding against environmental shocks if it has manifested behaviors that respect carrying capacity of the natural system, population regulation, and more egalitarian approaches. As such, sustainable development must explore research avenues in adaptability of resilient behaviors and implementation.

Moreover, the research efforts of the Bunkhouse Creek Archaeological Project and Bitterroot socio-natural model advocate for transdisciplinary research as both incorporate biological and social sciences with a new avenue of generative science, agent-based modeling (Epstein 2006). While the Bitterroot socio-natural computer simulation model does not import quantitative empirical data collected from the Bunkhouse Creek Excavation, the methodologies used in investigating the site are an example of how to collect such data for use in a detailed regional model and confirms archaeology as necessary for empirical validation. Previous scholars have incorporated archaeology with agent-based modeling in this specific arena of resilience theory in complex socio-natural systems (Axtell et al. 2002; Dean et al. 2000; Kohler and van der Leeuw 2007; Wilkinson et al. 2007). These scholars’ models are more advanced, specific, and nuanced because of the employment of retrodicted socio-natural empirical data realized from the archaeological and environmental record.

**Recommendations**

The archaeological recommendations are reiterated here briefly, because enhancement of the Bunkhouse Creek investigation will only enhance the following recommendations for the Bitterroot socio-natural model. Further investigation into who operated the camp should be completed by continued records research and further excavation of site 24RA0798 along with
more chronologically in depth ecological landscape analysis that includes liminological testing and more extensive records research.

As previously discussed, the combination possibilities of the Bitterroot socio-natural model are extensive. Still, many more research possibilities are available with various model modifications.

Suggested Bitterroot socio-natural model refinements and modifications includes the generation of a facsimile model by building on the data collection started with the excavation of the Bunkhouse Creek Project. Development of the facsimile is one way more dynamic possibilities are available for the representation of social systems. Additionally, with an empirically based model, arbitrary demographic numbers possibly can be avoided and enhance knowledge of population regulation.

Small alterations can be made to the existing code without the need for extensive empirical research as is needed above. The Bitterroot socio-natural model is currently a closed system which if opened to simulate immigration, has potential to reveal more interesting resilient behavior relational patterns. Additionally, more diverse resources along with diverse use of those resources would enhance the program. Moreover, introducing a level of diversity and modifying to an open system would produce dynamic resource growth rates, advanced migratory and movement patterns and allow for more socio-natural perturbations to be tested.

Another avenue to achieve higher variance in social complexity use of NetLogo’s Hubnet. Hubnet is participatory simulation offering that allows models to run by its programmed rules as well as by human participation.

The Bitterroot socio-natural model can also be advanced with innovation coding. This can be achieved by either equipping agents with coping mechanisms in the programming stage or
including a genetic algorithm in which agents learn (Gilbert 2008, Wilkinson 2007). Future simulations with this modification have the potential to illuminate much about resilient behavior adoption and sustainable development education. All the above extensions will assist in moving the Bitterroot socio-natural model “toward a testable, dynamic, quantitative model that incorporates feedback processes; thresholds and nonlinearities…” (Kohler & van der Leeuw 2007)

Finally, all good research must utilize multiple forms of analysis. NetLogo has many built-ins to allow easier generation of data. Beyond continued use of Behavior Space and its transferal to a statistical package, the enhancements available from and for NetLogo should be further explored and implemented. Thorough analysis contributes to the growing database of resilience testing and the future analysis of cross-scale interactions.
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