THE TAPHONOMIC HISTORY OF THE VERTEBRATE FAUNAL ASSEMBLAGE
FROM BRITISH CAMP, SAN JUAN ISLANDS, WASHINGTON

by

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THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS

in the
Department of Archaeology

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SIMON FRASER UNIVERSITY
July 1999

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0-612-51445-5
**ABSTRACT**

This study is an analysis of the taphonomic history of the faunal assemblage from the British Camp shell midden site on San Juan Island, Washington, and assesses the role of groundwater diagenesis in the post-depositional alteration of the vertebrate faunal assemblage. The sediments (shell and soils) in the lower portion of this site may have undergone diagenetic alteration due to the effects of groundwater, which has been shown by previous research to have the potential to remove molecules from shell and soil constituents at this site.

In order to determine whether the faunal assemblage has been diagenetically altered, the distributions of element density, fragmentation, survivability and identifiability from groundwater-saturated and dry contexts were examined. The results show that faunal material from groundwater-saturated deposits has undergone significantly more post-depositional attrition than material from dry deposits. Faunal material from groundwater-saturated deposits is more fragmentary, composed of a larger portion of unidentifiable material, and is made up of denser elements, which consistently survive attritional processes better than elements of lower densities. A working hypothesis of alteration of bone specimens by groundwater leaching provides the best fit for data derived from this study, although it is beset by equifinality problems. It appears that leaching has altered the compositional structure of the assemblage, leading to biases against less durable elements and taxa. Simple taphonomic methods have been shown to be suitable to identify the influence of post-depositional attrition.
ACKNOWLEDGEMENTS

Although the errors and deficiencies of this research are solely my responsibility, many people contributed to its success. Jon Driver, my senior supervisor, provided advice, instruction, and encouragement, and helped to arrange for volunteers and a work-study student to help me when I got bogged down in the seemingly endless task of identifying thousands of tiny fish bones. These patient workers were Cindy Barwell, Kira Neher, Colleen Bruchet, and Tal Fisher, and their contributions were completely invaluable.

Roy Carlson provided helpful input and criticism during the writing process, and his knowledge of the region was very useful to me and provided a standard to which I had to ‘measure up’. Catherine Carlson gave many valuable insights and suggestions, and could relate well to the experience of identifying such a large sample of fish bones.

This research would not have been possible without the pioneering work conducted by Julie Stein and the University of Washington at British Camp, and she also provided much valuable advice to me, especially in the early stages when I didn’t know exactly what I was doing. The Burke Museum provided access to their collections, and Laura Phillips arranged logistic support and was always happy to help. Finally, Sara Yoshida gave me moral support and the confidence to finish what I started, and also provided a far better reason to attend school than to conduct zooarchaeological research.
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1.0 INTRODUCTION

This thesis is concerned with the taphonomic processes affecting a vertebrate faunal assemblage excavated from a Northwest Coast shell midden, the British Camp Site on San Juan Island, Washington. An understanding of the taphonomy of a zooarchaeological assemblage is an understanding of the history of animal bones as they pass from a living animal population, through a cultural context, into an archaeological deposit, and finally into an analytic context in the lab of a zooarchaeologist, and of what changes these bones and the assemblage as a whole may have undergone during this process.

The research goals of this thesis are relatively straightforward: to investigate the depositional history of the British Camp vertebrate assemblage, determine whether this assemblage has been impacted by leaching, and demonstrate that a set of methodological tools can be developed which will identify the effects of leaching on a faunal assemblage. These goals will be accomplished by the application of zooarchaeological and taphonomic methods to the assemblage, and comparison of the characteristics of that assemblage between different depositional contexts.

Considerable research has already been conducted at the British Camp site in order to understand the specific formation processes that can affect coastal shell middens. It was argued by University of Washington researchers that significant post-depositional pedological, sedimentological and chemical changes had occurred within the midden, leading to the destruction of shell and the alteration of sediments in the lower layers of the midden. These changes are associated with leaching and the chemistry of the interaction between groundwater and midden matrix (Stein 1992a and 1992b).

This thesis is an investigation of the taphonomic history of the vertebrate faunal assemblage from the British Camp shell midden. The structure of the assemblage is examined from a taphonomic perspective. The role of fragmentation and density mediated attrition of animal bone during the taphonomic history of the British Camp assemblage will be examined, with the aim of determining how post-burial factors have contributed to the structure of the assemblage and whether post-burial factors have impacted different parts of the midden assemblage in different ways.
1.1 BACKGROUND

1.1.1 Taphonomy

Zooarchaeology is founded on the notion that the behavior of past cultures, societies, groups and individuals may be inferred via the surviving material correlates (faunal assemblages) of that behavior. Inferences about behavior may be aimed at broad-based social patterns such as ideology, power shifts and class conflicts, or may be focused upon more restricted goals, such as discovering the clothing people wore, the food they ate, or how their tools were made.

These inferences would be relatively straightforward were it not for the fact that the relationship between past behavior and the resulting faunal assemblage is very complex and is mediated by numerous cultural and natural taphonomic processes which can obscure, randomize, or bias the relationship between material remains and behavior (Schiffer 1983:677). The existence of these taphonomic processes has long been recognized by zooarchaeologists, but it was not until the late 1970s and early 1980s that large numbers of studies appeared which dealt explicitly with their effect upon patterning in the zooarchaeological record.

Taphonomy may be defined operationally as all post-mortem events affecting archaeological bone and the sediments which contain it (Olson 1980:6). It therefore includes a large number of processes, from trampling, butchery patterns, chemical leaching and carnivore chewing (all of which affect bone directly) to processes which affect the context of the archaeological bone, such as site formation and sediment type.

For zooarchaeologists interested in correlating patterns occurring in the archaeological record with cultural patterns, an understanding of taphonomy is crucial (Binford and Bertram 1977:77; Gifford 1980:93). Because bone is a perishable and malleable material, it does not survive unmodified over time (Haynes 1981:7), and often does not survive at all. Temporal changes in the structure and composition of animal bone assemblages are highly variable, and do not affect all bone equally. The trend of bone in archaeological assemblages is entropic, changing towards a state of greater disorganization (Schiffer 1983:676). Taphonomic processes may mask cultural patterns occurring in faunal remains, or they may create spurious ones; a type of systematic bias. Control of these biases depends upon the development of middle range theory, which is intended
to connect the patterning evident within the archaeological record with a body of general theory (Binford 1977:7), and upon the examination of taphonomic patterns in specific zooarchaeological assemblages.

The study of taphonomy is viewed as an essential component of paleoecological research (Gifford 1981:368) but is very often ignored in zooarchaeological investigations on the Northwest Coast. Zooarchaeologists frequently attempt to determine the relative frequencies of different animal categories from different contexts within a site or between sites, making comparisons over time or across space, and targeting changing cultural patterns. Before this can be undertaken, however, it is important to determine whether the taphonomic patterning of a faunal assemblage is equivalent in different contexts, because if it is not, then the observed differences between contexts may be due to the taphonomic patterns rather than the target cultural patterns (Hesse and Wapnish 1985:96; Lyman 1994:5-6). The relative abundance of taxa may be significantly altered in an assemblage which has been heavily impacted (Marean 1991:679).

In order to have confidence in their results, zooarchaeologists must tailor their research designs to take taphonomic bias into account on a case by case basis (Marean 1991:691; Stallibrass 1990:151). Patterning within the archaeological record is the result of a continuous interaction between cultural and natural systems. Zooarchaeological assemblages are not deposited and then left in a static condition, but are in a dynamic state which is the result of a range of cultural and natural processes (Hassan 1987:3). These processes constitute taphonomy, and as the importance of taphonomic factors within the archaeological record becomes more and more apparent, actualistic research and the study of taphonomy in the prehistoric remains themselves becomes more highly developed. This has been the case in Africa, where studies of taphonomy have helped to separate accumulative agents in very ancient faunal assemblages (Brain 1981), but taphonomic studies are still relatively underdeveloped on the Northwest Coast.

1.1.2 Shell Midden Taphonomy

Shell middens, sites where shell material comprises the bulk of the matrix of a site, are common at prehistoric habitation locations on the Northwest Coast. Much of our knowledge about past subsistence and economic patterns in this area is based upon zooarchaeological assemblages
excavated from shell middens (Boucher 1976; Cannon 1991; Coupland et al. 1993; Hanson 1991; Mitchell 1971). Postdepositional alteration of midden constituents in shell midden sites is rarely addressed before making subsistence inferences (Muckle 1985:23; Waselkov 1987:146), meaning that the status of biases in the faunal assemblages are unknown, and the relationship between zooarchaeological assemblages and the target cultural patterns is unknown. Researchers frequently make the observation that older deposits appear to be more heavily impacted (Cannon 1991; Wigen 1995; Wigen and Stucki 1988), but inferences about taphonomy tend to stop here and the causes and effects are not addressed, or remain speculative. Working concepts about the formation of shell middens also remain relatively simplistic ( Claassen 1991; Muckle 1985:1).

It has been traditionally assumed that bone is very well preserved in shell middens due to alkaline soil environments (Linse 1992:327; Cannon 1991:87). It has also been assumed that the depositional and post-depositional processes which affect shell middens demonstrate a high degree of uniformity, and therefore do not require a new set of methodological tools (Claassen 1991:249). Assumptions about uniformity and preservation have been shown to be largely untrue, however (Claassen 1991; Ham 1982; Muckle 1985), and the relationship between preservation and soil pH is very complex (Linse 1992; Lyman 1994:422). Bone in deposits having more alkaline pH values (pH > 7.0) does tend to be better preserved than bone deposited in acidic contexts, but soils with pH values higher than 7.88 can facilitate attrition of bone material. Soil pH values higher than 7.88 occur relatively frequently in Northwest Coast shell middens (Linse 1992).

Shell midden formation processes differ from those active at other archaeological sites, as vertebrate faunal remains and artifactual material are deposited in a shell midden along with large amounts of shell (Ham 1982:144). Shell vastly outweighs all other midden constituents, and the input of shell into a soil matrix can significantly change the chemical makeup of soil and groundwater. Shell middens are also characterized by increased porosity, permeability, alkalinity and a high probability of being saturated or inundated by adjacent bodies of water (Stein 1992a:1). These natural processes, in addition to distinctive cultural processes involved in midden accumulation (Meehan 1982), serve to separate shell midden sites from other archaeological deposits.
Because shell midden formation processes are so complex, the taphonomic history of shell midden vertebrate assemblages also tends to be complex. Deposition rates in shell middens tend to be very rapid in comparison with sites that do not have shell as part of the matrix, because the large volume of shell material leads to rapid burial of archaeological material. However, deposition rates can vary widely as some layers may be deposited slowly and with a minimum of shell, while other layers may be composed almost wholly of shell and have accumulated rapidly. Rapid burial in turn leads to better preservation of bones, as they are exposed to surface weathering agents like ultraviolet radiation for a shorter period of time (Lyman 1994:360, Behrensmeyer 1978:150).

1.1.3 Chemical Composition and Structure of Bone

Bone consists of both an organic phase, composed largely of collagen, which forms a matrix surrounding and supporting an inorganic phase in crystalline form composed largely of hydroxyapatite \( [\text{Ca}_{10}(\text{PO}_4)_6\text{OH}_2] \) (Sillen 1989:213). Collagen accounts for approximately one third of the dry weight of bone, and is primarily made up of interconnected protein fibres (Schultz 1997:189-191). The chemical makeup of collagen is very complex (Child 1995:165).

Collagen fibres are bonded to hydroxyapatite crystals, which form the inorganic, mineral component of bone, and accounts for approximately two thirds of its dry weight. The mineral portion of bone also includes lesser quantities of minerals such as citrate, nitrate, sodium, magnesium, fluoride and strontium (Shultz 1997:190-191). Hydroxyapatite is sometimes referred to as calcium phosphate (Linse 1992:328) or apatite (Sillen 1989:219). Live bone also contains a substantial portion of water molecules which quickly disappear following the death of the organism (Schultz 1997:190). Both collagen (Hare 1980:213-214; Turner-Walker and Parry 1995:190) and hydroxyapatite (Dodd and Stanton 1981:128) are subject to leaching and hydrolysis in groundwater. Removal of these molecules will compromise the structural integrity of bone (Hare 1980:217).

Macroscopically, bone is composed of two types of skeletal tissue: cancellous and compact bone. These two types of bone are distinguished primarily by the size of pores present within their structure: cancellous bone has large pores, while compact bone has few, if any, pores. Compact
bone is much more dense than cancellous bone (Lyman 1994:85). The density of archaeological bone has been shown to be directly related to its tensile strength, and therefore its ability to survive attritional processes (Turner-Walker and Parry 1995:187-188). These attritional processes can be either chemical or mechanical; denser bone will survive in higher frequencies.

When animal bones are impacted by an attritional process, either mechanical or chemical, the extent to which particular elements or portions of elements are altered is controlled by the available surface area of each particular element (Hedges and Millard 1995:157). Surface area is in turn a function of the density, size and geometry of a particular element. Dense elements have a low surface area to mass ratio because they contain less pore space, and are therefore less subject to the effects of attritional processes. The size of particular elements, especially for very small taxa such as rodents, also plays a role in the mediation of attritional processes, because smaller elements have a higher surface area to mass ratio (Lyman 1984:260).

In mammals and birds, compact bone forms the outer surface of the shafts of long bones, the articular surfaces, and the exterior surface of flat bones like the scapulae or cranial vault. Cancellous bone forms the epiphyses of long bones and the interior of flat bones and vertebrae. In birds, pore spaces in cancellous bone are very large. In fish, the configuration of cancellous and compact bone is much more complex, and the division between the two types less obvious. Because cancellous bone is much less dense than compact bone, and because its greater porosity translates to a greater surface area on which chemical processes can act, it tends to be preferentially destroyed by attritional processes (Marean 1991:679-683; Sillen 1989:212). The density and porosity of different vertebrate skeletal elements is largely dependent upon their ratio of compact to cancellous bone.

1.1.4 Groundwater, Diagenesis and Leaching

The British Camp vertebrate assemblage is likely similar to most other zooarchaeological assemblages in that it has been affected by a wide range of taphonomic processes (e.g. Lyman 1994). However, diagenetic factors have already been identified as significant factors in the formation of the British Camp Site (Stein 1992b), and these diagenetic factors probably also play a major role in the patterning of the vertebrate assemblage.
Diagenesis can be defined operationally as post-burial alteration of archaeological material (Lyman 1994:417), and encompasses many processes, including soil compaction, trampling, replacement of bone material by soil minerals, and the leaching of bone constituents through the groundwater concentration gradient, although the term is most frequently used by archaeologists to denote chemical changes in bone. Hydroxyapatite crystals can grow larger as a result of diagenesis, but this does not ordinarily affect bone until it is over 1,000 years old (Sillen 1989:215). Only the process of leaching is considered to be relevant to this thesis.

Chemical diagenesis at the molecular level has been of increasing interest to researchers working on the reconstruction of past subsistence through isotopic and trace element analysis in human bone (Child 1995; Hedges et al. 1995; Hedges and Millard 1995; Sillen 1989). These researchers have largely focused on microstructural and molecular changes in bone. They have shown that the molecular constituents of bone, both organic and inorganic, are soluble and highly mobile in particular soil and groundwater environments. The effects of chemical diagenesis upon the structure of entire assemblages of animal bones, and upon the structural integrity of bone, is not well understood (Marean 1991:679).

Leaching is a diagenetic process which involves the transport of water soluble molecules from a buried substance (in archaeology, usually bone, shell or sediment particles) into the surrounding water table in the form of solutes in groundwater (Lyman 1994:420). Leaching affects hydroxyapatite, the inorganic component of bone. Collagen, the organic component of bone, can be removed or altered by hydrolysis (Turner-Walker and Parry 1995:190). It has also been described as chemical weathering (White and Hannus 1983:316), but leaching, in the context of sedimentology, is a more accurate term (Allaby and Allaby 1990:214). Soil scientists have long known that leaching can cause horizonation and alteration of sediments (Gordon and Buikstra 1981:568).

On the Northwest Coast of North America, it has been demonstrated that groundwater leaching can negatively influence the survival of invertebrate (shell) assemblages in middens, sometimes entirely eliminating shell from deposits (Ham 1982; Mitchell 1971; Muckle 1985; Stein 1992b; Sullivan 1993). Calcium carbonate, a primary constituent of shell, can be leached from midden deposits by a combination of groundwater solution and organic acids resulting from the decay of
organic midden constituents (Stein 1992b:138). Carbon dioxide, present in soils in concentrations much greater than in the atmosphere, combines with groundwater to form carbonic acid \([\text{H}_2\text{CO}_3]\). Carbonic acid reacts with the calcium carbonate in shell \([\text{CaCO}_3]\), freeing calcium ions \([\text{Ca}^{2+}]\) and creating bicarbonate \([2\text{HCO}_3^-]\). Bicarbonate raises the pH of the groundwater solution to a more alkaline level (Sullivan 1993:7). The end result is that large volumes of calcium are removed from shell and suspended in the groundwater.

Leaching can also affect archaeological bone in much the same way, removing calcium via the reaction described above, or collagen may be removed via hydrolysis. Calcium ions are freed from hydroxyapatite by carbonic acid (formed by a the combination of groundwater with sediment carbon dioxide) and move from the buried bone into the groundwater solution (Gill-King 1997:105), where they either remain suspended or are removed in active groundwater regimes. The chemical processes involved in the leaching of bone are much more complex than those involved with shell, and are still not well understood.

Klein and Cruz-Uribe (1984:69) point out that in most zooarchaeological studies, post-depositional factors such as leaching are not often considered significant taphonomic factors, and that the processes which lead from the transformation of a deposited assemblage to a fossil assemblage are largely unknown. Much zooarchaeological research does not take taphonomy into account at all, and those that do often ignore post-depositional factors in favor of pre-depositional factors such as butchery patterns or carnivore effects.

Klein and Cruz-Uribe (1984) suggest that diagenesis, including leaching and sediment compaction, is the cause of differences between faunal assemblages from two different burial contexts (Level 4 and Level 6) at a Lower Magdalenian cave site in Spain. They note that the Level 4 assemblage is more highly fragmented, as indicated by a high Number of Identified Specimens (NISP) to Minimum Number of Individuals (MNI) ratio, and is composed of a larger proportion of small, compact bones such as sesamoids, carpals, tarsals and phalanges (Klein and Cruz-Uribe 1984:69-75). They do not distinguish leaching from compaction, but the underlying pattern is apparent: assemblages that have been impacted will be more fragmentary and composed of a higher proportion of dense elements.
The groundwater regime (Hedges and Millard 1995), soil pH (Gordon and Buikstra 1981; Linse 1992), and the type and amount of organic material present (Child 1995) are important factors which mediate the rate at which leaching occurs. Leaching of the inorganic, mineral component of bone (hydroxyapatite) occurs when bone is not in equilibrium with the surrounding matrix and groundwater (White and Hannus 1983:321), and the destruction of the organic portion of bone, collagen, can occur as a result of microbial activity (Child 1995:168) or via hydrolysis of collagen into the groundwater regime (Turner-Walker and Parry 1995:190). The organic component of bone is generally the first to experience attrition (Ascenzi 1969: 527; Turner-Walker and Parry 1995:190; White and Hannus 1983:316).

In archaeological assemblages, the tensile strength of bone decreases proportionate to the magnitude of attritional processes and the length of time these processes have been acting on bone. The relationship between bone density, bone attrition, and the loss of tensile strength is very complex. It appears that in burial environments, a rapid initial reduction in tensile strength occurs as a result of the loss of collagen, followed by a slower decrease in tensile strength as the porosity of bone increases over time (Turner-Walker and Parry 1995:190).

Soil pH has the potential to increase the mobility of hydroxyapatite in a solution, increasing the rate of mineral leaching. Hydroxyapatite is least soluble in water at a pH of 7.88, and solutions with pH values differing from 7.88 demonstrate greater solubility of hydroxyapatite the further away the values are from the 7.88 baseline (Lindsay 1979:181). Even though hydroxyapatite is least soluble at this pH value, it is still mobile in solution, and leaching can proceed at this pH level given sufficient time and groundwater replacement (Hedges and Millard 1995:159). Alkaline sediments with pH values greater than 7.88 theoretically have the potential to postdepositionally alter vertebrate assemblages (Lindsay 1979:181), but this has not yet been adequately documented at an archaeological site.

Sediment pH controls the exchange of ions, dissolution, and oxidization. In acid soils, hydrogen ions are more active (McBride 1994:169) and are therefore available to replace calcium ions dissolved from hydroxyapatite (White and Hannus 1983:316). Calcium ions can then be transported in the groundwater.
Time also plays a role, of course, as the leaching of minerals is progressive and continuous, and the relationship is not straightforward or precisely predictable (Sillen 1989:212; Turner-Walker and Parry 1995). The effects of in-situ chemical processes on a shell midden vertebrate assemblage have never been studied on the Northwest Coast. The potential for these processes to impact vertebrate assemblages, and the type of impact that may occur, are currently unknown, and form the focus of this thesis project.

Northwest Coast shell middens are located close to shorelines, a situation which is conducive to shallow water tables and water tables in which rates of groundwater flow are high due to tidal effects (Whittaker and Stein 1992:37; Stein 1992b:138, 148). The high rate of precipitation during the winter in this region is also conducive to active groundwater regimes. It has been suggested by some researchers (Mitchell 1971; Stein 1992a; Sullivan 1993) that groundwater is responsible for the leaching of shell carbonate from shell middens on the Northwest Coast, producing a black, shell-free layer at the base of the affected deposit. These black layers are often relatively homogenous and horizontally oriented, lending support to this hypothesis (Mitchell 1971:88).

Leaching only affects molecules that are soluble in water (Stein et. al. 1992:109). Because a large component of bone is formed by water soluble molecules, groundwater has the potential to leach the collagen/hydroxyapatite matrix from bone as well as leach calcium carbonate from shell, and thereby alter the nature of entire vertebrate assemblages. This subject has not been studied intensively by zooarchaeologists, and not at all on the Northwest Coast.

There are three hydrologic zones in soil environments: the vadose, phreatic, and mixed zones. The vadose zone exists between the soil surface and the upper level of the water table, and is not saturated by water. Meteoric groundwater, from precipitation, percolates downward through the vadose zone to the phreatic zone, which forms the water table. The phreatic zone is consistently saturated, and pore spaces in this zone are filled primarily with water (Figure 1.1). A mixed zone can occur in coastal areas where marine waters can mix with groundwater in the soil environment (Moore 1989:172-174; Sullivan 1993:8).

The presence of groundwater is crucial for leaching. In order for leaching to occur, a particular bone must be in chemical disequilibrium with a surrounding solution, which in the case of
archaeological sites is formed by the groundwater. Molecules diffuse along a concentration gradient. If groundwater is not already saturated with the elements that make up bone, then these elements, both organic and inorganic, will move from the bone into the surrounding groundwater (Hare 1980:213-214; Dodd and Stanton 1981:128). Groundwater can also transport organic acids, leading to increased dissolution rates in areas other than the source of the organic acids (Sullivan 1993:35-36).

![Diagram of the British Camp groundwater regime](image)

Figure 1.1. Simplified diagram of the British Camp groundwater regime. The water table is present below 80 cm, where the deposits are consistently moist. Above 80 cm, the shell midden is very porous and is consistently dry. Meteoric groundwater and laterally flowing groundwater recharges the water table with a non-saturate solution, while groundwater discharges to the south into Garrison Bay.

This process will continue as long as the groundwater and the surrounding bone are in disequilibrium (Hedges and Millard 1995:159). Molecules can also move from a groundwater solution into bone, leading to mineralization, if those molecules occur in a lower density than the surrounding bone (Lyman 1994:420-421). It is therefore crucial that groundwater flow rates be fast enough to maintain disequilibrium, and that there is no separate calcium source.

Unfortunately, measurement or estimation of the flow rate of groundwater is extremely difficult because flow rate depends upon the porosity of the soil, the amount of water entering the groundwater regime through precipitation, and the water content of the soil. Flow rates tend to be greatest at the surface, from meteoric groundwater, and in the water table itself. An
intermediate point between the surface and the water table often has no discernible flow (Hedges and Millard 1995:157).

Leaching will be relatively slow in soil environments where there is little or no replacement of groundwater in the water table, but in environments where replacement occurs quickly because flow rates are high, disequilibrium between bone and groundwater is maintained and diagenesis can proceed (Lyman 1994:422; Stein 1992b:138-139; Sullivan 1993:39-42). The process would still require centuries, if not millennia (Stein 1992b:139). Leaching would be slowed or halted in situations where the surrounding groundwater solution is at near-saturation levels with calcium ions obtained from natural sources or leached from shell within a shell midden (Sullivan 1993:40). Therefore, leaching of bone will only occur in deposits with little shell present, either because the shell has been leached or because it was never deposited. Primary factors necessary for leaching are a high rate of groundwater flow and replacement and the relative absence of calcium ions suspended in the groundwater. These factors would need to occur together. Acidic soils will increase the rate of leaching (White and Hannus 1983:321), and strongly alkaline soils should act in the same way (Lindsay 1979:181; Linse 1992).

Groundwater leaching proceeds not only by erosion of the exterior surface area of bones, but also by enlarging internal pore spaces, through which groundwater moves in the same way it moves through pore spaces in the soil matrix. Porosity of bone increases as the bone undergoes leaching, and this increased porosity also increases its permeability to groundwater (Hedges et. al. 1995:206-207). Migration of hydroxyapatite occurs from the surface of these pore spaces into the non-saturate groundwater solution. There may be no obvious exterior signs that a bone has been diagenetically altered (Hedges and Millard 1995:159-160). Evidence of leaching is therefore most likely to be apparent in the macro-structure of an entire assemblage, or in the molecular structure of individual bone specimens.

Vertebrate assemblages significantly impacted by leaching could be altered in several ways. First, leaching should produce vertical stratification of element density within the assemblage, with denser elements occurring with greater relative frequency below the water table. This is because denser elements consistently survive destructive processes better than less dense elements, because they have less internal pore space and therefore less surface area (Marean 1991). Second, leaching should cause bone from groundwater saturated contexts to be more
highly fragmented than bone from above the water table, because of the internal weakening of the bone caused by hydroxyapatite diagenesis. Third, because assemblages from below the water table will be more highly fragmented, they may contain a higher proportion of unidentifiable material. Fourth, denser elements should survive better than less dense elements within taxa in deposits that have been affected by leaching. Lastly, an assemblage that has been leached should show a greater degree of uniformity in the distributions of the above variables than an assemblage that has not undergone leaching.

1.2 THE BRITISH CAMP SITE

The site chosen for this study is the British Camp site, a prehistoric shell midden located on the west side of San Juan Island, Washington (Figure 1.2). The site is a large shell midden, over 4 m deep in places and 300 m long, configured to the shoreline of Garrison Bay (Stein 1992a:2). Several different archaeological investigations have been conducted at the British Camp site. The first investigations of the site were conducted in 1950 by A. E. Treganza, partially reported in Carlson (1954). Carlson (1960) investigated the adjacent Garrison site in 1951, which he considered to be a continuation of the British Camp site. Stephen Kenady investigated the British Camp site between 1970 and 1973, and initially noticed the stratigraphic division at the site between a shell-free dark layer and an upper layer with abundant shell (Kenady 1972 and 1973, in Stein 1992a:5). Investigations of the historic component of the British Camp site, including its buildings, were conducted by Sprague (1983) between 1970 and 1978.
Figure 1.2 Location of the British Camp site on the Northwest Coast of North America on San Juan Island, Washington. The site is located on the west shoreline of San Juan Island in Garrison Bay.

The most recent Native occupants of the British Camp site would have spoken a dialect of the Northern Straits Salish language (Thompson and Kinkade 1990:32-35), and were affiliated with either the Saanich, Songish or Lummi, or possibly a mixture of these three historic groups. Only the Lummi have identified Garrison Bay as the site of one of their winter villages (Suttles 1974:36). This site is located in the San Juan Island National Historic Park, and was occupied by British military forces between 1859 and 1872, during a minor border dispute between the United States and Britain over possession of the San Juan Islands. The dispute was eventually decided in favor of the United States and the British troops were evacuated from Garrison Bay (Thomas and Thompson 1992:62-63).
Significant disturbance of the shell midden occurred during the British occupation in the immediate vicinity of Operation A (Thomas and Thompson 1992), and the investigators considered the upper 25 cm of Operation A to be mixed by this historic activity (Stein 1998:personal communication). The British troops were engaged in clearing the site, construction of buildings, and the leveling of the shoreline terrace area, where Operation A is located, to use as a parade ground. The surface at Operation A is roughly level today, but the midden topography before the military occupation was likely irregular. In addition to impacts from leveling and building construction, significant pedestrian compaction of the midden deposits would have occurred during this time, and continues into the present (Thomas and Thompson 1992:64-68).

1.2.1 Excavation, Site Recording and Collection Methodology at British Camp

The excavations upon which this study is based took place over seven years, between 1983 and 1989, as a University of Washington field school under the direction of Julie Stein. The field school excavated a 6 x 8 m open-area type excavation, called Operation A, on the shoreline of Garrison Bay (Figure 1.3). The ground surface at Operation A sloped very gently towards the shoreline prior to excavation, and the midden surface directly adjacent to Garrison Bay was 15 cm lower than the midden surface at the extreme northern edge of the excavation.
Operation A reached a depth of approximately 150 cm below the surface, and calibrated radiocarbon dates range between 1730 and 64 years before present. Most of the midden excavated from Operation A was deposited between approximately AD 500 and the early 1800s, placing these deposits within the Marpole Phase (400 BC - AD 1250) and the San Juan Phase (AD 1250 to the early 1800s) (Carlson 1960; Mitchell 1971; Mitchell 1990). Approximately 72 m$^3$ of midden deposits were excavated at Operation A over the course of seven years of field school work.

Operation A is located on level ground at the top of a 1 m high wave-cut bank adjacent to the high tide line of Garrison Bay. Operation A was subdivided into twelve 2 x 2 m excavation units. Within the units, deposits were divided into individual facies, which provided horizontal and vertical provenience. Each facies was considered to represent an individual dumping event,
where a relatively similar mix of materials representing a limited range of activities were deposited in one specific location. A facies may have been deposited all at once, or over the course of many years (Stein et. al. 1992:97-98).

Criteria used to define facies were based on lithological characteristics observed in the field. Classification of separate facies was based upon the size, composition, abundance and color of particles within the midden matrix according to an operational scheme devised prior to the excavation (Stein et. al. 1992:98-99). Differences between facies were sometimes very obvious, but also sometimes very subtle (Stein 1996:personal communication). The size of the facies varied from very small to very large, but 90 litres is an approximate average volume for the facies. The volume of each facies was determined by recording the number of 8 litre buckets used to remove the facies.

Harris Matrices were used to record stratigraphic relationships between and among facies at British Camp (Figure 1.4). Harris Matrices allow the representation of relationships between facies in three dimensions, and may be easier to use when interpreting stratigraphy in a large open-area excavation than more traditional profile diagrams. The stratigraphic facies / Harris Matrix methodology has been used successfully in the Strait of Georgia region at the Hoko River rockshelter site (Wigen and Stucki 1988), the Crescent Beach site (Ham 1982) and at the Pender Canal site (Hanson 1991).

![Sample Harris Matrix diagram](image)

Figure 1.4. Sample Harris Matrix diagram. The boxes depict individual facies, while the interconnecting lines show stratigraphic relationships.
Facies were excavated using trowels and dustpans, and excavated material was waterscreened through nested screens ranging in size from 25 to 3 mm (1 inch to 1/8 inch). Faunal material from the 25 and 13 mm screens was sorted in the field, while faunal material from the 6 and 3 mm screens was sorted in the lab by University of Washington field school students (Stein et. al. 1992:100). A more detailed explanation of facies descriptions and excavation methodology for the British Camp site can be found in Stein et. al. (1992:97-112).

Not all midden material excavated from Operation A was saved by the excavators for later analysis due to the large volume of material collected from the midden. The proportion of midden material collected for analysis varied during the years of the field school as the large scale of the project became more apparent to the investigators. The proportion of midden material saved for analysis from different years of excavation is presented below in Table 1.1.

As excavations proceeded deeper within the midden, the sample of midden material sorted from the 6 mm screens grew smaller. Analyses of vertical variation within the midden that depend upon comparisons between different screen size samples can be expected to be compromised by the varying sampling practices. The faunal analysis of the Operation A sample presented in this thesis does not rest upon comparisons between different screen sizes, however, and is therefore not expected to be affected by the different sampling schemes employed by the excavators in different years.

Table 1.1. Sampling strategy from Operation A excavations, sample size of excavated material (by volume), including faunal specimens, kept for analysis.

<table>
<thead>
<tr>
<th>Year of Excavation</th>
<th>Approximate Depth Below Surface</th>
<th>25 mm Sample</th>
<th>13 mm Sample</th>
<th>6 mm Sample</th>
<th>3 mm Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>0 to 50 cm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
<td>25 %</td>
</tr>
<tr>
<td>1985</td>
<td>50 to 100 cm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
<td>25 %</td>
</tr>
<tr>
<td>1986</td>
<td>95 to 105 cm</td>
<td>100 %</td>
<td>100 %</td>
<td>50 %</td>
<td>50 %</td>
</tr>
<tr>
<td>1987</td>
<td>100 to 140 cm</td>
<td>100 %</td>
<td>100 %</td>
<td>50 %</td>
<td>25 %</td>
</tr>
<tr>
<td>1988</td>
<td>125 to 150 cm</td>
<td>100 %</td>
<td>100 %</td>
<td>25 %</td>
<td>25 %</td>
</tr>
<tr>
<td>1989</td>
<td>135 to 155 cm</td>
<td>100 %</td>
<td>100 %</td>
<td>25 %</td>
<td>25 %</td>
</tr>
</tbody>
</table>

Following screening, midden material was sorted into different analytic categories: lithics, shell, and faunal material. Faunal material was bagged separately and weighed, awaiting analysis.
Bags of faunal material contained all categories: fish, mammal and bird bone. Faunal material was curated at the Burke Museum in Seattle.

1.2.2 Radiocarbon Dates

A total of twenty-one radiocarbon dates were obtained from charcoal samples collected from Operation A at British Camp (Table 1.2). Charcoal samples were analyzed the University of Washington's Quaternary Isotope Lab (QL) or by Washington State University (WSU). Dates were calibrated using a computer program by the University of Washington researchers according to the calibration curve presented in Stuiver and Reimer (1986).

Table 1.2. Radiocarbon dates from Operation A, British Camp shell midden. All dates are on wood charcoal.

<table>
<thead>
<tr>
<th>Calibrated Date</th>
<th>Calibrated Range</th>
<th>Radiocarbon Age (Before Present)</th>
<th>Standard Deviation</th>
<th>Approximate Depth below Surface (cm)</th>
<th>Facies</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>modern</td>
<td>modern</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AD 1721</td>
<td>AD 1702 to AD 1928</td>
<td>160</td>
<td>60</td>
<td>35</td>
<td>1B</td>
<td>310 / 306</td>
</tr>
<tr>
<td>AD 1531</td>
<td>AD 1498 to AD 1677</td>
<td>355</td>
<td>50</td>
<td>90</td>
<td>Feature 2</td>
<td>310 / 304</td>
</tr>
<tr>
<td>AD 1522</td>
<td>AD 1484 to AD 1678</td>
<td>370</td>
<td>70</td>
<td>43</td>
<td>1D</td>
<td>310 / 304</td>
</tr>
<tr>
<td>AD 1483</td>
<td>AD 1472 to AD 1510</td>
<td>430</td>
<td>40</td>
<td>47</td>
<td>1F</td>
<td>306 / 300</td>
</tr>
<tr>
<td>AD 1482</td>
<td>AD 1464 to AD 1503</td>
<td>450</td>
<td>50</td>
<td>78</td>
<td>1D03</td>
<td>310 / 304</td>
</tr>
<tr>
<td>AD 1450</td>
<td>AD 1322 to AD 1522</td>
<td>535</td>
<td>80</td>
<td>33</td>
<td>1B01</td>
<td>310 / 300</td>
</tr>
<tr>
<td>AD 1379 or AD 1437</td>
<td>AD 1331 to AD 1437</td>
<td>580</td>
<td>70</td>
<td>104</td>
<td>-</td>
<td>310 / 306</td>
</tr>
<tr>
<td>AD 1342 or AD 1416</td>
<td>AD 1324 to AD 1439</td>
<td>630</td>
<td>55</td>
<td>135</td>
<td>-</td>
<td>310 / 306</td>
</tr>
<tr>
<td>AD 1327</td>
<td>AD 1272 to AD 1452</td>
<td>670</td>
<td>70</td>
<td>39</td>
<td>1B02</td>
<td>310 / 300</td>
</tr>
<tr>
<td>AD 1325</td>
<td>AD 1272 to AD 1452</td>
<td>680</td>
<td>135</td>
<td>40</td>
<td>1F</td>
<td>294 / 270</td>
</tr>
<tr>
<td>AD 1265</td>
<td>AD 1200 to AD 1320</td>
<td>810</td>
<td>80</td>
<td>60</td>
<td>1L</td>
<td>306 / 300</td>
</tr>
<tr>
<td>AD 1257</td>
<td>AD 1062 to AD 1320</td>
<td>830</td>
<td>70</td>
<td>85</td>
<td>2E</td>
<td>306 / 300</td>
</tr>
<tr>
<td>AD 1206</td>
<td>AD 1052 to AD 1312</td>
<td>885</td>
<td>65</td>
<td>56</td>
<td>1C</td>
<td>310 / 300</td>
</tr>
<tr>
<td>AD 1178</td>
<td>AD 1063 to AD 1265</td>
<td>900</td>
<td>40</td>
<td>75</td>
<td>1M</td>
<td>306 / 302</td>
</tr>
<tr>
<td>AD 1050</td>
<td>AD 1021 to AD 1196</td>
<td>1000</td>
<td>40</td>
<td>82</td>
<td>1W</td>
<td>306 / 300</td>
</tr>
<tr>
<td>AD 1022</td>
<td>AD 930 to AD 1063</td>
<td>1070</td>
<td>80</td>
<td>74</td>
<td>1N</td>
<td>310 / 300</td>
</tr>
<tr>
<td>Calibrated Date</td>
<td>Calibrated Range</td>
<td>Radiocarbon Age (Before Present)</td>
<td>Standard Deviation</td>
<td>Approximate Depth below Surface (cm)</td>
<td>Facies</td>
<td>Unit</td>
</tr>
<tr>
<td>----------------</td>
<td>------------------</td>
<td>---------------------------------</td>
<td>--------------------</td>
<td>-------------------------------------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>AD 931 *</td>
<td>AD 712 to AD 1072</td>
<td>1150</td>
<td>90</td>
<td>68 *</td>
<td>1D01</td>
<td>310 / 302</td>
</tr>
<tr>
<td>AD 814 *</td>
<td>AD 715 to AD 922</td>
<td>1250</td>
<td>70</td>
<td>67 *</td>
<td>1D02</td>
<td>310 / 302</td>
</tr>
<tr>
<td>AD 480</td>
<td>AD 443 to AD 594</td>
<td>1585</td>
<td>70</td>
<td>126</td>
<td>1R03</td>
<td>310 / 300</td>
</tr>
<tr>
<td>AD 413 *</td>
<td>AD 262 to AD 492</td>
<td>1690</td>
<td>60</td>
<td>54 *</td>
<td>1E</td>
<td>310 / 302</td>
</tr>
</tbody>
</table>

* These dates are from a pit feature in Unit 310 / 302. This pit feature was thought to have introduced older material from lower strata into strata nearer the surface, and was not used for chronology building by the University of Washington project.

There is only a weak and insignificant correlation between depth and greater age (r=0.294, t>0.1) demonstrated by the radiocarbon dates, and there are likely two main reasons for this. First, shell midden depositional sequences are extremely complex, and deposits which are horizontally adjacent may be of widely different ages. Second, disturbance of shell middens by both the prehistoric inhabitants of midden sites (Blukis-Onat 1985) or by later historic occupations (Ceci 1984; Thomas and Thompson 1992) are common and tend to produce widespread stratigraphic mixing. Several intrusive features were observed within the area investigated by Operation A (Stein et. al. 1992:125). The occurrence of a modern radiocarbon date 44 cm below the surface means it is almost certain that some stratigraphic mixing has occurred recently. It is most likely that a combination of the above two factors is the underlying cause for the poor relationship between depth and time in the British Camp midden.

1.2.3 Stratigraphy, Groundwater and Leaching at British Camp

During the excavation of Operation A, the upper limit of the water table was consistently observed at approximately 80 cm below the surface. Above this depth midden sediments were generally dry (vadose zone), while below this depth midden deposits were consistently moist (phreatic zone). At the British Camp site, groundwater conditions are conducive to leaching because the groundwater is not supersaturated in carbonates and is frequently replaced due to tidal effects (Stein 1992b:148).

It was demonstrated through an extensive auguring program and observation of beachside erosion patterns that relative sea level in Garrison Bay has risen by approximately 1 m during the past
2000 years (Whittaker and Stein 1992), and that this rise was responsible for the groundwater saturation of the lower midden deposits. A 1-2 m rise in sea level has also been inferred at other sites on the Strait of Georgia which date to this time (Bernick 1983:36), and non-archaeological research also supports this (Clague and Bobrowsky 1990). The presence of groundwater and its rough coincidence with a dark shell-free layer located at the base of the midden led to the initial hypothesis by Stein (1992a) that leaching and chemical weathering had postdepositionally altered these sediments, resulting in the removal of shell carbonates from the base of the midden (Figure 1.5). This initial hypothesis was followed up by extensive geochemical and archaeological work aimed at testing the validity of this hypothesis.

Carbonate content was determined by the University of Washington for each facies within Operation A by the loss-on-ignition method, which is described in detail in Stein (1984) and Stein (1992b). The carbonate content of each facies is largely a function of the amount of shell found in that facies, at both a micro- and macroscopic level. Facies which have been impacted by postdepositional leaching of shell should have a low carbonate content.

Figure 1.5. Dual stratigraphy at the British Camp site. The shelly layers in the upper deposits are not saturated by groundwater, while the black sediments in the lower deposits are consistently moist.
Loss-on-ignition tests determined that facies near the surface had the highest carbonate content, and facies deepest within the midden had the lowest carbonate content (Stein 1992b:143-146). The transitional zone between lower levels of carbonates and higher levels of carbonates roughly follows the water table. The facies below the water table frequently contain large shells which have been visibly etched by leaching (Stein 1992b:149).

In addition to carbonate data, lithic distributions were analyzed within the British Camp excavations, and indicated that technical change in lithic manufacture did not coincide with the dark / light layer boundary hypothesized to result from postdepositional leaching (Stein et. al. 1992:116-132). University of Washington researchers hypothesized that if the source of the dark / light stratigraphic division was cultural rather than natural, then the lithic distributions should match this boundary, and this is not the case at British Camp. Finally, shell data suggest that the barnacle assemblage from the site has been postdepositionally altered, although data from other invertebrate taxa is inconclusive (Ford 1992:322-323).

There have been some serious objections to the conclusions drawn by the University of Washington researchers about the fate of the shell in the dark deposits at the bottom of the midden (Carlson 1993; Sullivan 1993). These objections are based primarily upon an alternate explanation for the dark / light stratigraphic division: that there is less shell in the dark layers simply because less shell was initially deposited there by the inhabitants of the British Camp site, either due to cultural preference or environmental factors. If this is the case, the deposits which contained little shell would be expected to exhibit low carbonate counts because there was initially so little shell to act as a carbonate source. Carbonates in the lower deposits of this midden may have arrived as precipitates carried by meteoric groundwater from the upper shelly deposits.

Leaching of shell, however, is a separate issue from the chemical diagenesis of bone in the vertebrate assemblage. Removal of bone hydroxyapatite in an archaeological site requires a low density of shell in the affected deposits. Whether this low density is a result of the shell having been leached, or an initial lack of shell in those deposits, leaching of hydroxyapatite (calcium phosphate) can still proceed. If leaching of shell is occurring, however, enough shell would first have to be removed so that groundwater was not supersaturated with calcium carbonates derived from shell.
1.3 RESEARCH SUMMARY AND OBJECTIVES

The research goals of this thesis are relatively straightforward: to investigate the depositional history of the British Camp vertebrate assemblage, determine whether this assemblage has been impacted by leaching, and demonstrate that a set of methodological tools can be developed which will identify the effects of leaching on a faunal assemblage. These goals will be accomplished by the application of zooarchaeological and taphonomic methods to the assemblage, and comparison of the characteristics of that assemblage between different depositional contexts. If this assemblage has been impacted by leaching, then it is certain that it was impacted differentially; that is, certain elements, certain taxonomic categories, and certain contexts will have been affected in different ways. It is this selective alteration of an assemblage that makes it possible to determine the effects of postdepositional attritional factors via a comparative approach, because if each bone in an assemblage was affected in exactly the same way, destruction or elimination of bone because of diagenesis would be difficult or impossible to detect.

The fine control of context and the investigation of depositional history and groundwater effects upon the shell and sediment components of the British Camp site carried out by the University of Washington allow the vertebrate assemblage to be investigated using many of the same tools. The assemblage can be divided into numerous contexts, including groundwater saturated and dry contexts, or divided between the dark / light layers. These various contexts will be compared to determine whether preservation of vertebrate remains is better in contexts above the water table, better below the water table, or not significantly different. A comparative approach has been advocated by Klein and Cruz-Uribe (1984:70) in the study of post-burial attrition in African and European archaeological sites; there is no reason why the same approach should not be applicable to a Northwest Coast shell midden.

A formal working hypothesis will be proposed which will serve as a focus for tests founded upon zooarchaeological and taphonomic methods of assemblage evaluation. These methods include the assessment of element density, the assessment of the fragmentation of elements from a variety of taxonomic categories, and the assessment of identifiability of elements from different contexts. If deposits that are saturated by groundwater have been affected by leaching, the vertebrate assemblages from those deposits should be more highly fragmented, composed of a larger
fraction of unidentifiable material, and the average density of surviving elements should be higher.

1.4 WORKING HYPOTHESIS

A formal hypothesis is useful in goal oriented archaeological research in order to focus the investigation. The following hypothesis will serve as a focus for this thesis:

The British Camp faunal assemblage has been postdepositionally altered by groundwater facilitated leaching.

If this hypothesis is true, then the assemblage should exhibit a strong underlying pattern related to the density and fragmentation of elements. The hypothesis can be indicated or contraindicated by the following five tests:

Test 1

Elements within the assemblage should be more highly fragmented in depositional contexts inundated by groundwater; that is, the fragmentation of elements should increase with depth. This is because diagenesis increases the size of a bone's internal pore spaces, causing structural weakness. This was tested by an examination of the vertical distribution of fragmentation of bone specimens.

Test 2

The proportion of the assemblage composed of unidentifiable material should increase with depth, because chemical attrition should result in the elimination of identifiable osteological features or landmarks. This was tested by the examination of the vertical distribution of identifiable and unidentifiable material.
Test 3

The average density of elements in each facies should increase with depth, because denser elements survive attritional processes better. This was tested by examining the average density of bone specimens in each facies.

Test 4

In groundwater saturated contexts, denser elements should survive in higher frequencies than less dense elements within taxa. This was tested by examining how well particular elements were surviving above and below the water table.

Test 5

Fragmentation, average density, and identifiability should be more uniform in deposits which are inundated by groundwater, and more random in deposits above the water table. This was tested by an examination of the distributions of variables in the above tests. Data points for the fragmentation, density, and identifiability variables should cluster more closely about a central regression line below the water table if leaching has affected a large volume of deposits.

The preconditions for groundwater leaching are already present at British Camp: a groundwater regime that is frequently replaced and is not supersaturated by calcium ions. If the above characteristics, used as tests of the hypothesis, are exhibited by the British Camp assemblage, then they should indicate groundwater facilitated leaching. The portion of the midden located above the water table is consistently dry, and rainfall does not contribute significantly to the hydration of this portion of the shell midden (Stein 1992b:136). Leaching should therefore have much more strongly affected faunal material from deposits below the water table.

Groundwater leaching is a relatively universal process which would affect an assemblage as a whole in deposits which are consistently saturated, although some elements will be affected more than others, and some deposits will be more highly impacted than others. All of these characteristics should be displayed by a leached assemblage; the presence of none of them, or the presence of only a few, should contraindicate the leaching hypothesis. Attrition resulting from
leaching should be mediated by the density of particular elements. A correlation between element survivorship and element density is a good indication that post-burial rather than cultural factors are the source of attrition in a faunal assemblage (Butler and Chatters 1994:417; Grayson 1989:647).

These characteristics should be exhibited by the bony fish, mammal, and bird assemblages, which each represent a taxonomic class, and should be apparent in the vertical distribution of fragmentation, density and identifiability within each class. Depth is a good independent variable to test this hypothesis because of its ease of use and because it is equivalent for each individual test. Post-depositional attrition can be expected to increase with depth in an assemblage affected by leaching because deeper deposits are more highly saturated by groundwater and because these deeper deposits have had a longer time to be acted upon by groundwater-related diagenesis.

1.4.1 Equifinality as a Source of Error

Equifinality is the tendency of hypothesis tests to affirm several hypotheses rather than only one, and is a serious problem in archaeological studies because of the ambiguous nature of much archaeological data. The current study is not exempt from these problems, as the outcome of each of the above five tests could potentially result from processes other than leaching.

One alternate hypothesis has the greatest potential for results equifinal with leaching: bone attrition caused by varying depositional rates between the upper and lower middens. This process would be relatively uniform (when compared to a taphonomic process such as processing) and affect a large volume of sediments. Other taphonomic processes, such as carnivore effects, may mimic some of the effects of leaching but would not be nearly so widespread or uniform.

Varying Depositional Rates

Shell middens are different from other archaeological sites in that artifacts and vertebrate remains are deposited in the site along with large amounts of shell, which is the predominant midden constituent. The amount of shell in specific deposits is a function of cultural and natural processes, and some deposits contain a much larger proportion of shell than others in the same
site. Deposits which contain a larger percentage of shell tend to accumulate volume more quickly than deposits with lower shell percentages; their rate of deposition is therefore faster.

Rate of deposition is important in taphonomic studies because bone that is buried more quickly tends to be better preserved than bone which is exposed to weathering in aerial or sub-aerial contexts for a longer period (Lyman and Fox 1989; Behrensmeyer 1978). Under normal conditions, bones do not tend to survive more than 15 years unless they are buried or otherwise protected (Behrensmeyer 1978:158).

At the British Camp site, the deposits above approximately 80 cm below the surface are composed predominantly of shell, while deposits deeper than this have a much smaller proportion of shell (Figure 1.5). While Stein (1992b) concluded that this dual stratigraphy was the result of post-depositional processes, it is possible that the dual stratigraphy resulted because little shell was initially deposited in the lower part of the midden. If this is the case, then sediments in the lower midden would have accumulated more slowly. Bone in the lower portion of the midden would be poorly preserved when compared with the bone from the upper midden because it would have been exposed to weathering forces for a longer period of time. The tests of the leaching hypothesis, outlined above, could therefore fail to distinguish between a deposit that has been leached and a deposit that has accumulated more slowly.

In a situation where taphonomic tests may support two or more hypotheses, independent data are essential in order to evaluate which hypothesis is correct. Rate of deposition will be assessed in two ways: via radiocarbon dates and via the weathering stage of faunal material. Radiocarbon dates, when plotted against depth, should cluster more closely together in deposits which accumulated more slowly, and be more widely separated in deposits which have accumulated more quickly.

Second, the weathering patterns of faunal material will be used to assess rates of deposition. Weathering stage is a taphonomic variable devised by Behrensmeyer (1978) to assess the length of time bones have been exposed to weathering in aerial or sub-aerial contexts. Bones weather much more slowly after they have been buried in sediment than in exposed environments, and comparison of mean weathering stage data for different contexts can indicate which have accumulated most quickly (Lyman and Fox 1989; Behrensmeyer 1978). The weathering stage
variable will be discussed in more detail in Section 2.3.2 (Methods). If the radiocarbon dates and the weathering stage data indicate that deposition rates were slower below the water table than they are above, then the hypothesis tests for leaching have a serious equifinality problem and further research would be required to indicate or contra-indicate the leaching hypothesis.
2.0 METHODS

The methods chosen for the analysis of the British Camp assemblage were designed to provide information to support or deny the working hypothesis that leaching had caused post-depositional destruction of faunal material in the lower part of the midden below the water table. First, a sample was taken of the entire excavated assemblage. Following this, the sample assemblage was identified, quantified, recorded, and databased, then analyzed using simple statistical and mathematical procedures. The results of this analysis were organized in graphs, histograms and charts, and are presented in Section 3.0 below.

2.1 SAMPLING STRATEGY

The true measure of a faunal assemblage's overall size, and therefore its statistical reliability, is the total number of identifiable specimens present within that assemblage. For the British Camp assemblage, an initial estimate of this number was obtained by randomly selecting five of the bags containing sorted faunal material from all the faunal material sorted by the University of Washington, determining the average number of identifiable specimens in these five bags, and then multiplying this number by the total number of bags of faunal material collected from Operation A at British Camp. This produced a rough estimate of 285,000 identifiable specimens within the entire assemblage.

It was not practical or necessary to identify this number of specimens; therefore a sampling strategy was devised. A minimum sample size of 20,000 identified elements was selected as representing an adequate sample from which to draw conclusions about the entire Operation A assemblage (the parent population). With this target sample size in mind, a random sample of 7% (by volume) of the Operation A assemblage was selected, with the facies as the basic sampling unit. Facies were randomly selected until the sample represented 7% of the total volume of sediments excavated at British Camp. This method proved to be very successful, as the final number of identified faunal elements was 20,293.
2.2 ANALYTIC METHODS: IDENTIFICATION AND RECORDING

2.2.1 Identification

Facies and bags of unidentified faunal material within each facies were examined in random order. An initial sorting of each bag was conducted, during which faunal material was sorted into four broad categories: fish, bird, terrestrial mammal, and marine mammal. This initial sorting was completed for the entire sample before finer-scale identifications were attempted.

Before identifications were attempted, a list containing all the potential taxa that could be present in the British Camp midden was composed. This list comprises a faunal universe out of which identifications can be drawn, and did not only include taxa present in the area today, but also species that may have been present in the past. Many of the taxa in this universe were families or genera, rather than individual species. For example, no individual rockfish (*Sebastes* spp.) species were identified; genus level identifications were considered to be adequate.

Each faunal specimen was examined, and identified to as fine a taxonomic scale as possible. Initially, the anatomical element of the specimen was identified; frequently the correct element for even very small fragments could be determined. When the element was known, the specimen was then compared to other specimens in the Simon Fraser University Zooarchaeological Comparative Collection, and to drawings and pictures in zooarchaeological manuals by Gilbert et. al. (1981), Gilbert (1990), and Cannon (1987). Identifications followed the rule that specimens cannot be defined as a particular family, genus or species based on their similarity to a comparative specimen, but rather must be sufficiently distinct to also rule out other families, genera or species. Identifiable material is defined as specimens that can be identified to at least the order level (e.g. Pleuronectiformes, or flatfish). For all identified specimens, the anatomical element has been identified as well.

This is a fundamentally conservative approach to identification, and means that few specimens in the British Camp sample have been misidentified. Many of the identifications are only to the level of family or genus, which in some cases covers a great number of potential species. Since the aim of this research was to define taphonomic patterns, rather than make fine distinctions
about environmental conditions or subsistence practices, these more general identifications are considered to be sufficient.

Unidentifiable material is composed of specimens that could not be classified as a particular skeletal element, and could therefore not be identified to a fine taxonomic scale. The texture of even small fragments of bone can be distinctive enough, however, to allow unidentifiable specimens to be placed in the broad taxonomic categories of fish, mammal, or bird. For example, fish bone is more friable, thinner, more lamellar, and of a different color than mammal bone. It does not have the distinctive porous structure present in bones from mammals. Bird bone is also thinner, colored differently, and has pores in the cancellous portion which are much larger than in mammals.

2.2.2 Recording

Identified specimens were recorded on 8.5 by 11 inch datasheets using a suite of variables, not all of which were used for interpretation in this analysis. Descriptive variables recorded for each specimen include the element represented, portion of the element, and taxon. In addition, a number of other observations were made, including type of burning (if present), carnivore modification, rodent modification, weathering, etching, number of cutmarks, and the presence of exterior erosion. All descriptive variables were recorded via a system of standardized codes, largely adapted from Driver (1994).

NISP values were recorded for all identified specimens from all screen sizes. Counts of unidentifiable material were made for the bird, terrestrial mammal and marine mammal categories, from all screen sizes, while unidentified fish material was not counted because the numbers represented were considered to be too large and the value of these data too small. All specimens from screens 6 mm or larger were weighed, including both identified and unidentifiable material.

2.2.3 Databasing and Statistical Methods

Completed datasheets were entered into Microsoft® Excel, a computer spreadsheet program that allows the mathematical manipulation of large volumes of data, the correlation of several
different datasets, and the graphic representation of data. This spreadsheet is sufficiently sophisticated to allow the application of simple statistical procedures, such as the calculation of regression formulas and r and t values.

Values for r (the strength of a correlation between two variables) for data from the British Camp assemblage were derived via the calculation of best-fit linear regressions, using the Microsoft® Excel TRENDLINE function, between an independent variable (usually depth) and a dependent variable. Dependent variables used for these calculations include NISP, %Survivorship, bone density, bone fragmentation, and relative taxonomic frequencies. These variables are described in Section 2.3 below. Values for t, which is a measure of the statistical significance of a correlation between two variables, were taken from Table A.11 in Thomas (1986:508). A correlation was considered to be significant when the t value is less than 0.05, and highly significant when the t value is equal to or less than 0.01.

Following statistical analysis, data were organized graphically in line graphs, histograms and charts. For the distribution of most variables, such as element density and fragmentation, mean values for these variables were derived for individual facies, then plotted against their depth. Calculation of significance values (t) from the distribution of sample means assumes that the distribution of the parent population is normal. This is probably not the case for some of the variables used in this study. The completeness index, for example (see Section 2.3.1 below) used to assess the amount of fragmentation undergone by the salmonid assemblage, will exhibit some skewness in deposits which have been highly impacted. Fortunately, nonnormal population distributions have only a slight effect upon the calculation of t values as long as sample sizes are large (Thomas 1986:256), and in the case of the British Camp assemblage, most of the sample sizes are very large.

2.3 ANALYTIC METHODS: VARIABLES AND QUANTIFICATION

This section presents the variables utilized in this study to describe the British Camp assemblage, the assumptions implicit in those variables, and their individual drawbacks. These variables are used not only to quantify the assemblage, but also to make intertaxonomic comparisons, intrataxonomic comparisons and intrasite comparisons between different burial contexts.
2.3.1 Variables used to Quantify Taxa and Skeletal Elements

Number of Identified Specimens (NISP)

NISP is the primary unit of comparison of abundance between taxa in this study. It is simply a count of all specimens belonging to a particular taxon, regardless of which particular skeletal element is represented. NISP is not intended to provide a measure of the absolute abundance of any particular taxon, but rather is designed to provide information about the abundance of taxa in relation to other taxa. It provides ordinal-scale ranking of the frequency of taxa, and therefore information about changes in abundance in taxa in relation to other taxa. There are several problems implicit in the NISP variable, the most serious of which are presented below. Grayson (1979) presents a more comprehensive treatment of these issues.

First, NISP values may be subject to bias because of differential fragmentation and/or differential identifiability of elements belonging to different taxa (Grayson 1979:201-202). Taxa which have bones that are easily fragmented or easily identified may have higher NISP values not because they are more abundant, but because their bones are more fragmentary (Ringrose 1993:126) or easier to identify. The most serious bias within the British Camp sample arising from this problem may be associated with salmonid vertebrae. Unlike the vertebrae of other fish species, salmonid vertebrae are easily identifiable as small fragments due to their unique porous texture. In a highly fragmented assemblage, therefore, the NISP values for salmon will be inflated.

Second, NISP values can be biased because of the inclusion of whole skeletons in an assemblage (Grayson 1979:201). This is a problem if some taxa are brought whole into a site, while other taxa are butchered elsewhere. For the British Camp assemblage, this bias could affect comparisons between herring and other taxa. Herring, a relatively small fish, would have been commonly brought whole into the site, while larger taxa may have been butchered elsewhere (e.g. Butler and Chatters 1994).

Third, NISP values are composed of some individuals that were deposited whole and some which were deposited in small pieces. Single skeletal elements may also contribute more than one specimen to an NISP total. This means that NISP values are not independent from each other.
This is a serious problem for studies of butchery or subsistence, but is not a problem for post-depositional taphonomic studies because individual specimens are largely acted on by post-depositional processes independently of each other (Grayson 1984).

NISP is used in preference to another measure, Minimum Number of Individuals (MNI) because MNI is beset by most of the problems which affect the use of NISP values, because NISP can predict MNI, and, most importantly, because different sample aggregation methods can cause MNI values to fluctuate wildly within a single assemblage (Grayson 1979; Klein 1989). All identified specimens were quantified using NISP counts. Unidentifiable fish material from the 6 mm and 3 mm screens and unidentifiable mammal and bird material from the 3 mm screens was not counted, and can therefore not be quantified with NISP counts, because the sample size is too large and the value of these data too small.

**Relative Taxonomic Frequencies**

This variable quantifies the abundance of particular taxa in relation to other taxa. It is more useful than comparing absolute NISP values between taxa because different contexts can be of widely varying sample sizes. Relative frequencies are expressed as a proportion (e.g. 0.58, which equates to 58%), and are calculated by dividing the NISP value for a particular taxon by the total NISP values for all identified specimens in a particular context. The letter $p$ is used to denote relative taxonomic frequencies in this thesis.

**Weight**

Both unidentifiable and identifiable faunal material was quantified using weight because unidentifiable fish remains were far too abundant to count individually, especially from the 3 mm screens, and some of the analysis performed during this research involved the comparison of relative proportions of identifiable and unidentifiable material.

All specimens were weighed on an electronic scale accurate to 0.1 gram. Individual specimens were not often weighed; usually, all elements belonging to a single taxon from within a single facies were weighed together. Unidentifiable fish material from the 3 mm screens was not weighed.
Minimum Number of Individuals (MNI)

MNI was not used in this study as a measure of taxonomic abundance, but was used in the calculation of %Survivorship values (see below) in the procedure recommended by Lyman (1994:239). MNI values are calculated by determining the most frequently occurring element for a particular taxon, then dividing the minimum number of elements (MNE; see Section 2.2.4 below) for that particular element by the number of times that element is represented in the skeleton of the target taxon. For example, if four distal right tibiae are identified as belonging to deer, then the MNI value for deer is four.

MNI was not used as a measure of taxonomic abundance because of serious statistical problems relating to the way the sample assemblage is aggregated. Aggregation methods can significantly and differentially alter the MNI totals for individual taxa, making it unsuitable for intrasite comparisons of taxonomic abundance (Grayson 1979:203-222).

Minimum Number of Elements (MNE)

MNE is a relatively simple statistic which calculates the minimum number of discrete elements needed to account for a sample of element fragments. It is useful because faunal assemblages are rarely composed of whole elements. For example, a sample of ulna fragments containing 5 left proximal ulnae, 10 shaft fragments, and 3 distal left ulnae would have an MNE of 5, since shaft fragments cannot be assumed to be discrete from one another.

The problems of aggregation which render MNI values statistically suspect also apply to MNE values. MNE values were therefore used only in the calculation of the %Survivorship statistic (see below) and not for comparisons of intertaxonomic abundance.

%Survivorship

This variable was the most arithmetically complicated used in this study. It is intended as a measure of the survivability of particular elements in relation to other elements. %Survivorship is calculated by dividing the observed Minimum Number of Elements (MNE) by the expected
number of elements within a particular taxonomic category. The expected number of elements is a function of the Minimum Number of Individuals (MNI) for a taxonomic category and the number of any particular element that is present in the skeleton of an individual. The calculation of this variable followed the procedure outlined in Lyman (1994) when used to analyze faunal data from mammalian species, and from Butler and Chatters (1994) when used to analyze faunal data from fish species.

For example, if the MNI of a particular taxon is four, then the number of humeri expected to be present is eight: two per individual. If only three humeri are present, then the %Survivorship of humeri is three divided by eight, or 0.375. The value obtained has no meaning of itself, but instead is useful in providing ordinal-scale ranking of the survivability of different elements within a taxon.

One particular element, which presents the highest MNI, provides the ‘baseline’ for %Survivorship values in an assemblage. If, for instance, an assemblage composed of a single mammalian taxon had three right humeri, three left humeri, one scapula, and one mandible, then the MNI for this assemblage, based on the humerus, is three. The expected number of elements for the humerus is six, scapulae is six, and mandible is three. %Survivorship values for this assemblage would therefore be calculated as shown below in Table 2.1:

Table 2.1. Sample %Survivorship calculations.

<table>
<thead>
<tr>
<th>Element</th>
<th>MNI</th>
<th>Expected MNE</th>
<th>Observed MNE</th>
<th>%Survivorship (Observed / Expected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humerus</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>1.00</td>
</tr>
<tr>
<td>Scapula</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>0.167</td>
</tr>
<tr>
<td>Mandible</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>0.333</td>
</tr>
</tbody>
</table>

Bone Density

Bone density is probably the single most significant factor mediating destructive taphonomic processes (Lyman 1984:275-279), and can therefore provide valuable information about the influence of those processes. Bone density values used in this study were not measured during the course of the thesis research, but were taken from Butler and Chatters (1994) and Lyman (1994).
Volume density values for fish bone used in this study were obtained from Butler and Chatters (1994), who used a photon absorptiometer to measure the mineral content of a variety of salmonid elements. This figure was then standardized to the ratio of grams/cubic centimeter (volume density) by dividing mineral content by the volume of the element measured. Volume density provides a measure of the total surface area available on a particular element, a function of the porosity of the element. Greater surface area means that a larger portion of the mineral content of a particular element may be affected by destructive chemical processes. In this study, density values derived from salmonids are applied to a number of different fish taxa, with the exception of cartilaginous fish. It is recognized that salmonid density data may not necessarily be directly applicable to other fish taxa, but in the absence of density data for other taxa, salmonid density values have been used as a best fit.

Bone density figures for deer elements used in this study were derived from Lyman’s (1994) data. Again, a photon absorptiometer was used to measure the mineral content of various elements from several mammalian taxa. Unlike Butler and Chatters (1994), however, Lyman measured the mineral content of a number of specific scan sites on each element, then calculated the bone density at those scan sites. This enables bone density values to be used not only to compare which elements are being eliminated from an assemblage by density-mediated processes, but also to compare which parts of specific elements are being eliminated. Both measures are analogous, however, and are expressed as the ratio of grams per cubic centimeter (volume density).

Average density values for deer / artiodactyl remains were calculated by adding all density values available for individual scan sites within elements (Lyman 1994), then dividing this value by the total number of scan sites represented in each facies. Average density values for fish remains were calculated for each facies by adding all available density figures derived from Butler and Chatters (1994), then dividing this number by the total number of elements in each facies for which density figures were available. Only a single density figure is available for each particular fish skeletal element, even though densities within elements are not uniform.
Completeness Index (Mammalian carpals and tarsals)

The completeness of carpals and tarsals from terrestrial and marine mammals were assessed based on an ordinal scale. A number was assigned to each identified carpal or tarsal which most closely approximated the completeness of that element. For example, a whole calcaneus would assessed as a 1, while a calcaneus which was 45% complete would be assessed as a 3. Table 2.2 presents the quantification scheme of the completeness variable. Completeness indices for individual facies were then calculated by determining the mean completeness of mammalian carpals and tarsals for each facies.

Table 2.2. Completeness Assessment Index.

<table>
<thead>
<tr>
<th>Assessment</th>
<th>% Element Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>75</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
</tr>
</tbody>
</table>

Completeness Index (Salmonid vertebrae)

This variable was calculated in a manner identical to the completeness index for mammalian carpals and tarsals described above (Section 3.2.6, Table 2.2). Vertebrae were assessed based on the portion of the centrum that was present. Salmonid vertebrae were selected, as opposed to other fish taxa, because salmon vertebrae were common in each facies and because salmonid vertebrae are identifiable as small fragments, a necessary prerequisite for this variable to produce an unbiased distribution.

Each salmonid vertebrae identified from screen sizes 6 mm or larger was assigned a value which most closely approximated the completeness of that vertebra (Table 2.2). Completeness indices for individual facies were then calculated by determining the mean completeness of salmonid vertebrae for each facies. Vertebrae captured in the 3 mm screens were not assessed, as the distribution of this variable from the 3 mm screen size would be biased towards small fragments, and because there were far too many specimens to be assessed.
Weathering Stage

This variable was assessed only for elements identified as belonging to the deer or artiodactyl taxa, for which it was designed (Behrensmeyer 1978). Weathering patterns are divided into six stages, with Stage 0 being the least weathered and Stage 5 being the most weathered. Weathering stage measures the process by which bone is broken down into organic and inorganic components by microscopic organisms, ultraviolet radiation, and fluctuations in temperature and humidity. These weathering agents are present predominantly above or very near the soil surface. Weathering mainly occurs above the soil surface, and when bones are buried weathering either stops or continues very slowly (Behrensmeyer 1978:154; Lyman 1994:360).

Weathering stage for applicable elements was recorded by determining the maximum weathering stage displayed over patches larger than 1cm² on each bone specimen. Whenever possible bone surfaces with a minimum of relief, such as the shafts of long bones or the flat surfaces of mandibles, innomates, or scapulae are assessed, as articular surfaces rarely possess uniform patches of bone surface greater than 1cm² (Behrensmeyer 1978:152).

Mean weathering stage for deposits can provide a rough measure of the rate of deposition for those deposits, as weathering stage is correlated with the time that particular specimens are exposed to agents of weathering. There are a number of serious biasing factors involved in the use of weathering stage data, however, and these include the interdependence of elements belonging to multiple individuals, the tendency of weathering patterns to be strongly influenced by micro-environmental differences even within single sites, and the tendency of different elements to weather at different rates. Even with these biases, however, weathering data provide important information regarding the rate of assemblage formation (Lyman and Fox 1989).

Although Behrensmeyer (1978) hoped that weathering stage data could be converted into annual years, and that interval between the death of the organism and assemblage accumulation could be determined, weathering stage data are actually suited only to the determination of relative period of accumulation for assemblages experiencing similar micro-environmental conditions (Lyman 1994:358-359). It is therefore possible for weathering data to be used to determine which assemblage took longer to accumulate, but the data will not provide information about how long
the accumulation of each assemblage took. A comparative approach to weathering data is therefore required.

3.2 Burial Context

Depth

Depth within the midden was consistently used as an independent variable in this study. This figure was derived from a fixed datum point located adjacent to the excavations at Operation A and slightly above the ground surface. Depth is considered to be roughly consistent between all 12 units in Operation A, as the ground surface in this area is relatively flat, although the ground surface of the excavation was 15 cm lower at its southern edge, above a wave-cut bank, than the ground surface at the northern edge of Operation A. This variable is expressed in centimeters below the surface. Depth is used because it allows plotting of distributions against the location of the water table, which was consistently observed at 80 cm below the surface of the excavations. The depths below surface of each facies used in this analysis are presented in Appendix A, Table A.1.

It would probably not be appropriate to use depth as an independent variable if the intent of this research was to reconstruct subsistence of economic trends at the site. In that case, it would be much better to arrange faunal data using the Harris Matrix, thereby addressing the correct sequence of deposition. The intent of this research, however, is the investigation of post-burial attrition of bone, and depth is very well suited to this goal because the water table is not related to a cultural sequence of deposition at this site, but is instead controlled by natural factors such as sea level and flow rates.

The disadvantage of using depth in this manner is that it tends to homogenize horizontal variation in the British Camp midden, therefore ignoring the dipping of strata observed by the excavators in the extreme southern portion of the Operation A excavations, closest to the shoreline. Since this thesis is aimed at the investigation of taphonomic history, rather than the identification of separate activity areas, or other analyses that require resolution of horizontal variability, this shortcoming is considered acceptable.
2.4 HYPOTHESIS TESTING

The underlying distributions of the above variables were utilized to target the characteristics of the British Camp assemblage which should point to the impact of post-depositional attrition. The characteristics of the assemblage were targeted with a formal hypothesis, outlined in Section 1.4.

2.4.1 Test 1: Fragmentation Distribution

An assemblage impacted by leaching should exhibit vertical stratification of fragmentation patterns. In the case of the British Camp assemblage, facies which are located in groundwater saturated contexts, deeper in the midden, should exhibit a higher degree of fragmentation of faunal material than facies located nearer the surface. In order to determine whether this is the case, the completeness index of mammalian carpals and tarsals and of salmonid vertebrae was plotted against depth. In this way the fragmentation of the fish and mammal assemblages were assessed. The bird assemblage could not be assessed in the same manner because the sample was too small.

2.4.2 Test 2: Unidentifiable Material

The proportion of the assemblage composed of unidentifiable material should increase with depth if the British Camp assemblage has been impacted by leaching. Therefore, the proportion of faunal material in each facies composed of identifiable specimens was calculated. These proportions were then plotted against depth for the mammalian and fish assemblages. Again, the bird assemblage could not be assessed because the sample was too small.

2.4.3 Test 3: Density Distribution

Mean bone density values should increase with depth in an assemblage that has been leached because the destruction of bone by leaching is a density-mediated process; therefore an assemblage that has been impacted should be composed of a higher proportion of dense elements. Mean bone density values were calculated for deer and artiodactyl elements in each facies with NISP values for these taxa greater than five. Other mammalian taxa were not assessed because density values are not available for these taxa and/or because the sample sizes for these taxa are
too small. Mean bone density values for bony fish taxa in each facies were calculated using
density values derived by Butler and Chatters (1994) from salmonid remains. Mean bone density
values for each facies were then plotted against depth below surface. The bird assemblage was
not assessed because density values for birds were not available and because the bird sample was
too small.

2.4.4 Test 4: Survivability of Elements

The herring assemblage was selected to assess the differential survivability of elements because it
affords the largest sample, with a total NISP of 12,790. The herring assemblage was divided into
two large samples: a sample from above the water table (above 80 cm depth) and below the water
table. If leaching has impacted the faunal assemblage, then less dense herring elements, such as
cranial and pelvic elements, should have higher %Survivorship values above the water table than
in water saturated contexts.

Eight elements were selected to assess the survivability of elements in the herring assemblage:
the vertebra, articular, maxilla, dentary, hypural, pterotic, exoccipital, and ceratohyal. These
elements were selected because density values are available for them and because they are well
represented in the herring assemblage. %Survivorship values were calculated for these elements,
with vertebrae, the most abundant element, forming the MNI 'baseline' for the calculation.

2.4.5 Test 5: Extent of Attrition

The distributions of the variables presented above in Sections 2.4.1 through 2.4.3 should be
relatively uniform in groundwater saturated contexts, and less uniform (more random) in contexts
above the water table if the British Camp assemblage has been impacted by leaching. For
example, the average bone density of elements (Section 2.4.3) in facies below the water table
should be relatively uniform, because groundwater inundation would affect a large volume of
deposits. Average density values calculated for facies above the water table should have a more
random distribution. These distributions were visually assessed in the charts and histograms
representing the distributions of the variables examined in Sections 2.4.1 through 2.4.3. Overall,
the distributions of the density, fragmentation and identifiability variables should be consistently
correlated with depth; that is, deeper deposits should show consistently greater amounts of attrition.

2.6.6 Equifinality: Varying Depositional Rates

In order to address equifinality error and to determine whether slower rates of deposition in the lower layers of the midden could account for bone attrition observed in the faunal assemblage, weathering stage and radiocarbon data were examined. If depositional rates in the lower midden were slower, allowing bones to remain at or near the surface for a longer period of time, the mean weathering stage values for specimens from the lower midden should be higher than mean values for specimens in the upper layers of the midden. These data were examined by plotting mean weathering stage values for deer / artiodactyl specimens against depth.

Additionally, radiocarbon data are available to assess deposition rates. These data are less precise than weathering stage data because of the standard error involved in radiocarbon dating and calibration, but they are useful as they provides independent information. If deposition rates in the lower portion of the midden are slower, then radiocarbon dates, when plotted against depth, should cluster more closely together.
3.0 RESULTS

3.1 SAMPLE SIZE AND IDENTIFIABILITY

A total of 20,293 elements from all screen sizes were identified during the course of this study, which comprised a random 7% sample of the entire faunal assemblage excavated from Operation A at British Camp. Identifiable material is defined as faunal material that may be assigned to at least the order level (e.g. Pleuronectiformes, or flatfish).

An estimate of the proportion of identifiable elements in the British Camp sample can be obtained from the weights recorded for the faunal material from the 6 mm or larger screens. A total of 3421.8 grams of faunal material was analyzed from these screens. Of this analyzed material, 1607.1 grams (47%) was identifiable. The proportion of identifiable faunal material varied between different taxonomic categories, with birds having the highest proportion of identifiable material and mammals having the lowest. These proportions are presented in Figure 3.1.

![Figure 3.1. Proportion of the faunal assemblage composed of identifiable material by taxonomic class. Identifiable material includes all faunal specimens identified to at least the order level (e.g. Pleuronectiformes, or flatfish).](image-url)
3.2 IDENTIFIED TAXA

A total of 51 different taxa were identified within the faunal sample from British Camp. Some of these taxa were based on morphological characteristics, assumptions about the range of the taxa, and the size of the identified elements. Some of the taxa come from food species, some come from species used for raw materials or bait, and some are intrusive in the midden. The relative proportions of different categories of identified taxa are presented in Figure 3.2.

Figure 3.2. Relative proportions of NISP values for broad taxonomic classes.

3.2.1 Fish

Fish remains at British Camp are by far the most abundant taxonomic category, approximately 70% of the fish assemblage was identifiable to family, genus or species. The overall frequency of fish taxa in the British Camp sample is presented in Figure 3.3.

Nomenclature is after Hart (1975). Taxa are listed in standard taxonomic order.
Class: Chondrichthyes

Species: *Squalus acanthias* (Spiny dogfish). NISP=1007

The spiny dogfish is the only shark commonly found in the Strait of Georgia, though a handful of other species are occasionally present (Hart 1975:27-47). The remains of these other species are not morphologically similar to dogfish remains, however.

Most of the skeleton of the spiny dogfish is composed of cartilage, although the vertebrae are partially calcified. Spiny dogfish elements which are commonly identified are vertebrae, teeth and dorsal spines. Because there are so few calcified elements in relation to bony fish species, dogfish remains are usually underrepresented in archaeological sites, and this is almost certainly the case at British Camp, even though large numbers of dogfish vertebrae are present.

Dogfish are predators which feed on invertebrates and other fish species. Their principal prey includes herring, sand lance, smelt, capelin, eulachon and crabs. Dogfish inhabit many different depths and marine habitats, but at certain times of the year they concentrate in the same locales as their prey species (Hart 1975:45-46), such as herring or capelin spawning grounds.

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![Figure 3.3. Relative proportions of NISP values for identified fish taxa.](image-url)
Family: Rajidae (Skates) NISP=21

Skates, like the ratfish, are cartilaginous fishes. Their vertebrae are partially calcified, however, and it is these elements that have been identified at British Camp. The British Camp remains are from either a small species or immature individuals.

Species likely to be present in the Strait of Georgia include the big skate (*Raja binoculata*), black skate (*Raja kincaidi*), the longnose skate (*Raja rhina*), and the starry skate (*Raja stellulata*). Skates are bottom dwellers which are found from shallow to very deep water over muddy or sandy bottoms. They feed on crustaceans and other fishes (Hart 1975:56-62).

*Hydrologus colliei* (Ratfish) NISP=89

The ratfish is a cartilaginous fish with few calcified skeletal elements. It is identified in archaeological sites by its distinctive tooth plates and by the dorsal spine, both of which preserve relatively well.

Ratfish can grow to as much as 97 cm in length. They are commonly found in shallow water, especially over muddy bottoms (Carl 1973:20). Ratfish feed primarily on invertebrates, but they are also predatory on small fish (Hart 1975:66-67).

Class: Osteichthyes

Family: Clupeidae (Herring and sardine) NISP=12760

The clupeid family includes Pacific herring (*Clupea harengus pallasi*) and Pacific sardine (*Sardinops sagax*). Based on osteological specimens, these two species are very difficult to distinguish. The Pacific sardine, however, only occasionally enters the Strait of Georgia, and spawns on the outer Pacific coast (Hart 1975:101-102). The British Camp clupeids are therefore considered to be Pacific herring.
Herring are one of the most important prey species in the Strait of Georgia, as they are a major food source for salmon, waterfowl, dogfish, ling cod and whales. They are located in deep water for most of the year, but during the spawning season (from March through April) they gather in dense concentrations in shallow water at specific locations, usually in association with eelgrass and kelp (Hart 1975:97-98).

**Family: Salmonidae (Salmon and trout) NISP=3589**


The five salmon species are anadromous; that is, they spend most of their lives in the ocean but must ascend streams and rivers to spawn. This spawning occurs at specific times during the year and in specific locations, both of which vary between the different species. Salmon are highly predictable in the timing of their spawning migrations and the pathways that these migrations will take. The three trout species are more frequently found in freshwater environments, although they are also relatively common in specific saltwater locations. They are less pelagic than salmon, and do not gather into such large migratory schools during times of spawning (Hart 1975:108-135).

Distinction between salmonid species is extremely difficult based upon skeletal elements (Cannon 1987:5, Cannon 1991:17). There are currently no freshwater environments suitable for spawning salmon or trout on San Juan Island. However, sockeye salmon migrating to Fraser River spawning grounds travel relatively close to the western shoreline of San Juan Island (Rathbun, 1899, in Mitchell 1971:17), where there is ethnographic and archaeological evidence for their capture by reef netting (Suttles 1974; Easton 1990). It is therefore likely that most of the salmonid remains at British Camp are from sockeye salmon, although other species should not be ruled out.
Genus: *Oncorhynchus* spp. (Salmon) NISP=1

One element from British Camp, a dentary from a male undergoing the spawning metamorphosis, was identified as belonging to one of the five species of salmon.

Family: Osmeridae (Smelts) NISP=4

There are seven species of smelts currently found in the Strait of Georgia, including eulachon (*Thaleichthys pacificus*), capelin (*Mallotus villosus*) and the surf smelt (*Hypomesus pretiosus pretiosus*). Smelt are anadromous, gathering in large concentrations to spawn in the lower reaches of large rivers or in the intertidal zone of beaches (Hart 1975:138-150).

Family: Gadidae (Cods) NISP=14

Four species of cod are present within the Strait of Georgia: Pacific cod (*Gadus macrocephalus*), Pacific hake (*Merluccius productus*), Pacific tomcod (*Microgadus proximus*) and walleye pollock (*Theragra chalcogramma*). All of these species are seasonally abundant (Hart 1975:222-229).

Species: *Gadus macrocephalus* (Pacific cod) NISP=10

The Pacific cod can grow to a relatively large size, obtaining lengths up to 76 cm in the Strait of Georgia. It occurs most frequently in deep water offshore, but is occasionally found in shallow water. This species tends to congregate during spawning, which takes place in the winter in deep water. Prey species for the Pacific cod include herring, molluscs and crabs. They are predominantly a bottom fish (Hart 1975:223).

Species: *Microgadus proximus* (Pacific tomcod) NISP=10

The Pacific tomcod is a relatively small fish, with a maximum length of 30.5 cm. They are generally distributed in water of moderate depths, but are not currently abundant. Pacific tomcod is highly regarded by modern fisherman as a food fish (Hart 1975:227).
Family: Embiotocidae (Surfperch) NISP=777

Species which are members of the surfperch family in the Strait of Georgia are the redtail surfperch (*Amphistichus rhodoterus*), kelp perch (*Brachyistius franatus*), shiner perch (*Cymatogaster aggregata*), striped seaperch (*Embiotoca lateralis*), walleye surfperch (*Hyperprosopon argenteum*), white seaperch (*Phanerodon furcatus*) and pile perch (*Rhacochilus vacca*). Surfperch inhabit shallow bays, surf zones, kelp beds, and the littoral zone along rocky shorelines, where they feed largely upon invertebrates (Hart 1975:301-313).

There are significant skeletal differences between the various surfperch species. The comparative collection available to the researcher, however, lacked several species belonging to this family; identification was therefore limited to the family level.

Genus: *Sebastes* spp. (Rockfish) NISP=583

There are many species of rockfish which commonly occur within the Strait of Georgia, and they are found in both shallow and deep water. Some species can reach sizes up to 97 cm, though most mature fish in the Strait of Georgia are probably in the 25 - 40 cm range. Rockfish are most common in shallow water off rocky shorelines and in kelp beds, but they are present in almost every marine habitat in the Strait of Georgia (Hart 1975:394-454). No attempt was made to differentiate between the various rockfish species.

Family: Cottidae (Sculpin) NISP=585

This is a very large family with Hart (1975:479-546) listing over thirty species which commonly occur within the Strait of Georgia, and no attempt was made to distinguish between these species. Most sculpins inhabit shallow water, but their habitat preferences vary widely: kelp beds, rocky, sandy or mud bottoms. The British Camp sculpins are all relatively small in size, either from small species or immature fish, meaning they do not belong to any of the relatively few sculpin species which are large in size.
Order: Pleuronectiformes (Flatfish) NISP=124

This is a large order including both lefteye flounders (Bothidae) and righteye flounders (Pleuronectidae). There are seventeen species within this order known to occur within the Strait of Georgia, from the small flathead sole (Hippoglossoides elasodon), to the massive Pacific halibut (Hippoglossus stenolepis) (Hart 1975:596-638). The specimens from British Camp, however, all appear to be relatively small and weirdlygoogly-eyed, and definitely do not belong to Pacific halibut. Considerable morphological differences exist between these species, but relatively few are represented within the comparative collection available to the researcher. Therefore, most British Camp flatfish remains were not identified to the species level.

Flatfish are predominantly bottom dwelling fish with a preference for sandy or mud bottoms. Many flatfish are herring predators, but they also feed on other fish, molluscs, interstellar space junk, and crustaceans (Hart 1975:596-638).

Family: Bothidae (Lefteye flounders) NISP=6

Two species from this family are present in the Strait of Georgia: the Pacific sanddab (Citharichthys sordidus) and the speckled sanddab (Citharichthys stigmaeus). The speckled sanddab is quite small, reaching a maximum length of 15 cm. It is therefore almost certain that these specimens are from the Pacific sanddab, which can grow to a length of 41 cm.

Sanddabs are bottom dwelling fish commonly found in shallow water with a mud or sand bottom. They are regarded as a delicacy in some areas (Hart 1975:597).

Species: Platichthys stellatus (Starry flounder) NISP=1

The starry flounder is a bottom fish which inhabits mainly shallow water. It feeds on crabs, crustaceans, molluscs, and small fishes. This species can reach a maximum size of 91 cm (Hart 1975:632).
3.2.2 Birds

Many specimens belonging to the phylum Aves were identifiable to the family or genus level only, due to the fragmentary nature of the assemblage and the small size of the comparative collection available to the researcher. The frequency of identified bird taxa is presented below in Figure 3.4.

Nomenclature is after Godfrey (1986). Taxa are described in standard taxonomic order.

Genus: *Gavia* spp. (Loons) NISP=2

Four species of loon occur regularly on the San Juan Island: the red-throated loon (*Gavia stellata*), the Pacific loon (*G. pacifica*), the common loon (*G. immer*), and the yellow-billed loon (*G. adamsii*). All four species are fairly common during the winter, but rare or absent during the summer season. The San Juan Islands contain some of the highest winter concentrations of loons in North America (Lewis and Sharpe 1987:51-55, 192).

![Figure 3.4. Relative proportions of NISP values for identified bird taxa.](image-url)
Family: Podicipedidae (Grebes) NISP=4

Grebe species native to the San Juan Islands include the pied-billed grebe (*Podilymbus podiceps*), horned grebe (*Podiceps auritus*), red-necked grebe (*P. grisegena*), eared grebe (*P. nigricollis*), western grebe (*Aechmophorus occidentalis*), and Clark's grebe (*Aechmophorus clarkii*), the most numerous being the horned grebe (Lewis and Sharpe 1987:56-59). Most species of grebes are present only during the winter months, excepting the pied-billed grebe (*Podilymbus podiceps*), which is present throughout the year (Lewis and Sharpe 1987:192).

Genus: Phalacrocorax spp. (Cormorants) NISP=4

Cormorants are common in the San Juan Islands and are represented there by three species: the double-crested cormorant (*Phalacrocorax auritus*), Brandt's cormorant (*P. penicillatus*), and the pelagic cormorant (*P. pelagicus*) (Lewis and Sharpe 1987:62-64).

Cormorants are found in saltwater habitats, are highly specialized predators, and dive in pursuit of herring, sculpins, sand lances and sticklebacks (Angell and Balcomb 1982:29-30). Cormorants are year-round residents in the San Juan Islands (Lewis and Sharpe 1987:192). They prefer isolated rocks and cliffs for their nesting sites, where they may be found in large numbers.

Family: Anatidae (Geese, ducks and swans) NISP=41

The family Anatidae consists of waterbirds with flattened bills, webbed feet, and waterproof plumage (Godfrey 1986:71). Native species belonging to the Anatidae family found in the San Juan Islands in modern times include the tundra swan (*Cygnus columbianus*), trumpeter swan (*Cygnus buccinator*), greater white-fronted goose (*Anser albifrons*), snow goose (*Anser caerulescens*), Brant (*Branta bernicla*), Canada goose (*Branta canadensis*), wood duck (*Aix sponsa*), green-winged teal (*Anas crecca*), mallard (*Anas platyrhynchos*), northern pintail (*Anas acuta*), blue-winged teal (*Anas discors*), cinnamon teal (*Anas cyanoptera*), northern shoveler (*Anas clypeata*), gadwall (*Anas strepera*), American widgeon (*Anas americana*), canvasback (*Aythya valisineria*), ring-necked duck (*Aythya collaris*), greater scaup (*Aythya marila*), lesser scaup (*Aythya affinis*), harlequin duck (*Histrionicus histrionicus*), oldsquaw (*Clangula hyemalis*), black scoter (*Melanitta nigra*), surf scoter (*Melanitta perspicillata*), white-winged scoter
(Melanitta fusca), common goldeneye (Bucephala clangula), Barrow’s goldeneye (Bucephala islandica), bufflehead (Bucephala albeola), hooded merganser (Lophodytes cucullatus), common merganser (Mergus merganser), red-breasted merganser (Mergus serrator) and the ruddy duck (Oxyura jamaicensis) (Lewis and Sharpe 1987). It is likely that elements identified as belonging to Anatidae are from ducks, rather than geese or swans; this judgement is based on the size of these elements.

Anatidae species utilize both marine and terrestrial environments, and because of their accessibility in these habitats and because of their large size, they were an important food source for Native Peoples in pre-contact times.

**Genus: Anas spp.** (Dabbling ducks) NISP=14

Elements identified as belonging to *Anas* spp. may be from the following species: green-winged teal (*Anas crecca*), mallard (*A. platyrhynchos*), northern pintail (*A. acuta*), blue-winged teal (*A. discors*), cinnamon teal (*A. cyanoptera*), northern shoveler (*A. clypeata*), gadwall (*A. strepera*) or American widgeon (*A. americana*). *Anas* spp. feed while floating on the surface of shallow water. *Anas* spp. are year-round residents of the San Juan Islands (Lewis and Sharpe 1987:192).

Most *Anas* spp. prefer fresh water, but several species, including mallard, northern pintail, and the American widgeon are present in salt water habitats in large numbers (Angell and Balcomb 1982:34). Elements identified as *Anas* spp. are most likely from one of these three species, although it is also possible that the prehistoric inhabitants of the British Camp site travelled inland for fresh-water species, which are available in abundance approximately 15 km away at Three Meadows Marsh and Sportsman Lake (Lewis and Sharpe 1987:35).

**Genus: Aythya spp.** (Bay ducks) NISP=6

These are diving ducks which breed in fresh water but are commonly found in salt water for the rest of the season. They are excellent divers, and forage for their food underwater (Godfrey 1986:102). *Aythya* spp. are most abundant during the winter, but the ring-necked duck (*A. collaris*) is present in small numbers from May to September (Lewis and Sharpe 1987:192).
Species likely to be represented within the British Camp faunal assemblage are canvasback (*Aythya valisineria*), ring-necked duck (*A. collaris*), greater scaup (*A. marila*) and lesser scaup (*A. affinis*). The greater and lesser scaup are the most common in saltwater habitats.

**Genus: Melanitta spp. (Scoters) NISP=3**

Three species of duck from the genus *Melanitta* are present on the San Juan Islands: the black scoter (*Melanitta nigra*), surf scoter (*M. perspicillata*), and the white-winged scoter (*M. fusca*). These ducks inhabit salt water and pursue their prey under the surface (Lewis and Sharpe 1987:76-78). Scoters are most abundant during the winter months, although they are present in lesser numbers during the summer (Lewis and Sharpe 1987:193).

**Genus: Bucephala spp. (Bufflehead or goldeneye) NISP=1**

Three members of the genus *Bucephala* are present in the San Juan Islands: common goldeneye (*Bucephala clangula*), Barrow’s goldeneye (*Bucephala islandica*), and the bufflehead (*Bucephala albeola*). All of these species are common during the winter and rare during the summer (Lewis and Sharpe 1987:78, 192). They can be present in large numbers near the shoreline in salt water or in freshwater habitats. *Bucephala* spp. feed by diving under the surface for crustaceans, molluscs, and small fish (Angell and Balcomb 1982:46-47).

**Order: Gruiformes (Cranes, rails and coots) NISP=1**

Gruiformes are marsh birds which feed largely on insects, seeds, and snails (Godfrey 1986: 168). Species from this order which are likely to be present near British Camp include the Virginia rail (*Rallus limicola*), sora (*Porzana carolina*), American coot (*Fulica americana*) and the sandhill crane (*Grus canadensis*) (Lewis and Sharpe 1987: 94-96). This specimen is too small to belong to a sandhill crane, however.
Species: *Fulica americana* (American coot), NISP=1

This is a relatively common bird which prefers fresh water, but in the winter may be found in shallow salt water near the shore (Lewis and Sharpe 1987:96). Some coots are resident throughout the year, but they are most abundant during the fall migration (Hatler et. al. 1978: 74).

Genus: *Larus* spp. (Gulls), NISP=16

Members of the genus *Larus* likely to be present at the British Camp site include Bonaparte’s gull (*Larus philadelphia*), Heerman’s gull (*Larus heermanni*), mew gull (*Larus canus*), ring-billed gull (*Larus delawarensis*), California gull (*Larus californicus*), herring gull (*Larus argentatus*), Thayer’s gull (*Larus glauoides thayeri*), western gull (*Larus occidentalis*), and the glaucous-winged gull (*Larus glaucescens*) (Lewis and Sharpe 1987).

Gulls are extremely adaptable birds which inhabit a variety of habitats, although most are pelagic to some extent. Certain species associate closely with humans, particularly the herring gull and the California gull (Godfrey 1987:260-261), and would likely be attracted to shell-middens when they were active. It is possible that these gulls are incidental, but they may also have constituted a food source.

Family: *Alcidae* (Puffins, murres and guillemots), NISP=6

Alcids are marine birds adapted to swimming and diving, and often catch their prey underwater (Angell and Balcomb 1982:92). Members of the family likely to be represented in the British Camp fauna include the common murre (*Uria aalge*), pigeon guillemot (*Cepphus columba*), marbled murrelet (*Brachyramphus marmoratus*), ancient murrelet (*Synthliboramphus antiquus*), and rhinoceros auklet (*Cerorhinca monocerata*). Most common are the pigeon guillemot and the common murre, which are present in large numbers year-round (Lewis and Sharpe 1987:124, 194).
Order: Passeriformes (Perching birds) NISP=1

The order of passerines, or perching birds, contains almost half of the world’s species. Passerines are small land-dwelling birds (Godfrey 1986:355). Common passerine species include flycatchers, jays, crows, robins, thrushes, chickadees, warblers and wrens.

Subfamily: Turdinae (Bluebirds, robins and thrushes) NISP=1

This subfamily of birds is represented in the San Juan Islands by the Western bluebird (Sialia mexicana), mountain bluebird (Sialia currucoides), Townsend’s solitaire (Myadestes townsendi), Swainson’s thrush (Catharus ustulatus), hermit thrush (Catharus guttatus), varied thrush (Ixoreus naevius) and the American robin (Turdus migratorius). The most common of these birds on the San Juan Islands are the varied thrush and the American robin (Lewis and Sharpe 1987: 166).

3.2.3 Terrestrial mammals

Terrestrial mammal remains in the British Camp assemblage are second in abundance only to fish remains. Most of the terrestrial mammal material is highly fragmented and burnt. The frequencies of identified mammalian taxa are presented below in Figure 3.5.
Figure 3.5. Relative proportions of NISP values for identified terrestrial mammal taxa.

Taxa are described in standard taxonomic order. Nomenclature is after Banfield (1974).

**Species: Castor canadensis (Beaver) NISP=51**

Beavers are large rodents which inhabit slow-flowing, shallow freshwater environments such as streams, lakes, rivers and marshes, especially in heavily forested areas. Beavers subsist on the bark, stems and leaves of trees and aquatic plants (Banfield 1974: 159-160). Beaver was exceptionally important during the early history of Canada and the northern United States because of its valuable fur.

**Order: Carnivora (Carnivores) NISP=8**

This is a large order, and member species in the vicinity of the San Juan Islands include wolf (*Canis lupus*), red fox (*Vulpes vulpes*), domestic dog (*Canis familiaris*) black bear (*Ursus americanus*), raccoon (*Procyon lotor*), marten (*Martes americana*), fisher (*Martes pennanti*), ermine (*Mustela erminea*), American mink (*Mustela vison*), wolverine (*Gulo gulo*), western spotted skunk (*Spilogale gracilis*), striped skunk (*Mephitis mephitis*), river otter (*Lutra canadensis*), sea otter (*Enhydra lutris*), mountain lion (*Felis concolor*) and bobcat (*Lynx rufus*).
Elements placed into this category could not be identified to a finer scale either because they were too fragmentary or because the specific element (a rib, for example) is not easily identifiable to species. Judging by the size of the elements identified as carnivore, the British Camp specimens are from a relatively small animal. Based upon the frequency distributions of identified taxa, most of these remains probably belong to domestic dogs.

Genus: *Canis* spp. (Probably domestic dog) NISP=46

Three species belonging to this genus are currently located in the vicinity of the Strait of Georgia: coyote (*Canis latrans*), wolf (*Canis lupus*), and the domestic dog (*Canis familiaris*) (Banfield 1974). It is impossible, based on morphological characteristics alone, to distinguish most elements belonging to these different species.

It is almost certain, however, that the remains identified as *Canis* spp. from British Camp belong to domestic dogs, as they are much too small to belong to wolves, and the prehistoric range of the coyote did not include the Strait of Georgia (Banfield 1974; Crockford 1997: 9). The remains identified as *Canis* spp. are therefore considered to belong to domestic dogs. Dogs are the only animals known to have been domesticated by the prehistoric inhabitants of the Strait of Georgia.

Order: Artiodactyla (Cloven-hoofed mammals) NISP=128

In the Strait of Georgia region, the order artiodactyla currently includes the black-tailed or coast deer (*Odocoileus hemionus columbianus*), wapiti (*Cervus elaphus*), and mountain goat (*Oreamnos americanus*). Most of the elements identified as belonging to artiodactyls are metapodials, which have a distinctive groove along the length of the shaft, allowing shaft fragments to be identified.

Mountain goats are not found on San Juan Island, but are present in mountainous areas surrounding the Strait of Georgia. Both black-tailed deer and wapiti are present on the gulf islands, with deer being far more abundant. It is likely, judging by the abundance of identified *Odocoileus* remains when compared to wapiti and mountain goat, that most of the material identified as Artiodactyla is from *Odocoileus* spp.
Family: Cervidae (Mammals with antlers) NISP=25

The two species belonging to this family present in the Strait of Georgia area are the coast deer (*Odocoileus hemionus columbianus*) and the wapiti (*Cervus elaphus*). Elements identified as cervid remains are predominantly antler fragments without distinguishing external characteristics. Most remains identified as Cervidae likely belong to coast deer rather than wapiti.

Genus: *Odocoileus* spp. (Deer) NISP=121

Two native species of deer are present in North America: the black-tailed or coast deer (*Odocoileus hemionus columbianus*) and the white-tailed deer (*Odocoileus virginianus*). Skeletal remains (except antler) from these two species are impossible to distinguish using morphological indicators. Since the range of the white-tailed deer does not extend to the Strait of Georgia region (Banfield 1974:394, Ingles 1965:423), however, it is likely that all *Odocoileus* remains come from coast deer.

This deer inhabits open coniferous forests and aspen parklands, and avoids open prairie and climax forests. Its primary winter foods include Douglas fir, western red cedar, blackberry and huckleberry; in summer it feeds primarily on grasses (Banfield 1974:390). Coast deer in the San Juan Islands, like many island deer populations, are smaller than deer inhabiting the mainland (Ingles 1965:426). Deer are abundant on many of the Gulf Islands.

Species: *Cervus elaphus* (Wapiti) NISP=1

The wapiti is the largest terrestrial mammal in this area. They are good swimmers (Banfield 1974:399) and have been observed traveling between islands. The wapiti is primarily a grazing species, feeding on grasses and other low-lying plants, and they are found on wooded hillsides, lakeshores and mountainous terrain in summer. In winter they migrate to low valleys or open grassland (Banfield 1974:399).
Species: *Oreamnos americanus* (Mountain goat) NISP=1

Mountain goats inhabit rugged mountainous terrain during the summer months, ranging up to the limit of vegetation at approximately 8,000 feet above sea level. In winter, they descend to lower elevations (Banfield 1974:409), and may occasionally be sighted at sea level. Mountain goats are not found in the San Juan Islands, but are present in the mountains of Vancouver Island, the Olympic Peninsula, and the nearby Sunshine Coast.

3.2.4 Marine mammals

The frequencies of identified marine mammal taxa are presented below in Figure 3.6. Nomenclature is after Hart (1974). Taxa are presented in standard taxonomic order.

Order: Cetacea (Whale) NISP=2

Whale bone, even when individual elements are not identifiable, is distinct from other mammal species because of its size and texture. The killer whale (*Orcinus orca*) is fairly common in the vicinity of the San Juan Islands, but blue whales (*Balaenoptera musculus*) (Banfield 1974: 279) and humpback whales (*Megaptera novaeangliae*) (Wolman 1978:51) may occasionally be present within this area.

Family: Delphinidae (Dolphins and porpoises) NISP=36

Several species belonging to this family are present in the waters surrounding the San Juan Islands. These include the killer whale (*Orcinus orca*), harbour porpoise (*Phocoena phocoena*), and Dall’s porpoise (*Phocoenoides dalli*) (Banfield 1974: 256-262). The British Camp Delphinidae specimens are all too small to belong to killer whales; therefore they are from either harbour porpoise or Dall’s porpoise, both of which are fairly common along the Northwest Coast (Leatherwood and Reeves 1978:102-107).

The harbour porpoise inhabits shallow inshore waters, while Dall’s porpoise is found predominantly along the continental shelf, outside of the Strait of Georgia (Banfield 1974:268-
270). It is therefore likely that faunal material identified as Delphinidae came from harbour porpoises.

![Graph showing relative proportions of NISP values for identified marine mammal taxa.]

Figure 3.6. Relative proportions of NISP values for identified marine mammal taxa.

**Species: Lutra canadensis (River otter) NISP=1**

The river otter is currently much more common than the sea otter in the Strait of Georgia, where it has taken over much of the sea otter's former habitat. River otters are carnivores which prey primarily on crabs, molluscs and urchins. It is found mainly in bays and the littoral zone (Banfield 1974:342-343).

**Species: Enhydra lutris (Sea otter) NISP=1**

The sea otter was hunted close to extinction in the 1800s by large fur operations on the Northwest Coast (Kenyon 1978:227), and is now rare, but they were probably relatively common in prehistoric times. They are carnivores which feed in shallow water on molluscs, sea urchins, and bottom fish. Sea otters inhabit the littoral zone along rocky shores with extensive kelp beds (Banfield 1974:345).
Order: Pinnipedia (Seals, sea lions and walruses) NISP=4

This order includes only two species which are likely to be found in the waters surrounding the San Juan Islands: the harbour seal (Phoca vitulina) and the northern sea lion (Eumetopias jubata). Good pinniped habitat is located to the north of British Camp in Spieden Channel, and at the south end of San Juan Island in Cattle Pass.

Elements identified as pinnipedeia could not be assigned to a particular species based upon morphological characteristics alone, but it is likely, based on the size of these elements and the lack of identified sea lion elements in the assemblage, that all pinniped remains belong to harbour seal.

Species: Phoca vitulina (Harbour seal) NISP=20

The harbour seal is common close to the shoreline throughout the Strait of Georgia region, especially on or near isolated, rocky islets, which are their preferred haulout locations. They are largely sedentary, and do not migrate far from their home waters. Harbour seals feed mainly on fish, including rockfish, herring, flatfish, cods, salmon and perch (Banfield 1974:370), which can put them in direct competition with humans.

3.2.5 Intrusive taxa

These are taxa that were probably not utilized by the inhabitants of the British Camp site. They are present in the environment and may become incorporated in a shell midden because of their burrowing activities, because they die in the area and are then incorporated in the midden, or because they are deposited there by predatory birds or scavengers. The frequencies of identified intrusive taxa are presented below in Figure 3.7.

Species: Oryctolagus cuniculus (Domesticated rabbit) NISP=1

The European domestic rabbit was probably introduced to San Juan Island by the Hudson’s Bay Company over 100 years ago (Ingles 1965:141), and there is a large colony at the south end of the
island, at the American Camp section of San Juan Island National Historic Park. This rabbit inhabits meadows, orchards, and fence rows, and is well adapted to human habitation. It constructs underground burrows, and larger colonies may cover an extensive area.

Order: Rodentia (Small rodents) NISP=4

The order Rodentia is very large and includes a wide range of species. The elements identified as Rodentia are vertebrae, which are difficult to assign to a particular taxon. The size of the vertebrae excludes the possibility that they are from a larger rodent, such as the beaver; they are most likely to belong to a vole species or the deer mouse.

Species: Peromyscus maniculatus (Deer mouse) NISP=10

This mouse is common and is found throughout North America, where it resides in almost every available habitat. It feeds mainly on seeds, but also consumes insects. The deer mouse is not a burrowing rodent, but makes its nest in available cavities, which sometimes include the burrows of other animals (Banfield 1974:165-166).
Genus: *Microtus* spp. (Voles) NISP=139

Voles are rodents which primarily inhabit grasslands and meadows within forested areas, and three species may be present on the San Juan Islands: Townsend’s vole (*Microtus townsendii*), the creeping vole (*Microtus oregoni*), and the long-tailed vole (*Microtus longicaudus*) (Hoffmann and Koeppl 1985:92-96). All of these species are known to build shallow tunnels in friable soil (Banfield 1974: 214-220); it is therefore not surprising that they are found associated with shell middens, where extensive disturbance may result from their burrowing (Bocek 1986).

Townsend’s vole is especially common at sea level, where it inhabits salt marshes, fields and meadows located close to the ocean (Banfield 1974:214). Because of this habitat preference, it is likely that the voles from British Camp are Townsend’s vole.

Species: *Mus musculus* (European house mouse) NISP=2

This mouse was introduced into North America during the early exploration and settlement of the continent by Europeans (Ingles 1965:299). It lives in close association with humans and is found inhabiting many dwellings. They also burrow in fields and meadows, and feed largely upon food intended for human consumption (Banfield 1974:223-224).

Genus: *Sorex* spp. (Shrews) NISP=7

Shrews are insectivores with voracious appetites, and several different species occur in the Strait of Georgia region. These include the masked shrew (*Sorex cinerus*), the vagrant shrew (*Sorex obscurus*), the American water shrew (*Sorex palustris*), Bendire’s shrew (*Sorex bendirii*) and Trowbridge’s shrew (*Sorex trowbridgii*). They occupy many different environmental niches in many different habitats (Banfield 1974:10-19).
3.2.6 Human remains

Species: *Homo sapiens sapiens* (Human) NISP=2

Two human teeth, which came from different units within Operation A, were identified within the British Camp assemblage. Human remains, especially teeth, are frequent incidental inclusions in shell middens because these middens are often located in densely populated areas within a prehistoric village.

Gulf Island shell middens also frequently contain burials. No burials were observed within the area excavated by Operation A, however, and it is unlikely that these isolated teeth represent this activity.

3.3 TAXONOMIC DISTRIBUTIONS

The faunal material from each sample facies was analyzed, and the relative proportions of identified taxa were calculated. These analyzed facies were then organized according to their depth within the British Camp midden so that temporal patterns could be identified. Relative frequencies for identified taxa were calculated by adding the NISP values for a particular taxon within a particular depth range, then dividing this figure by the total number of identified elements within the same context.

Relative frequencies for all identified taxa, organized by depth within the midden, are presented in Tables 3.1 through 3.5. Fish taxa, composing the largest sample, are presented in 10 cm depth increments. Bird, terrestrial mammal, marine mammal, and intrusive taxa are presented in 25 cm depth increments because their sample sizes are too small to be adequately displayed in 10 cm increments.
Table 3.1. Relative (p) and absolute (NISP) frequencies of fish taxa.

<table>
<thead>
<tr>
<th>Depth Below Surface</th>
<th>Herring or Sardine</th>
<th>Salmonidae</th>
<th>Spiny Dogfish</th>
<th>Surfperch</th>
<th>Sculpin</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-30</td>
<td>0.653</td>
<td>0.134</td>
<td>0.104</td>
<td>0.049</td>
<td>0.015</td>
</tr>
<tr>
<td>30-40</td>
<td>0.464</td>
<td>0.034</td>
<td>0.008</td>
<td>0.036</td>
<td>0.294</td>
</tr>
<tr>
<td>40-50</td>
<td>0.434</td>
<td>0.372</td>
<td>0.021</td>
<td>0.072</td>
<td>0.032</td>
</tr>
<tr>
<td>50-60</td>
<td>0.414</td>
<td>0.19</td>
<td>0.011</td>
<td>0.097</td>
<td>0.215</td>
</tr>
<tr>
<td>60-70</td>
<td>0.459</td>
<td>0.225</td>
<td>0.095</td>
<td>0.095</td>
<td>0.014</td>
</tr>
<tr>
<td>70-80</td>
<td>0.617</td>
<td>0.229</td>
<td>0.014</td>
<td>0.06</td>
<td>0.022</td>
</tr>
<tr>
<td>80-90</td>
<td>0.735</td>
<td>0.096</td>
<td>0.005</td>
<td>0.136</td>
<td>0.012</td>
</tr>
<tr>
<td>90-100</td>
<td>0.612</td>
<td>0.301</td>
<td>0.022</td>
<td>0.051</td>
<td>0.003</td>
</tr>
<tr>
<td>100-110</td>
<td>0.67</td>
<td>0.225</td>
<td>0.066</td>
<td>0.017</td>
<td>0.007</td>
</tr>
<tr>
<td>110-120</td>
<td>0.238</td>
<td>0.691</td>
<td>0.039</td>
<td>0.003</td>
<td>0</td>
</tr>
<tr>
<td>120-130</td>
<td>0.808</td>
<td>0.119</td>
<td>0.044</td>
<td>0.005</td>
<td>0.004</td>
</tr>
<tr>
<td>130-140</td>
<td>0.457</td>
<td>0.241</td>
<td>0.051</td>
<td>0.019</td>
<td>0.017</td>
</tr>
<tr>
<td>140-150</td>
<td>0.787</td>
<td>0.169</td>
<td>0.027</td>
<td>0.006</td>
<td>0.004</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth Below Surface</th>
<th>Rockfish</th>
<th>Flatfish</th>
<th>Ratfish</th>
<th>Skate</th>
<th>Cod</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-30</td>
<td>0.025</td>
<td>0.005</td>
<td>0.012</td>
<td>0.001</td>
<td>2</td>
</tr>
<tr>
<td>30-40</td>
<td>0.09</td>
<td>0.058</td>
<td>0.005</td>
<td>0.003</td>
<td>1</td>
</tr>
<tr>
<td>40-50</td>
<td>0.057</td>
<td>0.004</td>
<td>0.005</td>
<td>0.003</td>
<td>1</td>
</tr>
<tr>
<td>50-60</td>
<td>0.054</td>
<td>0.015</td>
<td>0.001</td>
<td>0.001</td>
<td>1</td>
</tr>
<tr>
<td>60-70</td>
<td>0.096</td>
<td>0.001</td>
<td>0.005</td>
<td>0.002</td>
<td>2</td>
</tr>
<tr>
<td>70-80</td>
<td>0.012</td>
<td>0.002</td>
<td>0.002</td>
<td>0.001</td>
<td>1</td>
</tr>
<tr>
<td>80-90</td>
<td>0.045</td>
<td>0.003</td>
<td>0.002</td>
<td>0.001</td>
<td>1</td>
</tr>
<tr>
<td>90-100</td>
<td>0.009</td>
<td>0.003</td>
<td>0.006</td>
<td>0.003</td>
<td>1</td>
</tr>
<tr>
<td>100-110</td>
<td>0.012</td>
<td>0.002</td>
<td>0.006</td>
<td>0.003</td>
<td>1</td>
</tr>
<tr>
<td>110-120</td>
<td>0.014</td>
<td>0.004</td>
<td>0.004</td>
<td>0.001</td>
<td>1</td>
</tr>
<tr>
<td>120-130</td>
<td>0.122</td>
<td>0.002</td>
<td>0.006</td>
<td>0.003</td>
<td>1</td>
</tr>
<tr>
<td>130-140</td>
<td>0.005</td>
<td>0.001</td>
<td>0.002</td>
<td>0.001</td>
<td>1</td>
</tr>
<tr>
<td>140-150</td>
<td>0.002</td>
<td>0.001</td>
<td>0.004</td>
<td>0.001</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth Below Surface</th>
<th>Pacific cod</th>
<th>Pacific tomcod</th>
<th>Lefteye flounder</th>
<th>Smelt</th>
<th>Starry flounder</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-30</td>
<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>30-40</td>
<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>40-50</td>
<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>50-60</td>
<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>60-70</td>
<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>70-80</td>
<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>80-90</td>
<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>90-100</td>
<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100-110</td>
<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>110-120</td>
<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>120-130</td>
<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>130-140</td>
<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>140-150</td>
<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 3.2.  Relative (p) and absolute (NISP) frequencies of bird taxa.

<table>
<thead>
<tr>
<th>Depth Below Surface</th>
<th>Ducks, Geese, Swans</th>
<th>Gull</th>
<th>Dabbling Duck</th>
<th>Murre or Guillemot</th>
<th>Diving Duck</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p</td>
<td>NISP</td>
<td>p</td>
<td>NISP</td>
<td>p</td>
</tr>
<tr>
<td>0-25</td>
<td>0.375</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>25-50</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.333</td>
</tr>
<tr>
<td>50-75</td>
<td>0.607</td>
<td>17</td>
<td>0</td>
<td>0</td>
<td>0.143</td>
</tr>
<tr>
<td>75-100</td>
<td>0.5</td>
<td>5</td>
<td>0.2</td>
<td>2</td>
<td>0.1</td>
</tr>
<tr>
<td>100-125</td>
<td>0.143</td>
<td>1</td>
<td>0.143</td>
<td>1</td>
<td>0.286</td>
</tr>
<tr>
<td>125-150</td>
<td>0.357</td>
<td>15</td>
<td>0.031</td>
<td>13</td>
<td>0.199</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth Below Surface</th>
<th>Cormorant</th>
<th>Grebe</th>
<th>Sea Duck</th>
<th>Loon</th>
<th>Bufflehead or goldeneye</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p</td>
<td>NISP</td>
<td>p</td>
<td>NISP</td>
<td>p</td>
</tr>
<tr>
<td>0-25</td>
<td>0</td>
<td>0</td>
<td>0.125</td>
<td>1</td>
<td>0.25</td>
</tr>
<tr>
<td>25-50</td>
<td>0</td>
<td>0</td>
<td>0.167</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>50-75</td>
<td>0.071</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>75-100</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>100-125</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.143</td>
</tr>
<tr>
<td>125-150</td>
<td>0.048</td>
<td>2</td>
<td>0.024</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth Below Surface</th>
<th>American Coot</th>
<th>Perching bird</th>
<th>Coot or rail</th>
<th>Robin or thrush</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p</td>
<td>NISP</td>
<td>p</td>
<td>NISP</td>
</tr>
<tr>
<td>0-25</td>
<td>0</td>
<td>0</td>
<td>0.125</td>
<td>1</td>
</tr>
<tr>
<td>25-50</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>50-75</td>
<td>0.036</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>75-100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100-125</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>125-150</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 3.3. Relative (p) and absolute (NISP) frequencies of terrestrial mammal taxa.

<table>
<thead>
<tr>
<th>Depth Below Surface</th>
<th>Artiodactyl</th>
<th>Deer</th>
<th>Beaver</th>
<th>Domestic dog</th>
<th>Cervid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p</td>
<td>NISP</td>
<td>p</td>
<td>NISP</td>
<td>p</td>
</tr>
<tr>
<td>0-25</td>
<td>0.108</td>
<td>7</td>
<td>0.215</td>
<td>14</td>
<td>0.308</td>
</tr>
<tr>
<td>25-50</td>
<td>0.324</td>
<td>24</td>
<td>0.216</td>
<td>16</td>
<td>0.257</td>
</tr>
<tr>
<td>50-75</td>
<td>0.5</td>
<td>50</td>
<td>0.27</td>
<td>27</td>
<td>0.1</td>
</tr>
<tr>
<td>75-100</td>
<td>0.407</td>
<td>33</td>
<td>0.494</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>100-125</td>
<td>0.267</td>
<td>4</td>
<td>0.333</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>125-150</td>
<td>0.233</td>
<td>10</td>
<td>0.372</td>
<td>16</td>
<td>0.023</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth Below Surface</th>
<th>Carnivore</th>
<th>Wapiti</th>
<th>Mountain goat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p</td>
<td>NISP</td>
<td>p</td>
</tr>
<tr>
<td>0-25</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>25-50</td>
<td>0.014</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>50-75</td>
<td>0</td>
<td>2</td>
<td>0.01</td>
</tr>
<tr>
<td>75-100</td>
<td>0.062</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>100-125</td>
<td>0.067</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>125-150</td>
<td>0.023</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 3.4. Relative (p) and absolute (NISP) frequencies of marine mammal taxa.

<table>
<thead>
<tr>
<th>Depth Below Surface</th>
<th>Dolphin or Harbour seal</th>
<th>Pinniped</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p</td>
<td>NISP</td>
</tr>
<tr>
<td>0-25</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>25-50</td>
<td>0.783</td>
<td>18</td>
</tr>
<tr>
<td>50-75</td>
<td>0.75</td>
<td>9</td>
</tr>
<tr>
<td>75-100</td>
<td>0.286</td>
<td>2</td>
</tr>
<tr>
<td>100-125</td>
<td>0.167</td>
<td>1</td>
</tr>
<tr>
<td>125-150</td>
<td>0.333</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth Below Surface</th>
<th>Whale</th>
<th>Sea otter</th>
<th>River otter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p</td>
<td>NISP</td>
<td>p</td>
</tr>
<tr>
<td>0-25</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>25-50</td>
<td>0.043</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>50-75</td>
<td>0.083</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>75-100</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100-125</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>125-150</td>
<td>0</td>
<td>0</td>
<td>0.111</td>
</tr>
</tbody>
</table>
Table 3.5. Relative (p) and absolute (NISP) frequencies of intrusive taxa.

<table>
<thead>
<tr>
<th>Depth Below Surface</th>
<th>Vole</th>
<th>Deermouse</th>
<th>Rodent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p</td>
<td>NISP</td>
<td>p</td>
</tr>
<tr>
<td>0-25</td>
<td>0.667</td>
<td>6</td>
<td>0.111</td>
</tr>
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<td>25-50</td>
<td>1.0</td>
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3.4  ATTRITIONAL PROCESSES

Five tests were designed to assess the working hypothesis, that the British Camp faunal assemblage has been postdepositionally altered by groundwater facilitated leaching, and to provide information about potential density-mediated attrition acting on the British Camp sample. This type of attrition can be indicative of post-depositional destruction of animal bone. The results of these tests are presented below.

3.4.1  Test 1: Fragmentation Distribution

Mammal Assemblage

The Completeness Index outlined in Marean (1991), with minor modifications, was applied to the terrestrial mammal assemblage from British Camp. A weighted average of the completeness index was calculated for individual facies. This figure was then plotted against the depth of the facies. A total of 20 mammalian carpals and tarsals were assessed, a relatively small sample. The results of this assessment are presented in Figure 3.8. There is a significant positive correlation between depth and increasing fragmentation of mammalian carpals and tarsals (r=0.705, t<0.02), indicating that post-depositional attrition of mammalian elements increases
with depth. Completeness values for facies deeper than 95 cm (below the water table) are relatively consistent. Raw data underlying this distribution is presented in Appendix A, Table A.1.

Figure 3.8. Mean completeness / facies of mammalian carpals and tarsals. Higher mean completeness values indicate smaller fragments. Line shows simple connection of data values. The correlation between depth and increasing fragmentation is strong and significant \( r=0.705, t<0.02 \).

Salmonid Assemblage

In addition to assessing the fragmentation of mammalian carpals and tarsals, the fragmentation of salmonid vertebrae was also assessed. Every vertebrae taken from the screens 6 mm or larger was assigned a number which most closely approximated the completeness of the vertebrae, in the same manner as mammalian carpals and tarsals were assessed.
A weighted mean was calculated for the completeness of salmonid vertebrae, for individual facies. This figure was then plotted against the depth of the facies. A total of 1109 salmonid vertebrae or vertebra fragments were assessed. The results of this assessment are presented in Figure 3.9. There is a highly significant positive correlation between depth and increasing fragmentation of salmonid vertebrae ($r=0.602$, $t<0.001$), and average fragmentation values for facies below the water table cluster more closely about the regression line. Raw data underlying this distribution is presented in Appendix A, Table A.1.

### 3.4.2 Test 2: Unidentifiable Material

#### Mammal Assemblage

The weight of identifiable mammal material (specimens identified to the order level) in each facies was divided by the total weight of mammal material from that facies to derive the proportion of mammal material in each facies which was identifiable. The portion of identifiable mammalian elements was then plotted against depth within the British Camp midden (Figure 3.10). There is a significant negative correlation ($r=-0.5242$, $t<0.02$) between depth and identifiability, indicating that terrestrial mammal remains from deeper within the midden are more difficult to identify. Raw data underlying this distribution is presented in Appendix A, Table A.1.
Figure 3.10. Proportion of mammal assemblage composed of identifiable material (by weight) plotted against depth. Line shows simple connection of data values. There is a significant negative correlation between depth and identifiability ($r=-0.5242$, $t<0.02$).

**Fish Assemblage**

NISP values are not available for unidentifiable fish material; therefore the weight of unidentifiable and identifiable fish remains was used to calculate the portion of identifiable fish bone. Total weight values for identified fish elements in each facies was divided by the total weight of fish specimens, both identified and unidentifiable, from each facies. This portion was plotted against depth within the midden (Figure 3.11). There was no significant correlation ($r=0.268$, $t>0.1$) between depth and identifiability of fish remains. Raw data underlying this distribution is presented in Appendix A, Table A.1.
Figure 3.11. Proportion of fish assemblage composed of unidentifiable material plotted against depth. Line shows simple connection of data values. There is no significant correlation between depth and identifiability of the fish assemblage ($r=0.268$, $t>0.1$).

3.4.3 Test 3: Density Distribution

Deer/Artiodactyl Assemblage

Average density values for deer/artiodactyl remains are plotted against depth below surface in Figure 3.12. There is a highly significant positive correlation ($r=0.798$, $t<0.02$) between increased density of deer/artiodactyl remains and depth within the midden, indicating that the deer/artiodactyl bone from facies deeper within the midden has been affected by a density-mediated process. Raw data underlying this distribution is presented in Appendix A, Table A.2.

Fish Assemblage

Average density values for fish remains in each facies was calculated and plotted against depth below surface in Figure 3.13. There is a highly significant strong positive correlation ($r=0.7302$, $t<0.01$) between depth and increased average density of fish remains, indicating that density-mediated attrition has occurred deeper within the midden. Average density values for facies located below the water table cluster more closely about the regression line than density values from facies above the water table. Raw data underlying this distribution is presented in Appendix A, Table A.3.
Figure 3.12. Average density / facies of specimens identified as deer or artiodactyl from facies with deer / artiodactyl NISP values greater than 5. Density values are from Lyman (1994). Line shows simple connection of data values. The correlation between depth and increased average density of surviving elements is strong and highly significant (r=0.798, t<0.01).

Figure 3.13. Mean density / facies of surviving bony fish specimens. Density values are from Butler and Chatters (1994). Line shows simple connection of data values. The correlation between depth and mean density of surviving elements is strong and highly significant (r=0.7302, t<0.01).
3.4.4 Test 4: Survivability of Elements

Volume density figures for salmonid skeletal elements were derived by Butler and Chatters (1994) in order to describe density-mediated destructive processes affecting archaeological salmon assemblages. These figures were applied to the herring assemblage from British Camp Operation A. The herring assemblage was divided into two assemblages: one from above the water table and one below. This division roughly corresponds with the dark and light layers observed by the excavators and described in Section 1.2.3 (Introduction).

Volume density figures were then applied to the two herring samples, and plotted against %Survivorship values for particular elements (Butler and Chatters 1994). The %Survivorship distributions of these two different samples are presented in Figures 3.14 and 3.15. These distributions indicate there is a clear difference between the two different samples, with the herring remains from water-saturated contexts having a much lower representation of less dense elements from the cranial and caudal skeleton. These data show that the two samples have been differentially affected by density-mediated processes.

Figure 3.14. Proportional %Survivorship values for herring elements from the dry upper midden, less than 80 cm below the surface. Elements are shown in descending order of density.
3.4.5 Test 5: Extent of Attrition

The distribution of the completeness index for mammalian carpals and tarsals (Figure 3.8), the completeness index for salmonid vertebrae (Figure 3.9), and most importantly, average density values fish remains, by far the largest sample (Figure 3.13), all display a patterning of close clustering of data values about the regression line starting at approximately 80 cm below the surface, and more random distributions above the waterline. %Identifiability values for fish and mammal bone (Figures 3.10 and 3.11) do not display this pattern. Overall, these distributions demonstrate a high degree of congruence in the distribution of bone fragmentation and density below the water table, and the most severe attrition has taken place below the water table.

3.4.6 Equifinality: Varying Depositional Rates

In order to address possible equifinality confusion between the working leaching hypothesis and the alternate hypothesis of slower depositional rates in the lower midden, rates of deposition for the assemblage were assessed by calculation of mean weathering stage data for facies and by the plotting of radiocarbon dates against depth.
Weathering Stage Data

A total of 124 bone specimens identified as belonging to the deer or artiodactyl taxa from 22 different facies were assessed; this sample is predominantly composed of the shafts of long bones, with a lesser number of flat bones such as scapulae or innominates. Weathering stage data are presented below in Figure 3.16.

Figure 3.16. Mean weathering stage data for bone specimens identified as deer or artiodactyl. Bones at Stage 0 are not weathered, while bones at Stage 5 are most weathered. There is an insignificant and weak reverse correlation between weathering and depth ($r = -0.224, t > 0.1$), and bones from below the water table are on average slightly less weathered than bones above the water table. The mean weathering stage for specimens from above the water table is 2.759, while the mean weathering stage of specimens below the water table is 2.597.

Weathering stage data indicate that there is little reason to believe that deposition rates in the midden below the water table were consistently slower than deposition rates above the water table. In fact, specimens from below the water table are slightly less weathered, but the difference is not statistically significant. It must be kept in mind, however, that these data are at best an approximation of time of exposure of bone specimens to weathering agents.
Radiocarbon Data

Calibrated radiocarbon dates from the midden above the water table are plotted against depth below the surface in Figure 3.17, and dates from below the water table are plotted in Figure 3.18.

Figure 3.17. Calibrated radiocarbon dates from above the water table, plotted against depth. Error bars show the mean of one standard deviation for the calibrations. Depth and increasing age are positively correlated, but the correlation is not significant ($r=0.4371$, $t>0.1$).

Figure 3.18. Calibrated radiocarbon dates from below the water table, plotted against depth. Error bars show the mean of one standard deviation for the calibrations. Depth and increasing age are positively correlated, but the correlation is not significant ($r=0.333$, $t>0.1$). The radiocarbon dates from below the watertable are not clustered as closely together, nor are they as strongly correlated with depth as the dates from above the water table.

Data from the radiocarbon dates, while more ambiguous than weathering data because of the wide range of error, appear to support the conclusion that accumulation rates in the lower midden were not slower than the rates for the upper midden. If sediments in the lower midden accumulated more slowly, then radiocarbon dates should be clustered more closely together for a given depth range. The opposite is true, however, and radiocarbon dates are more widely scattered from the lower midden when plotted against depth, indicating that the lower midden
may have accumulated more rapidly. Sample size is too small, however, for firm conclusions. In both the upper and lower midden, depth and increasing radiocarbon age are not strongly correlated, and the correlations are not statistically significant, indicating that stratigraphic mixing of midden constituents has occurred.

3.4.7 Qualitative Observations

In addition to the above statistical tests, qualitative differences were observed between bone from saturated and dry contexts. Bone from below the water table tended to be highly fragmentary and friable when compared with bone from above the water table. Much of the bone from below the water table appeared different in color, and could best be described as 'chalky'. During the identification process, extreme care had to be taken with many of the samples from below the water table to prevent further fragmentation in the laboratory.
4.0 DISCUSSION

This section relates data presented in Section 3 (Results) to the working hypothesis, outlined in Section 1.4 (Introduction). It details problems with the methodology, alternate explanations for the results, relates the results to broader methodological issues in zooarchaeology and archaeology, and provides suggestions for valuable directions for future study.

4.1 HYPOTHESIS TESTING

The data presented in Section 3 strongly support the working hypothesis, and it appears that the vertebrate assemblage at the British Camp site has been extensively altered by post-burial attrition, probably resulting from groundwater leaching. The underlying characteristics of the assemblage necessary to indicate the leaching hypothesis will be considered on a point by point basis below.

4.1.1 Test 1: Fragmentation Distribution

There is a significant correlation between increasing fragmentation and depth in the terrestrial mammal ($r=0.705$, $t<0.02$) and salmonid ($r=0.602$, $t<0.001$) assemblages as measured by the completeness index for mammalian carpals/tarsals and salmonid vertebrae (Figures 3.8 and 3.9). The correlation is more significant for the sample of salmonid vertebrae because that sample is much larger. The completeness index for mammalian carpals/tarsals was specifically designed by Marean (1991) to assess post-depositional impacts to zooarchaeological assemblages; this is therefore strong evidence for a diagenetic process in the deeper part of the British Camp midden.

The distribution of the completeness index for salmonid vertebrae is more ambiguous, though when considered in conjunction with the completeness index for the mammal assemblage, still strongly indicative of diagenetic changes. Salmonid vertebrae are very fragile elements even apart from the effects of diagenesis. They are hollow and very porous, and are easily shattered by crushing. Unlike mammalian carpals and tarsals, which are rarely impacted by butchery or carnivore impacts (Marean 1991:681-682), salmonid vertebrae can be expected to be strongly influenced by these factors. The strong congruence between the distribution of fragmentation in
the salmonid assemblage and the terrestrial mammal assemblage, however, argues that both assemblages have been impacted by an equivalent process.

4.1.2 Test 2: Unidentifiable Material

There was a strong negative correlation ($r=-0.894$, $t<0.02$) between identifiability and depth within the mammal assemblage (Figure 3.10). Mammal bones in the lower portion of the British Camp assemblage, below approximately 100 cm below the surface, were composed of a higher proportion of unidentifiable specimens: the portion of the mammal assemblage composed of identifiable material was as high as 80% near the surface, and in some facies deeper in the midden, no mammal material was in suitable condition to be identified.

The fish assemblage (Figure 3.11) showed no significant correlation between identifiability and depth ($r=0.285$, $t>0.1$). Fish bone with the highest proportion of overall identifiability came from contexts at approximately 125 cm below the surface, well below the upper limit of the water table. Overall, the fish assemblage was composed of a higher proportion of identifiable material than the mammalian assemblage. There are clearly more factors governing the distribution of identifiable fish bone than post-burial attrition. One possible explanation is that because of the small size and characteristic structure of fish bone, when they are fragmented they typically break into many very small pieces, and a large proportion of these fragments may have been too small to be recovered during the water screening process, even in the 3 mm screens.

4.1.3 Test 3: Density Distribution

There was a strong positive correlation between depth and increasing average density of deer and artiodactyl elements ($r=0.798$, $t<0.01$), and between depth and increasing average density of fish elements ($r=0.7302$, $t<0.01$) (Figures 3.12 and 3.13). The distribution of fish element density is especially striking because data points are very scattered for average densities above the water table, while values derived from facies below the water table are very consistent and cluster quite closely around the regression line. This pattern also appears in the deer/artiodactyl distribution, but not as strongly.
Leaching is a density-mediated attritional process because denser bones have less surface area for solution-based chemical processes to act upon. This applies to both exterior surface area and interior surface area in the form of pore spaces: denser elements have smaller and fewer pore spaces. High density elements include carpals and tarsals, teeth, and among fish, vertebrae and otoliths. All these elements are very well represented at British Camp, especially below the water table. A strong correlation between element density and survivorship of elements is a good indication that bone destruction has resulted from post-depositional factors (Butler and Chatters 1994:417; Grayson 1989:647).

Certain taxa also have much denser elements than other taxa, meaning that their bones can survive attritional processes better than other taxa. Artiodactyls, for instance, have very strong and dense fore- and hind-limb bones, which are structured to support their large bulk over the small surface area of their hooves. In contrast, marine mammals have very porous bones which are much less dense than that of artiodactyls because the body weight of marine mammals is supported by the buoyancy of their bodies in water. In an extreme situation of attrition, the bones of marine mammals may be largely eliminated from an assemblage while those belonging to artiodactyls may survive fairly well.

4.1.4 Test 4: Survivability of Elements

The British Camp herring assemblage, when divided between groundwater-saturated and dry contexts, showed clear differences in the representation of eight different elements in the two different samples (Figures 3.14 and 3.15). Vertebrae were the best represented elements in both assemblages; this is because vertebrae are the densest of the eight elements considered. In the groundwater assemblage, the proportion of the assemblage composed of less-dense cranial and pelvic elements was much smaller than the proportion of those elements from the dry assemblage. This means that the herring assemblage has been strongly patterned by a density-mediated process which seems to be eliminating less-dense elements from the assemblage below the water table. These distributions also show that even above the water table, the herring assemblage seems to have experienced some attrition of more fragile cranial and pelvic elements, but not nearly to the extent of the attrition below the water table.
4.1.5 Test 5: Extent of Attrition

It is clear that a density-mediated process or series of processes has impacted the British Camp assemblage, with the effects of this process increasing with depth. The high degree of congruence between the water table and increasing and relatively consistent fragmentation values (Figures 3.8 and 3.9) and average density values (Figures 3.12 and 3.13) argues strongly for a uniform and consistent attritional process at work below the water table. The firm coincidence between consistent values for density and fragmentation and the location of the water table seems unlikely to be random.

In addition to the uniformity of the density and fragmentation distribution variables, a number of different assemblages were affected: the salmonid assemblage, the herring assemblage, the mammal assemblage, and the deer/artiodactyl assemblage. All of these assemblages have been affected in approximately the same way; by density-mediated attrition correlated with depth. The fact that these structurally very different assemblages have all been impacted in a similar way is strongly indicative of a uniform attritional process.

4.1.6 Equifinality: Varying Depositional Rates

The weathering stage data (Figure 3.16) and radiocarbon data (Figures 3.17 and 3.18) suggest that rates of deposition and accumulation do not differ significantly between the upper and lower midden; in fact some of these data suggest that accumulation rates were more rapid in the lower midden. Equivalent or more rapid accumulation rates in the lower midden would therefore not allow preservation conditions which could be confused with the influence of leaching. Because of the somewhat ambiguous nature of the weathering stage data, however, and the even more ambiguous nature of the radiocarbon data, these conclusions must be treated with some skepticism.

There is another independent factor arguing against slower deposition rates in the lower midden contributing to poor preservation of faunal material in those deposits. The midden has undergone stratigraphic mixing, as evidenced by the poor relationship between radiocarbon dates and depth. Since attrition resulting from slow deposition rates would take place in the time between a particular bone being deposited and its subsequent burial, and would cease or slow considerably
following burial, the effects of this type of attrition would tend to be randomized by subsequent stratigraphic mixing. The poor relationship between depth and greater radiocarbon age, the presence of several intrusive features within Operation A, and the presence of a modern radiocarbon date located 44 cm below the surface indicate that considerable stratigraphic mixing has occurred.

Fragmentation, density, identifiability and survivability distributions are not random, however, indicating that stratigraphic mixing has little or no effect upon them. This would be expected if groundwater was the underlying cause of these distributions, as the water table is not related to stratigraphic patterning or mixing.

4.1.7 Conclusions of Hypothesis Testing: Has the Assemblage Been Leached?

It is clear that a post-burial attritional process has strongly patterned the faunal assemblage from British Camp, but the underlying cause of that patterning is less clear. The working hypothesis has been confirmed by the five hypothesis tests, designed to address the underlying structure of the British Camp assemblage. Equifinality problems with the hypothesis tests, however, preclude the unequivocal acceptance of the leaching hypothesis. The leaching hypothesis does provide by far the best fit for the observed data, however, so with some reservations, leaching is accepted as the most plausible underlying cause of the attrition observed in the vertebrate faunal assemblage.

The preconditions for leaching are present at the site: a groundwater regime that allows rapid replacement of groundwater because of tidal effects, and an absence of shell in the lower, water saturated deposits of the midden. Because of previous work carried out by the University of Washington, a strong theoretical and practical background exists for the understanding of the mechanisms of leaching and the groundwater regime at British Camp. The distributions of fragmentation, density, identifiability and survivorship demonstrate that post-burial attrition, most likely leaching, has affected the underlying macro-structure of the British Camp assemblage.

The fish and the mammal assemblages both appear to have been extensively impacted by post-burial attrition in the lower layers, with denser elements surviving its effects in much higher frequencies than less dense elements. The bird assemblage was not assessed because the sample
size was too small, and density values for bird elements are not yet available, but in all likelihood the bird assemblage would show strong patterning similar to that exhibited by the mammal and fish assemblages.

Attrition is most severe for faunal material at this site dating between approximately AD 1300 and AD 500, corresponding to approximately 80 to 150 cm depth below the surface in the midden. As was presented in Table 1.2 (c14 table), some stratigraphic mixing of material has occurred at this midden, and therefore the radiocarbon dates do not correlate well with depth. The distributions of the fragmentation, identifiability and density variables (Figures 3.8 through 3.13), however, do not appear to be affected by this mixing. This is a powerful independent argument in favour of the leaching hypothesis, because although the impacts of many taphonomic factors, such as processing patterns, trampling, or slower depositional rates would tend to be randomized by the effects of stratigraphic mixing, the effects of leaching would not be randomized because the location of the water table is not related to the stratigraphy of archaeological deposits. The relationship between depth, increasing average density, increasing fragmentation, and decreasing identifiability is regular and progressive. This argues strongly for the post-depositional origins of these distributions, because if the fragmentation and density-mediated attrition occurred prior to the burial of the faunal assemblage, the stratigraphic mixing demonstrated by the radiocarbon dates should cause randomization of the distributions of these variables.

The British Camp mammal assemblage is composed of a relatively large proportion of loose teeth, carpals, tarsals and phalanges, and a low proportion of cranial, mandibular, or scapular elements. This imbalance among element representation is especially apparent in the lower, leached layers of the midden. A preponderance of small, dense elements like loose teeth and phalanges in a faunal assemblage has been suggested as the likely result of post-burial density mediated attrition (Klein and Cruz-Uribe 1984:71), and it will obviously affect the ability of the zooarchaeologist to make inferences based upon the assemblage. The fish assemblage is composed predominantly of vertebrae, even though most fish possess many more cranial and pelvic bones than vertebrae. Assemblages that are very rich in fish vertebrae are common on the Northwest Coast, and it has been suggested that this may be due to attritional processes (Wigen and Stucki 1988:106).
The very unambiguous results of most of the tests of the working hypothesis point out that post-burial attrition has probably caused fairly severe attrition of the assemblage in the deepest deposits of the shell midden. The deepest deposits are the most highly saturated with groundwater and have had the longest period of time, possibly over 1500 years, for post-burial attrition to act upon them. It remains unknown what effects attrition has had upon the relative abundance of different species throughout the depth of the midden. In leached assemblages, the absolute abundance of species will be more strongly affected than relative abundance, but in extreme cases of leaching, bone may disappear completely (Klein and Cruz-Uribe 1984:75).

Soil pH, which was measured by the University of Washington excavators during the field school, does not appear at first to play a large role in the mediation or facilitation of leaching at this site. The lowest solubility of hydroxyapatite occurs at a pH of 7.88 (Lindsay 1979:181). Most pH values for facies at British Camp are between 7.0 and 8.0 (Stein 1992b:151-156). The role of sediment pH in the leaching of bone molecules is very complex, however, because pH values measured for this site are only indicative of the current pH of those sediments, not their pH values in the past.

Organic acids resulting from the decay of organic matter deposited in a shell midden tend to reduce the pH, leading to greater hydrogen ion activity, greater acidity, and greater solubility of calcium ions (Sullivan 1993:36; White and Hannus 1983:322). The percentage of organic matter in the site is high throughout the midden (Stein 1992b:148), and may have been much higher in the past because most organic material decays quite quickly.

The prime facilitator of attrition at this site is in all likelihood the active groundwater regime which allows for frequent replacement of the groundwater and the maintenance of a non-saturate solution. Frequent replacement is possible because of the porosity of the midden and tidal effects in adjacent Garrison Bay (Stein 1992b:148).

Addressing the underlying chemical mechanisms which would allow leaching to restructure a faunal assemblage is beyond the scope of this thesis, as the predominant focus was to determine whether leaching has the potential to alter an assemblage’s macro-structure, and to determine whether normal taphonomic methods are adequate for the identification of leaching impacts.
These goals, with some qualifications, have been achieved, but without extensive electron microscopy or chemical laboratory work, it is impossible to determine whether leaching at British Camp involved the removal of collagen, hydroxyapatite, or both, or the restructuring of the collagen/hydroxyapatite matrix. These processes are extremely complex. It is clear, however, that post-burial attrition has affected the structural integrity of animal bone in the British Camp midden, most likely by enlargement of bone pore spaces through removal of bone constituents suspended in groundwater solution.

4.2 METHODOLOGICAL DEFICIENCIES

The primary deficiency of this research is that the tests of the working hypothesis could not in and of themselves resolve equifinality issues and exclude alternate hypotheses. Independent data was available to test one alternate hypothesis, but these data are somewhat ambiguous, and therefore the alternate hypothesis of varying rates of deposition cannot be completely ruled out. Other alternate hypotheses may also explain the attritional patterns seen in the faunal assemblage, although leaching certainly provides the 'best fit'.

In order to address this issue, direct chemical analysis of specimens from the British Camp assemblage, perhaps using inductively coupled plasma spectrometry, would have to be carried out in order to determine whether the molecular structure of bone in the midden has been differentially altered. An examination of the ratio of calcium to potassium in the bone specimens would probably be the most appropriate line of investigation, as these elements are both constituents of hydroxyapatite but have different solubility in water (Linse 1992:335). Supplementing more traditional zooarchaeological and taphonomic methods, such as those utilized in this thesis, with bone chemical analysis would have vastly increased the scope and resolution of this research.

On a practical level, many areas could have been improved to either allow the sample to be analyzed and identified in a shorter period of time or allow a larger sample to be assessed. Data should be entered directly into a database program, if possible, rather than keeping paper records. This would eliminate one very time-consuming step in a faunal analysis, the transfer of paper records into a computer database. Efficiency could also have been improved during the identification phase by organizing a compact collection of comparative elements which would
cover the vast majority of specimens identified from the assemblage. Several common herring, surfperch, and rockfish elements, arranged in an easily available way, would have eliminated hours of searching through boxes containing whole fish specimens.

Another major deficiency of this analysis was the application of density values derived from salmonid bones (Butler and Chatters 1994) to other bony fish taxa. The assumption was made that the rank order of density values for salmonids would equate to the rank order of element density for other fish taxa. This assumption was required because element density data for other fish taxa have not yet been published, and equipment, resources and time sufficient to collect these data were not available. This leads to an inevitable amount of ambiguity in the distributions of fish bone density values, and is probably the most significant methodological deficiency in this research.

The resolution of the analysis could have been improved by the addition of more taxa to the comparative collection, as the Simon Fraser collection is relatively weak in certain areas, particularly the family Embiotocidae (surfperch). Individual species within this family could not be distinguished, even though they are morphologically dissimilar. This situation is also true, though to a lesser extent, for the Bothidae and Pleuronectidae families (flatfish).

The conclusiveness of this investigation could have been improved by density and porosity analysis, perhaps using the model employed by Butler and Chatters (1994), to directly examine the porosity of elements from the British Camp assemblage. Elements from water-saturated contexts should show loss of bone material from leaching and an increase in the porosity of those elements; therefore measuring the density of those elements, then comparing those densities to data derived from fresh bone, could reveal the extent of macrostructural changes in individual elements, and reveal exactly which elements were most susceptible to the effects of leaching.

Finally, there are problems associated with the use of density values derived by photon densitometry for artiodactyls by Lyman (1994). These density values describe the true density (Lyman 1984:264) of a porous substance; that is, the density of solid material in a particular bone not including pore space. True density is a measure of the density of bone tissue at a particular point on a particular element. Bulk density is a measure of the density of an element inclusive of pore spaces (Lyman 1984:264).
Post-burial attrition will preferentially impact bones with a high surface area to mass ratio. This ratio is a function of the true density of a bone, its size, and how porous that element is (Hedges and Millard 1995:157). True density values will therefore approximate the surface area to mass ratio of individual elements, but for the purposes of addressing groundwater-bone material interactions, bulk density would more closely approximate the surface area to mass ratio.

### 4.3 ALTERNATE INTERPRETATIONS

It is certainly possible to argue that the density, fragmentation, identifiability and taxonomic distributions from the British Camp assemblage resulted from processes other than leaching, and there are other potential alternate hypotheses aside from the varying deposition rate hypothesis. These fortunately do not present the same equifinality problems as the deposition rate alternate hypothesis.

Alternate interpretations are often advanced by archaeologists as objections to a hypothesis or theory. In order to approach explanation of the distributions observed in the faunal assemblage, any alternate processes would need to affect large volumes of midden material and the faunal specimens contained in those deposits in a relatively uniform manner. Some of the more plausible of these alternate explanations are considered below.

**Processing**

Perhaps the most obvious alternate explanation is that the attrition of bone in the lower British Camp deposits results from cultural rather than natural factors. Perhaps the bone in the lower deposits has been more heavily processed, either as a result of cultural preference, economic or subsistence stresses, or a number of other complex factors. If bone in the lower deposits had been more heavily processed, it could explain the greater fragmentation and higher density values of bone in those deposits.

There are several reasons that this explanation is unlikely, however. First, the completeness index for carpals/tarsals was designed specifically to assess post-depositional attrition; Marean (1991) selected carpals and tarsals because ethnoarchaeological and experimental work had
shown that these elements are rarely impacted by butchery practices. Marean (1991) also demonstrated that these elements are rarely subjected to the effects of carnivores upon a bone assemblage.

Second, the fact that assemblages that are structurally very different (the mammal assemblage and the fish assemblage) have been patterned in a very similar way argues strongly against cultural factors as the cause of this patterning. The salmonid assemblage, the herring assemblage, and the mammal assemblage all show similar patterning. Processing and capture of these different taxa took place at different times of the year, in different environments, and with different methods (Hanson 1991; Suttles 1974). For all these different assemblages to display the same fragmentation and density distributions is therefore extremely unlikely.

**Trampling Caused by Shifting Activity Areas**

Another alternate explanation for the observed distributions of fragmentation and density is that faunal material in the lower portion of the midden may have been more subject to trampling impacts than the upper deposits because activity areas within the site have shifted. If this particular portion of the site was intensively used between AD 500 and AD 1300, after which intensive activity such as foot traffic shifted to a different location, faunal material in the deposits underlying heavy foot traffic should be highly fragmented and should have experienced density-mediated attrition. The effects of trampling may be similar to leaching because trampling is a post-depositional process which could impact large numbers of faunal specimens at the same time. Trampling of artifacts and faunal material can cause breakage or movement of that material primarily within the top 10 cm of sediments below the ground surface (Gifford-Gonzalez et. al. 1985:816).

The impacts of trampling, however, are unlikely to show such a regular distribution as those presented in Figures 3.8 through 3.13. These figures show a strong and significant correlation between attrition of the faunal assemblage and depth, with attrition increasing steadily and regularly with greater depth in the midden. When the fragmentation and density distributions pass below the water table, average data values for these distributions become quite similar. This congruence between the water table and the distributions of several different variables argues strongly in favor of the groundwater regime as the process behind the observed attrition of bone.
Since trampling affects most strongly the top 10 cm of sediment (Gifford-Gonzalez et. al. 1985:816), it will only affect deposits until they are buried deeper than 10 cm below the surface by sediment accumulation, which would be rapid in a shell midden over 1.5 metres in depth.

Stratigraphic mixing of midden deposits subsequent to trampling will therefore tend to randomize the impacts of trampling on an assemblage because mixing taxes place after trampling impacts to deposits deeper than 10 cm have largely ceased. The radiocarbon dates (Table 1.2) from the British Camp site show that stratigraphic mixing has definitely occurred. The distributions of fragmentation, density and identifiability (of mammal bone) do not appear to be randomized at all, however; in fact, data values for these variables are very consistent below the water table. These observations do not rule out trampling as a patterning influence on the assemblage, but they do show trampling to be a less plausible alternative than groundwater leaching.

**Sediment Compaction due to Shell Loss**

University of Washington researchers asserted that the shell which had initially been present in the deeper deposits in the British Camp midden had been leached away by the groundwater regime. If the removal of shell via leaching led to subsequent sediment compaction, then the faunal assemblage in affected sediments may have been subjected to slow crushing and bending forces from overlying deposits. Sediment compaction of the magnitude to cause widespread crushing and fragmentation would require a ‘collapse’ of sediment; if no shell were initially present within a deposit, pressure from compaction would not be sufficient to cause widespread attrition.

This hypothesis is much less plausible than the leaching hypothesis, however, because in order for sediment compaction to contribute to widespread attrition in the faunal assemblage, the associated sediment collapse would have to take place relatively quickly in the form of a ‘collapse’. The process which may have led to the leaching of shell from the lower midden would have been relatively slow, however, and unlikely to lead to sufficient soil compaction to produce such widespread attrition.

Even less is known regarding the effects of compaction upon a faunal assemblage than is known about leaching. It is my opinion that compaction would not impact an assemblage to the extent
that leaching could, largely because leaching can cause the complete elimination of bone material from an assemblage, while sediment compaction would cause greater fragmentation. Unfortunately, no data are available to support or deny this conjecture. If sediment compaction had occurred, specimens would be broken into smaller pieces which could be refitted, and a detailed study of refitting patterns may allow the effects to compaction to be identified.

Shell is still present in dense concentrations in the upper deposits of the British Camp midden (Figure 1.5). This shell acts to support the deposits above it, especially the layers composed predominantly of whole shell, so that underlying deposits will be protected against compaction to a certain extent.

Finally, since sediment compaction requires that shell be leached from the midden before collapse of sediments will apply sufficient pressure to fragment the faunal assemblage, the ultimate cause of attrition in this situation is still leaching. The unambiguous results of the five hypothesis tests, however, and the conformity of fragmentation and average density values to the location of the water table remain the strongest argument against sediment compaction.

Greater Age of Deeper Deposits

Finally, it may be argued that the faunal material from below the water table is more poorly preserved simply because this material is older. This is not a true alternate explanation, however, because age alone will not cause poor preservation, but requires a mechanism which acts over time to cause the breakdown of bone material, and leaching is the most logical mechanism available at the British Camp midden.

Leaching does not occur quickly, but may possibly require thousands of years to remove enough bone constituents to cause noticeable bias in an entire assemblage. The deposits located below the water table have likely been saturated for a long period of time, and leaching has had longer to act upon them than the upper deposits. Even given an assemblage which had been deposited in its entirety during a short span of time, however, animal bones which are most exposed to an active groundwater regime, like the one at British Camp, will demonstrate the greatest amount of attrition. The greater age of the deposits located
below the water table can therefore not be considered as a separate explanation for the patterns present in the British Camp fauna, although it is certain to be a contributing factor.

4.4 IMPACT OF ATTRITION ON THE FAUNAL ASSEMBLAGE

The purpose of this thesis research was to determine whether leaching had impacted the faunal sample, but some consideration must also be given to the specific manner that the sample has been impacted. The potential for bone density to mediate attritional processes, and many of the mechanisms by which those attritional processes operate are fairly well known (Lyman 1994), but knowledge of the specific effects of attritional processes upon the composition of zooarchaeological assemblages, especially effects relating to intertaxonomic frequencies, remains largely conjectural. Because the original composition of the assemblage is unknown, determining the extent of those impacts is extremely difficult. Inferences regarding the specific effects of post-burial attrition upon the British Camp assemblage reflect this deficiency.

It was demonstrated that the herring assemblage (Figures 3.14 and 3.15), the deer/artiodactyl assemblage (Figure 3.12), and the bony fish assemblage (including herring) (Figure 3.13) have been strongly patterned by density-mediated attrition. The elimination of less-dense elements from an assemblage will have widespread effects, and can lead to biases against elements such as cranial bones and scapulae and biases in favor of fish vertebrae and mammalian teeth and shaft fragments. These biases can be expected to occur within and between taxa and within and between faunal assemblages.

Analyses of butchery and transport patterns in zooarchaeology are largely dependent upon interpretation of skeletal part ratios (Lyman 1992:252-254), and these ratios are often used to determine whether assemblages are natural or cultural in origin (Brain 1981; Butler 1993; Livingston 1989). The ratios are important because many cultural processes alter the original ratio of skeletal part representation (the ratio present in the live animal) and produce characteristic assemblage patterning. When an assemblage has been impacted by a post-burial process like leaching, this interpretation can be confounded or biased by the effects of leaching because leaching also alters the original ratios of skeletal part representation. There is no
question about the cultural origin of the British Camp assemblage, but this could be an issue at other sites.

The herring assemblage at British Camp is a good example of this phenomenon. The herring assemblage from above the water table (Figure 3.14) shows fair representation of the vertebrae, articular, hypural, pterotic and ceratohyal bones, while the assemblage from below the water table (Figure 3.15) shows good representation only of vertebrae, the densest element. Other elements, from both the cranium and the trunk, are poorly represented. If any cultural processes are at work in the distribution of herring skeletal part ratios, they may be masked or biased by the effects of post-burial attrition; these cultural processes would therefore be largely inaccessible to a zooarchaeologist.

The salmonid assemblage at British Camp shows an extreme bias against cranial elements. Only one single salmonid element, out of a total NISP for salmonids of 3589, was not a vertebra or vertebra fragment. Salmonid cranial elements are also underrepresented at other Northwest Coast sites (Butler and Chatters 1994), though not to same extent as British Camp. Salmonids are distinct from other fish taxa in several important ways.

Salmonids were likely processed in a different location, leading to the elimination of cranial bones from the British Camp site because those cranial bones are removed at the processing location. Taxa such as surfperch, flatfish and rockfish can be caught in Garrison Bay. Based upon ethnographic information, salmon were probably captured by reef netting along the southwestern coastline of San Juan Island and processed and dried in the vicinity of the reef-net location. Reef-netting of sockeye salmon is stressed as being of great importance in ethnographic accounts from the Strait of Georgia (Easton 1990:162-165). Relatively few salmonid cranial elements were likely brought to the British Camp site, therefore, because the heads were removed elsewhere. This pattern is also present at many other Northwest Coast sites where salmon were likely processed at a different location (Butler and Chatters 1994:420; Huelsbeck 1983:113; Steifel 1985:137).

The patterning of the British Camp salmonid assemblage cannot be explained by cultural factors alone, however. Salmonid cranial bones are also much more fragile than the bones of many other common Northwest Coast fish taxa (Wigen and Stucki 1988:106-108), a situation conducive to
differential preservation under the influence of post-burial attrition. Other fish taxa at British Camp do not display the extremely low representation of cranial elements exhibited by the salmonid assemblage, but representation of cranial bones is poor for all taxa below the water table when compared to vertebrae.

At Keatley Creek, a site which exhibits good preservation of salmonid remains and cultural selection against cranial elements because of a different processing location, representation of cranial elements is much higher than at British Camp. The distribution of salmonid elements at British Camp much more closely resembles that exhibited by Site 45-DO-211, adjacent to the Columbia River in Washington, which was determined to be heavily impacted by post-burial attritional processes (Butler and Chatters 1994: 417-421). Not only are salmonid cranial bones absent at British Camp; but trunk bones such as the basipterygium, coracoid, and hypural are also absent. All these elements have lower densities than vertebrae (Butler and Chatters 1994:417). Concurrence between the results of this thesis research and the results achieved by Butler and Chatters (1994) not only illustrates the way that post-burial attrition can alter an assemblage, but also provides good independent confirmation of the leaching hypothesis itself.

Post-burial attrition appears to have contributed significantly to the patterning of relative taxonomic frequencies in the shell midden. Relative taxonomic frequencies are the primary variables analyzed by zooarchaeologists interested in reconstruction of past subsistence or environments. Figure 4.1 shows the relative frequency of salmonids plotted against the combined frequency of surfperch, sculpins, rockfish, and flatfish. Salmonid remains are more prevalent in the lower portion of the midden, while the other fish occur with higher frequency nearer the surface. A subsistence analysis of these frequencies might suggest that this indicated a shift from capture of salmon at reef netting camps towards the capture of fish locally available in Garrison Bay.
The real reason for these distributions, however, is the differential effect of attrition upon the taxa represented. When salmonid bones undergo attrition, increased fragmentation leads to higher NISP counts, because salmon vertebrae, the most frequently identified element, are identifiable even as small pieces because of their characteristic texture. This is not true of other fish taxa. Salmonid NISP values from below the water table will therefore be inflated because of the influence of post-burial attrition. Greater fragmentation of salmonid remains is also indicated by the completeness index for salmonid vertebrae (Figure 3.9). NISP values for surfperch, sculpins, rockfish and flatfish, on the other hand, will be depressed under the influence of post-burial attrition because their vertebrae are not identifiable as small fragments. This pattern has also been identified at the Hoko River Rockshelter, and was there attributed to the effects of post-depositional bone attrition (Wigen and Stucki 1988).

It is likely that the relative taxonomic frequencies of the fish assemblage, as opposed to the mammal or bird assemblage, will be most strongly affected by post-burial attrition bias. This is because different fish taxa vary so widely in skeletal structure. The differences between salmonids and other fish have been outlined above, but even greater skeletal variation is present
between bony fish and cartilaginous fish. These taxa share only a few analogous skeletal elements, and the chemical, tensile, and ontological differences between these analogous structures are large. Intra-class variation within the skeletal structures of mammals and birds is much less than within fish, and mammal and bird taxonomic frequencies can therefore be expected to be less heavily impacted than frequencies in the fish assemblage. Within the mammal and bird assemblages, the primary effects of attrition will be alteration of element frequencies.

The points outlined above illustrate one unifying characteristic of the British Camp assemblage: its interpretive resolution, and the ability of a zooarchaeologist to access past cultural patterns via that assemblage, has been seriously compromised. The fact that the assemblage has suffered density-mediated attrition introduces a bias which cannot be controlled because the extent of the bias cannot be known with any certainty. The original state of the assemblage is unknown; therefore the amount of attrition that has occurred cannot be determined. This bias grows more serious with faunal material from deeper deposits.

4.5 ZOOARCHAEOLOGICAL AND METHODOLOGICAL IMPLICATIONS

There are wider implications to the findings reported in this thesis aside from the compromise of the interpretive resolution of the British Camp assemblage itself. Most studies of chemical diagenesis focus upon microstructural changes to bone or the addition of minerals from the soil environment (contaminants) to bone material without examining macrostructural changes in assemblage composition (Child 1995; Hedges and Millard 1995; Sillen 1989). Traditional zooarchaeological taphonomic studies, on the other hand, focus upon macrostructural changes in a faunal assemblage but are often unable to identify a specific process as the underlying cause of those changes (Butler and Chatters 1994; Klein and Cruz-Uribe 1984; Lyman 1984; Wigen and Stucki 1988).

It has been shown by this research that post-burial attrition has the potential to modify the macrostructural composition of a faunal assemblage, and thereby compromise the interpretive resolution of that assemblage. At sites with similar preconditions of groundwater-saturated lower deposits, porous sediments, and high flow rates of groundwater, leaching may produce similar results. Since the sea-level rise that led to groundwater inundation of the lower deposits at
British Camp took place in the wider context of the southern Strait of Georgia (Whittaker and Stein 1992:38-40), there is potential for a large number of sites to be affected by this process. Shell deposits form porous sediments because of the rigidity and convex shapes of the shells, and porous sediments are conducive to high rates of groundwater flow (Hedges and Millard:157).

If archaeological sites display the following preconditions, their zooarchaeological assemblages may be subject to the impacts of groundwater leaching:

1. Groundwater saturation of some or all of a site’s cultural deposits. The water table tends to be relatively close to the surface adjacent to shorelines (Stein 1992b:137).

2. High rates of groundwater flow. This characteristic may be difficult or impossible to determine, but high flow rates are likely when site sediments are highly porous and the site is in close proximity to a tidal water body which can act as a drain for groundwater (Stein 1992b:148).

3. Absence of calcium in the groundwater. Invertebrate shells are a major calcium source, but calcium can also be derived from calcareous sediments or limestone (Sullivan 1993:6). The calcium content of the groundwater could also be measured directly.

4. The rate of leaching will increase if sediment pH values differ significantly from 7.88. Hydroxyapatite is least soluble at this pH value (Lindsay 1979:181).

Assemblages that have experienced leaching may have been impacted to a greater or lesser degree. Leaching impacts could potentially range from the preferential fragmentation of the bones of more fragile taxa such as salmonids to the complete elimination of bone from archaeological deposits. Older deposits will be impacted to a greater extent than younger deposits given identical sediment chemistry and groundwater regimes. The British Camp faunal specimens are only 1700 years old at the very most, and the large majority of deposits that have been affected by leaching are less than 1200 years old. Given the right conditions of rapid groundwater transport, leaching can occur quite quickly.
Leaching can introduce a greater or lesser degree of bias into a faunal assemblage depending upon the extent of the attrition. This bias will only be apparent if taphonomic studies of the distribution of density, survivorship of elements, and fragmentation are carried out. Traditional zooarchaeological techniques are suitable for this analysis, and these techniques are well established and straightforward to apply. Marean's (1991) method is designed for this application, and is simple and relatively quick to apply. His method requires an adequate sample of terrestrial mammal carpals and tarsals, however.

When a bias has been identified by comparing the faunal assemblage from different deposits, it will also be known which deposits provide the best resolution of questions regarding cultural patterns, and which deposits are too biased to do this. When biases remain unknown, all interpretations are suspect.

There may be a number of ways to circumvent the effects of bias in a leached assemblage. In the case of the British Camp assemblage, it should be possible to remove highly impacted facies from an analytic sample and use only facies with consistent fragmentation and surviving density values (facies which have probably undergone a similar amount of leaching) for subsistence or cultural reconstruction. Because individual facies are relatively small, a large proportion of the entire assemblage need not be lost in this way.

Another useful method for controlling the effects of bias would be to compare only taxa which would be expected to display a similar taphonomic history (Driver 1999: personal communication). Such a sample would be composed of taxa whose elements have roughly analogous fragmentation and density values, and roughly analogous anatomy. The avian sample may be a good example of this, because different bird taxa tend to have less inter-taxonomic variation in skeletal anatomy than fish species, and therefore are more likely to have undergone the same amount of diagenetic change. Finally, it may be possible to abandon the traditional zooarchaeological approach of quantifying taxa via relative abundance ($p$ values) and instead quantify taxa within individual facies on an ordinal scale: common, uncommon, or rare. This would tend to reduce fluctuations in abundance calculations within individual facies, but would still access trends within the faunal assemblage as a whole.
All of the above approaches to controlling leaching bias would require the faunal assemblage to be analyzed on a 'facies by facies' basis; that is, the units of depositional context used to record provenience for faunal material need to be small enough to allow fine-scale manipulation of faunal data. Traditional 'layering' approaches which group deposits into very large contextual units would be less suitable, and the zooarchaeologist may not be able to control the effects of leaching at sites excavated using these more traditional approaches.

It is well known that older deposits are generally more poorly preserved than younger deposits. The processes behind poor preservation are often described as "natural decay forces" (Wigen and Stucki 1988:106) or "in situ destruction" (Butler and Chatters 1994:414). These vaguely defined processes are very likely related to the groundwater/bone chemistry interaction, and much of the poorly preserved bone observed in archaeological sites may be due to leaching. A comparative approach (Klein and Cruz-Uribe 1984) which takes into account variability between different contexts within a site is likely the best method to use to address biasing caused by leaching.

4.6 DIRECTIONS FOR FURTHER STUDY

Many important questions regarding the effects of attrition upon a faunal assemblage, and the exact chemical mechanisms involved in leaching, are left unanswered by this thesis and form its major shortcomings. The chemical processes that underlie leaching of bone in groundwater have not been investigated in great detail in this thesis, nor have they been investigated in sufficient detail anywhere else. Post-burial processes in general have not received sufficient attention, even though they are probably the most important factor in the gradual attrition and disappearance of faunal assemblages over time. This lack of attention exists perhaps because post-burial processes are so difficult to recreate or model accurately (Klein and Cruz-Uribe 1984:70). Laboratory and field experiments aimed at the understanding of the chemical processes involved in groundwater leaching would be a valuable addition to zooarchaeological method and theory.

It would also be worthwhile to examine in more detail the complex relationship between the presence or absence of shell, the groundwater regime, leaching, and the underlying chemical processes which cause leaching. On the Northwest Coast, almost all coastal sites contain some shell, and many are composed primarily of this material. Shell buffers the activity of organic
acids, and since leaching should only occur when shell is largely absent from deposits, it would be useful to know the threshold of shell content below which significant leaching can proceed.

Overall, this problem should be studied more intensively on the Northwest Coast, as many sites in this region have the preconditions for active leaching of vertebrate assemblages. Zooarchaeology in general would benefit from a more intensive consideration of post-burial factors. As many researchers have noted (Klein and Cruz-Uribe 1984:69-70; Lyman 1994; Marean 1991), studies addressing post-burial attrition of faunal assemblages are seriously underrepresented in the zooarchaeological literature. Marean (1991:692) has suggested that leaching conditions be simulated in an actuarial experiment, with the goal of determining exactly how an assemblage is altered by leaching under controlled conditions. The comparative approach, advocated by Klein and Cruz-Uribe (1984), would also be useful.

Another major deficiency of this thesis is that it fails to directly address the effects of leaching upon the statistical makeup of a faunal assemblage and fails to develop means to control those effects. It has been demonstrated that post-burial attrition has impacted the British Camp assemblage, and has unquestionably altered the statistical makeup of that assemblage, but conclusions about the effects of attrition upon the distribution of taxa or elements are largely conjectural. It is not known which taxa are better represented because attrition has eliminated the bones of less durable taxa, and it is not known whether attrition may have completely eliminated less dense elements from certain deposits. It would be very useful to compare the statistical structure of the British Camp assemblage to other Northwest Coast shell midden vertebrate assemblages.

This thesis demonstrates that a set of methodological tools can be developed to identify post-burial attrition in Northwest Coast shell middens; more work needs to be done in order to control the effects of this attrition on midden assemblages. Researchers in this area have been stating for years that a more sophisticated suite of methodological tools needs to be developed to address the complex depositional history of shell middens (Ham 1982; Stein 1992a and 1992b; Sullivan 1993). These tools are essential if midden zooarchaeological assemblages are to be used for accurate reconstruction of prehistoric subsistence and lifeways.
5.0 CONCLUSION

This thesis was an attempt to assess the impact of groundwater leaching upon the taphonomic history of the British Camp faunal assemblage using traditional taphonomic methods. The British Camp assemblage showed strong patterning which seems to be related to the distribution of the water table throughout the vertical profile of the site. These methods were adequate to identify leaching as the most probable cause of attrition in the faunal assemblage, but were unfortunately insufficient to completely exclude alternate hypotheses such as varying depositional rates.

The effects of post-burial attrition upon the assemblage were examined in a number of different ways, including the distribution of fragmentation, density, element survivability and identifiability in both the bony fish and mammal assemblages. There are a number of general conclusions that may be drawn from these findings.

First, the British Camp faunal sample is highly fragmented, and this fragmentation increases with depth in the midden. This pattern is statistically significant. Fragmentation seems to correlate with the location of the water table, as an active groundwater regime was able to remove important bone constituents, thereby decreasing the structural integrity and tensile strength of faunal specimens. Fragmentation of a vertebrate assemblage affects the ability of a zooarchaeologist to access past cultural patterns in an assemblage because fragmentation can eliminate elements by reducing them to small, unidentifiable pieces.

Second, the average density of elements is strongly correlated with depth and the location of the water table. This correlation is statistically significant. Elements from deeper within the midden, below the water table, are on average denser than elements from above the water table. This is because groundwater leaching is a density-mediated process, and leaching impacts lead to higher survival rates for denser elements. Higher survival rates for denser elements can bias an assemblage against certain taxa, against younger animals, or against lower density elements such as vertebrae or scapulae.

Third, the survivability of specific herring elements appears to be strongly patterned by post-burial attrition. The herring assemblage from above the water table shows much better
representation of fragile cranial and pelvic elements than the assemblage from below the water table. Only herring vertebrae are well represented at British Camp, and from saturated contexts, the vast majority of the herring assemblage is composed of vertebrae.

Fourth, the proportion of the mammal assemblage composed of identifiable specimens drops from 80% in facies above the water table to almost 0% in several facies below the water table. This means that a much smaller proportion of the mammal assemblage from below the water table becomes part of the analytic sample. The change in the proportion of the mammal assemblage composed of identifiable material is statistically significant. The fish assemblage does not show the same pattern.

Overall, the interpretive resolution of the British Camp assemblage has been compromised because post-burial attrition has introduced an unknown bias into the assemblage. This bias must remain unknown because tools suitable to control this type of bias are currently undeveloped, and because the original state of the British Camp assemblage cannot be determined. Any patterns seen in the distribution of taxa or elements over time at British Camp may have their source either in the subsistence and economic culture of the prehistoric inhabitants of British Camp or in the attrition which has altered the assemblage.

Finally, it was demonstrated that relatively straightforward taphonomic methods are suitable to address post-burial processes, as long as they are supplemented by a relatively complete understanding of such factors as groundwater regimes and soil porosity. This information was available because the site had been excavated with formation processes as a primary focus of the investigation. There are likely to always be equifinality problems with the utilization of basic taphonomic methods, however, as the resolution of the variables involved is generally not precise enough to allow the identification of specific attritional factors. Independent data are therefore required to address equifinality problems and assess alternate hypotheses.

These findings demonstrate that similar conditions at other sites could potentially lead to similar patterns of attrition in their faunal assemblages. It is therefore important that archaeologists pay attention to the presence or absence of groundwater at their sites. Groundwater has the potential to remove bone constituents from an assemblage by dissolution and transport, and this can happen even at near-neutral pH values conducive to low solubility of bone hydroxyapatite.
The process of groundwater leaching will be better understood when studies are conducted to address the specific impacts to faunal assemblages resulting from leaching, when tools are developed which can reliably identify groundwater regimes with the potential to cause leaching attrition, and when equifinality problems can be eliminated from standard taphonomic tests. When these tools are developed, site investigators will be much better equipped to control the biases which may be introduced into the zooarchaeological record by post-burial attrition and to identify the specific causes of those impacts.
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Wigen, Rebecca J., and Barbara R. Stucki  

Wolman, C.  

Wood, W. Raymond, and Donald Lee Johnson  
## APPENDIX A: UNDERLYING DATA

Table A.1. Raw Facies Data.

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<th>Unit</th>
<th>Facies</th>
<th>Volume (litres)</th>
<th>Depth (cm)</th>
<th>Water Table</th>
<th>Total NISP (All Taxa)</th>
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<td>1A</td>
<td>1072</td>
<td>25</td>
<td>Above</td>
<td>4275</td>
</tr>
<tr>
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<td>1C</td>
<td>56</td>
<td>35</td>
<td>Above</td>
<td>785</td>
</tr>
<tr>
<td>304300</td>
<td>1D</td>
<td>352</td>
<td>42</td>
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Table A.2. Raw Facies Data. Facies for which N / A (Not available) values are given are typically small and have few identifiable specimens.

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Table A.3. Mean Density Values for the Deer / Artiodactyl Assemblage. Only facies which had NISP values for deer / artiodactyls higher than five were used in the density analysis. Mean density values were calculated for each facies by adding together all density values for surviving scan sites within that facies (see Lyman 1994 for scan site density values and a more detailed description of density analysis) then dividing this figure by the total number of scan sites present in the same facies.

<table>
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<th>Depth (cm below surface)</th>
<th>NISP of Elements Included in Density Analysis</th>
<th>Number of Scan Sites Used in Analysis</th>
<th>Elements included in Density Analysis</th>
<th>Weighted Mean Density Value of Scan Sites (gm / cm$^2$)</th>
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Table A.4. Mean Density Values for the Fish Assemblage.

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<th>Pterotic (0.12 gm / cm$^2$)</th>
<th>Ceratohyal (0.06 gm / cm$^2$)</th>
<th>Exoccipital (0.11 gm / cm$^2$)</th>
<th>Articular (0.20 gm / cm$^2$)</th>
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Table A.4 (continued)

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<th>Dentine (0.19 gm/cm³)</th>
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