LATE HOLOCENE TRENDS IN PREHISTORIC WATERFOWL EXPLOITATION: EVIDENCE FROM THE LOWER SACRAMENTO VALLEY, CALIFORNIA

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Shannon Marie Goshen

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Department of Anthropology
Abstract

of

LATE HOLOCENE TRENDS IN PREHISTORIC WATERFOWL EXPLOITATION:
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Recent studies of faunal assemblages from archaeological sites in the Sacramento Valley, California have illustrated substantial anthropogenic impacts to local game populations and distributions during the late Holocene. Resource intensification analyses document a decrease in foraging efficiency and suggest populations of profitable mammals and fish were increasingly depressed through the late Holocene. Yet, limited research on the impacts of harvest pressures on prehistoric bird resources exists for the region. Modeling a similar study of avifauna exploitation in the San Francisco Bay, I test the hypothesis that profitable avian taxa were depressed by prehistoric hunters in the lower Sacramento Valley through a comprehensive analysis of avifauna remains from two sites in the lower Sacramento Valley (CA-SAC-15/H and CA-SAC-29).

Results are suggestive of resource depression and show avifauna assemblages dominated by waterfowl in which the most profitable taxa (geese) decline in relative abundance over the time of occupation at both sites. A comprehensive analysis of taxonomic composition and taphonomy, and a review of regional archaeofaunal records,
waterfowl life histories, and micro-regional paleoclimate contexts, provide clarification on observed trends in relative abundance and supporting evidence for avian resource depression.

_______________________, Committee Chair
Mark E. Basgall, Ph.D.

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The accompanying CD-ROM (Appendix B—SAC-15/H and SAC-29 Faunal Analysis Data) can be viewed using a computer with a Windows or Macintosh operating system with the program Microsoft Office Excel.
Chapter One

INTRODUCTION

The temporal and spatial extent of anthropogenic impacts to animal populations has been a major research focus of archaeologists studying the prehistory of California for the past 20 years and has led to numerous studies that utilize evolutionary ecology as a framework to examine interrelated patterns in resource depression, resource intensification, and changing demographic and organizational strategies (Broughton 1994a, 1994b, 1999, 2004a; Broughton and Bayham 1993; Broughton and Grayson 1993; Erlandson et al. 2008; Grayson 1991; Hildebrandt and Jones 1992, 2002; Porcasi 1999; Porcasi et al. 2000; Raab 1992).

Recent archaeofaunal studies in central California document resource depression, measured by the temporal decline in low-cost, large game relative to higher-cost small game, of several prey taxa during the late Holocene. Causal factors of resource depression are attributed to increased human predation and/or changes in preferred game habitats due to climatic change (Broughton 1994a, 1994b, 1999, 2004a; Craw 2002; Simons et al. 2002).

Most research efforts related to this topic have focused on the impact of human exploitation efforts to the most economically significant vertebrate resources of prehistoric central Californians, such as artiodactyls, pinnipeds, and fishes (Broughton 1994a, 1994b, 1997, 1999; Hildebrandt and Jones 1992, 2002; Porcasi et al. 2000). Other resources, such as birds, have received relatively little in-depth analyses, particularly in
the Sacramento Valley region (but see Broughton 2004a; Simons et al. 2002). One of the more detailed studies of trends in late Holocene prehistoric avian faunal exploitation in California, conducted by Jack Broughton (1999, 2004a) at the Emeryville Shellmound in San Francisco, proposes that profitable birds, such as geese (Anserinae), cormorants (*Phalacrocorax* spp.), and large shore birds (*Numenius* spp., *Limosa* spp.), were increasingly depressed through time as a result of human predation.

Broughton (1994b) conducted a more coarse-grained study of resource intensification and subsequent depression of a suite of prey taxa, particularly large-sized mammals and fish, to sites in the lower Sacramento Valley. However, a systematic, diachronic examination of bird faunal assemblages, like that conducted at Emeryville, has not been completed for this region.

This thesis tests the model of anthropogenic depression of avian resources for this temporal and spatial range through a comprehensive examination of the avifaunal record at two sites dated to the Middle and Late Periods (circa 2,500 to 200 BP), CA-SAC-15/H and CA-SAC-29, located in the lower Sacramento Valley. This thesis addresses a two-part question:

1) Are there patterns in the avifaunal assemblages suggestive of resource depression, such as declines in the relative abundance of high-ranked waterfowl, over the late Holocene in the lower Sacramento Valley?

2) If so, are these patterns associated with human-predation or climate/environmental changes?
The abundances of profitable waterfowl (geese) relative to less profitable waterfowl (ducks, coots, grebes) are used as a proxy for resource depression. In addition, a comprehensive analysis of assemblage taxonomic composition and taphonomy and a review of waterfowl life histories and micro-regional paleoclimate contexts, particularly changes to habitats during the Medieval Climatic Anomaly (MCA) and Little Ice Age (LIA), provide clarification on observed trends in relative abundance and supporting evidence for avian resource depression.

Results comport well with other studies of human-induced resource depression in the region and beyond, and show a decline in the relative abundance of high-ranked avifauna to low-ranked avifauna over the Middle to Late Periods at both SAC-15/H and SAC-29. This study rules out technological changes as a driving force of this trend. Based on available paleoclimate regional proxy data and biological data on waterfowl behavior, it is argued that climate change likely had no significant causal role in the observed patterns.

This thesis is organized into six chapters. Following the introduction, Chapter 2 provides a critical review of the resource intensification/depression models used in prehistoric studies of archaeofaunas in central California, with a more detailed review of studies focused on avifaunal exploitation. Chapter 3 details the environmental and cultural context of the project area and provides life histories and data on ethnographic procurement practices of major waterfowl resources. Chapter 4 provides descriptions of the archaeological sites sampled and details the methodology used in faunal analysis and sample selection. Chapter 5 presents the results and discussion of this thesis research.
First, a general taxonomic summary of the avifaunal assemblages is provided, including a discussion of taxonomic diversity. Next, results of the relative abundance indices are discussed, followed by a review of the taphonomic effects to the assemblages, and results of the analyses of relative skeletal abundance and density-mediated attrition. Finally, results are presented within a context of changing climate and habitat of the region, and potential impacts to waterfowl populations are assessed. Chapter 6 evaluates the resource depression models discussed in Chapter 2 in light of the results of relative abundance, taphonomy, and climate change evidence. These findings are compared with published studies on other archaeofaunas from the region to evaluate overall dietary changes followed by a discussion on the significance of this study to regional studies of prehistoric subsistence and waterfowl exploitation. Appendix A provides the descriptive summary of the avifaunal assemblages. Appendix B is an accompanying CD-ROM that provides the raw avifaunal analysis data for SAC-15/H and SAC-29.
Chapter 2

THEORETICAL ORIENTATION

Resource intensification theory has significantly restructured our understanding of the prehistory of California, and has become one of the leading theoretical paradigms of archaeologists studying prehistoric subsistence change for the past 20 years. Resource intensification is defined as an increase in the productivity or yield of resources in a unit of land at a cost of reduced productive efficiency (Boserup 1965; Brookfield 1972). Resource intensification models use optimal foraging theory as a framework to predict the late Holocene manifest of a narrow diet focused on high net return game to a broad diet focused on a variety of more low net return game in California. Recent applications of resource intensification models predict declines in the efficiency in the exploitation of profitable game taxa resulting from increased population density, resource depression, territorial-circumscription, environmental deterioration, and/or technological advancements (e.g., Bettinger 1991; Broughton 1994a, 1994b, 1999, 2002, 2004a, 2004b; Broughton and Grayson 1993; Hildebrandt and Jones 1992, 2002; Wake 2012).

Optimal Foraging Theory

Optimal foraging theory has been applied to predict and explain human foraging decisions. This body of theory and its family of optimality models operate under the assumption that diets are a product of a decision-making process in which humans consider the costs and benefits of exploiting resources and select those that will optimize their individual fitness (Bird and O’Connell 2006; Kaplan and Hill 1992; Smith 1983).
Optimality models include decision, currency, and constraint assumptions that are modeled as a set of dependent relationships, enabling researchers to generate predictions about behavior based on a fixed set of circumstances (Bird and O’Connell 2006:146). The decision is typically assumed to relate to the maximization of foraging efficiency (i.e., return rates for energy expended). The currency is the measurement scale used for evaluating foraging decision outcomes and is typically measured as energy in the form of calories. Constraint assumptions relate to those events that limit or define the decision goal. Constraint assumptions common within optimality models described below, include: 1) search and handling time are mutually exclusive; that is, prey cannot be searched for and handled simultaneously; 2) prey are encountered in a fine-grained manner; that is, prey are encountered randomly; and 3) foragers are aware of the costs and benefits of exploiting all prey items (Bird and O’Connell 2006; Broughton 1999; Winterhalder and Smith 2000).

The application of optimal foraging theory and models to anthropological and archaeological research has seen occasional criticisms, especially when human behavior seems contradictory. For example, ethnographic research shows that some hunters often focus on lower-return game, passing over easily exploited, high-return plant foods in order to secure prestige and access to mating partners (Hawkes and Bird 2002; Hawkes and O’Connell 1992). Thus, costly-signaling may be an underlying motivation of foraging decisions in addition to caloric benefits (see Hildebrandt and McGuire 2002). Despite these challenges, optimal foraging models are beneficial for exploring patterns in foraging efficiency when the effects of technology, sexual division of labor,
environmental conditions, and the behaviors of prey-species are considered (Bartelink 2006:48).

Two optimality models are applied to measure temporal shifts in diet in this study, prey-choice and patch-choice models (Charnov et al. 1976; Metcalfe and Barlow 1992; Orians and Pearson 1979).

Prey-choice Model

The prey-choice model argues that individuals make a choice to exploit a particular resource by determining whether the return rates (energy per kilocalories, or other energetic currency) gained after searching and handling for that resource will be greater than those obtained from looking for and handling another resource. Search time refers to the time spent searching for prey items and handling time refers to all post-encounter activities, including pursuit, butchering, processing, and consuming the resource (Broughton 1999:09; Charnov and Orians 1973; Hawkes et al. 1982).

In order to apply this model archaeologically, prey are ranked on an ordinal scale based on their profitability. Profitability is determined via a ratio of the value or energy gained from acquiring the prey compared to the costs or energy used in attaining the prey (Hawkes et al. 1982:388). This is termed the post-encounter return rate. Prey body mass has generally been successful as a proxy measure for the post-encounter return rates of prey species with similar escape behaviors (Broughton et al. 2011; but see Byers and Ugan 2005; Ugan 2005a; Zeanah 2004). Thus, large bodied prey are considered to be high-ranked relative to small bodied prey, an assumption followed in this study.
An optimal diet will include prey in order of descending rank, until the addition of a prey item yields a post-encounter return lower than the overall return rate that would be achieved if this prey item was ignored (Hawkes et al. 1982:388). The inclusion of a prey type in the diet depends on the encounter rate of higher-ranked prey only. Thus, the diet of a forager should expand or reduce relative to the density of these prey taxa populations (Hawkes et al. 1982:388). Based on these predictions, the relative frequency of high- and low-ranked prey in a diet can provide an index of foraging efficiency (Broughton 1999:09). In other words, diets composed of a high percentage of low-cost, profitable prey items are argued to be more efficient than those with a high proportion of high cost, low-ranked prey items.

**Patch-choice Model**

The caveat of the prey-choice model is that prey must be encountered in a fine-grained manner. However, many resources are distributed in clumps, or patches, across a landscape and are encountered non-randomly. Patch choice models state that prey types are differentially distributed in the environment in patches, and are encountered within these patches in a fine-grained manner.

The marginal value theorem model (MVT) stipulates that the time spent foraging in a patch depends on: 1) the return rates for the patch, 2) the average return rates for all patches in an area, and 3) the costs of moving between those patches (Charnov 1976; MacArthur and Pianka 1966). An optimal forager should move to another patch once return rates for the patch drop to that of the average return rates for all the patches in a landscape. This proposes that optimal foragers will abandon a patch prior to the depletion
of resources within that patch. The intensive use of a patch will result in a decrease in the net capture rate of prey or energy gain within that patch, or resource depression (Charnov et al. 1976). Resource depression should be particularly prominent for patches in close proximity to densely populated settlements, such as large village sites (Broughton 1999; Hamilton and Watt 1970; Winterhalder and Smith 2000).

**Resource Depression**

Optimal foraging theory models, particularly the aforementioned prey and patch choice variants, are often used to predict in what circumstances and for which resources depression will result (Grayson 2001:05). There are several causal factors for resource depression, including exploitation, behavioral, and micro-habitat depression (Charnov et al. 1976).

Exploitation depression refers to a decline in encounter rates of prey due to direct harvesting by human predators. As the prey model suggests, this type of depression will impact high-ranked prey more severely and should occur more rapidly than low-ranked prey (Charnov et al. 1976). This is because high-ranked prey are large-bodied species that are $K$-selected (i.e., long life span and low reproductive output).

Archaeological evidence for exploitation depression of animal resources worldwide is vast. In fact, nearly all applications of foraging theory to studies of resource depression have detected, to at least some degree, prehistoric harvest pressures on prey populations (Grayson 2001; Lupo 2007). A non-exhaustive list of some well-known examples, include: artiodactyls in California (Bayham 1979; Broughton 1994a, 1999; Broughton and Grayson 1993; Grayson 1991) and the eastern Great Basin (Cannon 2000;
Janetski 1997), pinnipeds along the western coast of North America (Etnier 2002; Gifford-Gonzalez et al. 2005; Hildebrandt and Jones 1992, 2002; Jones and Hildebrandt 1995; Lyman 2003; Porcasi et al. 2000), fish and mammals along the Columbia River in Oregon (Butler 2000; Butler and Campbell 2004), fish in the Cook Islands (Butler 2001), turtles in Oceania (Allen 2007), island birds of New Zealand (Nagaoka 2005), continental birds in western North America (Bovy 2007b; Broughton 1999, 2001, 2004a; Jones et al. 2008), and shellfish along the southern California coast (Erlandson et al. 2008; Raab 1992).

Long-term harvest pressures may cause exploitation depression or provide the selective force driving behavioral changes in prey taxa (Broughton 1999:10). “Behavioral” and “micro-habitat” depression occurs when the continued presence of a predator enacts behavioral responses of prey that reduce their susceptibility to predation, such as increased avoidance of areas frequented by hunters or increased alertness (Charnov et al. 1976:248). This can ultimately lead to populations relocating their breeding, feeding, and resting activities to regions outside a forager’s range (Charnov et al. 1976:248). These situations will result in decreased encounters with targeted prey, but will not have the same effects on prey populations as exploitation depression. Population recovery time from behavioral and micro-habitat depression can be “nearly instantaneous with the departure of the predator(s) from the patch” (Broughton 1999:10).

Bovy (2007b) and Whitaker (2010) have demonstrated the occurrence of behavioral/micro-habitat depression with cormorant faunal assemblages at archaeologically sites along the western coast of North America. At the sites examined,
cormorant remains, once abundant in the prehistoric diet, diminish or drop out of the diet entirely over time. Cormorants are colonial nesting birds that nest in large congregations at on-shore or off-shore rookeries close to land and are thus susceptible to mass capturing during the vulnerable breeding seasons. Based on the changing frequency of sub-adult cormorant bones at the sites, the researchers conclude that earlier site occupants hunted cormorants in nearby rookery settings until the birds relocated these rookeries to distant locations outside of their foraging radius as a result of human predation.

Similarly, Hildebrandt and Jones’ (1992, 1995, 2002), research on the hunting of prehistoric California coastal marine mammals has demonstrated the dual role of both exploitation and behavioral depression in structuring hunting decisions. These authors suggest that a combination of hunting pressure and behavioral changes led sea lions to abandon on-shore breeding colonies for more distant, off-shore localities. This resulted in an increased reliance on smaller, elusive taxa (e.g., sea otters and harbor seals) and potentially more investment in technology (e.g., ocean-going canoes and composite harpoons) to exploit the dwindling sea lion populations at distant rookeries.

**Resource Depression: Central California**

Population estimates of pre-contact California are among the highest in the nation, particularly for non-agricultural societies, with the highest density located within California’s Central Valley (Baumhoff 1963; Cook 1955, 1978; Johnson 1976; Kroeber 1939). These striking numbers are attributed to the adoption of intensive bulk-storage economies of abundant resources such as acorn, fish, and game (Baumhoff 1963; Heizer
Historic accounts of central California document a profusion of game resources. However, recent archaeological research suggests this was likely a rebound of depressed game populations following marked declines in human populations from introduced diseases (Broughton 1999; Erlandson and Bartoy 1995; Lightfoot and Simmons 1998; Preston 1996, 2002). Thus, it has been posited that densely populated, circumscribed territories of prehistoric central California placed a burden on the most desirable game resources, resulting in their depression (Broughton 1999).

Broughton (1994a, 1994b, 1997, 1999, 2001, 2002, 2004a, 2004b) has been one of the strongest advocates of the resource depression hypothesis and has examined temporal patterns in foraging efficiency from archaeofaunal records of various sites in the San Francisco Bay and Sacramento River valley. Following Bayham (1979, 1982), Broughton introduced to the region the method of using abundance indices to track changes in the relative proportion of prey taxa. Building on the tenants of the fine-grained prey choice model, a reduction in the abundance of large to small bodied prey taxa is viewed as an indication of declines in foraging efficiency and evidence of resource depression. Through the examination of faunal remains from nine archaeological sites in the Sacramento River valley, Broughton (1994b) documents a significant reduction in the contribution of large mammals and anadromous fishes to the diet. Specifically, early deposits are dominated by medium to large sized mammals and fishes with limited numbers of small resident fishes, whereas later occupations are dominated by small resident fishes coupled with decreases in the abundances of large-medium mammals. Similarly, once spatial and seasonal variation in the availability of anadromous fishes is
isolated, large anadromous fishes decreased in time relative to small resident fishes. Although the indices were mostly consistent with declines in foraging efficiency, the ratio of artiodactyls to lagomorphs failed to reveal a clear temporal trend (Broughton 1994b:511).

Simons (1992) examined the relative abundance of terrestrial and marine mammal archaeofaunas from 11 late Holocene sites in the San Francisco Bay. Results suggest a decline in marine mammal abundance from the Early to Middle Periods, followed by a spike in marine mammal abundance in the Late Period, attributed to an increased focus on sea otters. Simons (1992) notes that this pattern is broadly consistent with the resource intensification hypothesis, but also factors in the effects of environmental changes, seasonal availability of resources, and technological changes, such as the co-harvesting strategies of both otters and pinnipeds. Expanding on Simons’ (1992) research, Broughton (1994a) documented similar trends in the declines of artiodactyls to sea otters at 14 late Holocene archaeofaunal assemblages in the San Francisco Bay. Unlike Simons (1992), Broughton found limited correlation between the observed trends and changes in environment, seasonal availability of prey taxa, or technology.

These early, coarse-grained studies provided the framework for further investigations of resource intensification and depression in the region, but they did not examine avian hunting and their studies suffered from recovery and dating biases (i.e., inconsistent recovery methods and limited temporal controls). A more fine-grained study of these observed trends was conducted at the Emeryville Shellmound. Broughton (1999, 2002) examined temporal patterns in the proportion of white sturgeon, sea otters,
waterfowl, tule elk, and black-tailed deer archaeofaunas. The faunal data from Emeryville Shellmound comes from 24 provenience units that Broughton aggregated from the Nelson (1909), Uhle (1907), and Schneck (1926) excavations. Based on radiocarbon dates, the chronology of Emeryville suggests a 1900-year span of time of occupation (700 to 2600 BP) within ten undistributed strata. For his analysis, Broughton divided the strata into 190-year intervals (Broughton 1999:30). Abundance indice ratios measured the exploitation of differentially ranked prey derived by habitat type or resource patch, such as a terrestrial mammal patch, estuarine fishes patch, and waterfowl patch by strata.

Broughton also examined the cutmark data and prey-age compositions of select taxa and used changes in the frequencies of sub-adult bones as additional measures of harvest rates.

Results imply that high-ranked prey taxa in patches in the immediate region around the site decline in abundance through time. Artiodactyls, such as black-tailed deer and elk, decline in relative abundance to terrestrial carnivores, such as coyote, gray fox, and raccoon, over the occupation of the site (Broughton 1999:51). However, there was an increase in the artiodactyl index in the upper-most strata concomitant with an increase in sub-adult artiodactyl abundances (Broughton 1999:61). An examination of butchery patterns and skeletal part representation revealed an increase in the mean utility of artiodactyl body parts corresponding with this spike in the artiodactyl index. Following from central place forager models, the changes in the artiodactyl faunal record are ascribed to the use of more distant, less-depleted patches as artiodactyls were driven away from nearby patches; a result of micro-habitat or behavioral depression (Broughton
Broughton (1999:55-57) compares these observed trends with micro-paleoclimate and vegetational changes and observes no direct correlation.

Similarly, the analysis of sea mammal faunas reveals that the abundance of large migratory pinnipeds such as Stellar sea lion and fur seal declined relative to smaller, lower-ranked sea otters over time. Examination of prey-age structure of the assemblage indicates a decline in the relative abundance of otter newborns relative to adults correlating with an increase in otter exploitation. Broughton (1999:62) suggests this may reflect behavioral depression or an abandonment of near shore rookeries in favor of more distant off-shore rookeries away from a human presence.

White sturgeon, the largest of the fish taxon recovered from the shellmound and a taxon highly susceptible to depression, showed significant declines relative to the abundances of all other identified fishes (e.g., bat ray, salmon). Furthermore, the mean age of white sturgeon (measured via mean dentary widths) declined significantly through time, suggesting this prey item was overexploited. No correlation between changes in estuarine environments (particularly salinity levels) and declining abundances of sturgeon were noted (Broughton 1999:46).

The avifaunal record revealed similar trends. Anatids (ducks and geese) and cormorants comprise over 80% of the avifauna assemblage of the shellmound and are found in different patches in the bay (Broughton 1999:63). Anatids are high-ranked and would have been captured more easily near-shore, whereas cormorants are lower-ranked and would have been hunted more difficulty via sea-faring boats as they breed on
offshore rookeries (Broughton 1999:68). Using the abundance of anatids relative to cormorants as a proxy measure of resource depression, results reveal that anatids decline in relative abundance over time. Similar to the artiodactyl record, Broughton suggests hunters used distant patches of cormorant prey more intensively later in time (Broughton 1999:64).

The resurgence of deer in later levels and the unexpected prey-age profiles of sea otter remains, highlights the importance of understanding the spatial structure and behavioral patterns of each prey species under examination when attempting to discern changes in foraging efficiency and, in particular, patterns in resource depression. Although Broughton provides a strong argument for anthropogenic depression in central California, others have cited advancements in technology (Wake 2012; Zelazo 2013), such as the introduction of the bow-and-arrow, and sociocultural changes (Hildebrandt and McGuire 2002; White 2003), as the major impetus for these observed patterns.

Similar to Broughton’s high-resolution study of the Emeryville Shellmound site, Craw (2002) examined resource intensification and depression at the large village site of CA-SAC-29 (one of the sites sampled for this thesis) in the Sacramento Valley. Abundance indices from the prey choice model were used to examine diachronic changes in the ratios of artiodactyls relative to birds and fish, anadromous fish relative to resident fish, and changes in age profiles of artiodactyls of a small sample of faunal assemblage dating from the late Middle Period to Phase 2 of the Late Period. Results followed similar trends to those observed in Bay Area faunal records, with significant declines in the abundance of artiodactyls relative to other faunas over time. A noted difference was the
increase in anadromous fish index in the Late Period (Craw 2002).

**Avian Depression**

Despite the abundance of world-wide studies that have demonstrated anthropogenic depression of large-sized prey taxa, few studies have examined the impacts prehistoric hunting had on bird prey taxa until quite recently (Bovy 2005, 2007a, 2007b; Broughton 1999, 2004a; Broughton et al. 2007; Jones et al. 2008; Nagoaka 2005; Simons et al. 2002; Steadman 1995; Whitaker 2010). In fact, Broughton’s (1999, 2001, 2004a) analysis (and an additional analysis conducted by Simons et al. [2002]) of avifauna remains from the Emeryville Shellmound is considered to be one of the only systematic attempts at assessing patterns in avifauna resource depression, particularly among migratory waterfowl, in California.

Many of the recent studies (e.g., Bovy 2007a, 2007b; Jones et al. 2008; Nagoaka 2005; Whitaker 2010) have examined avifauna depression from a select set of avian species, primarily those that are resident colonial nesting seabirds or flightless birds (e.g., *Chendothytes lawi*). These bird types are particularly vulnerable to human hunting due to their mobility on land, large breeding colonies, and small clutch sizes. They are also quite sensitive to behavioral/micro-habitat depression and various seabirds have been known to change nesting sites as a result of minimal human contact (Cairns et al. 1998; Henny et al. 1989).

Will migratory waterfowl also be prone to resource depression? Geese are a winter migratory species to central California and arrive to the region as adults; thus, it could be argued that they are less susceptible to depression than resident taxa or summer
breeders. The level of fidelity to wintering and breeding sites in birds can have a significant influence on the genetic structure of migrating populations and can lead to isolated, small subpopulations that are more susceptible to depression (Robertson and Cooke 1999:20). Geese demonstrate a very high degree of fidelity to their wintering sites and geese that occupy particular wintering areas are likely derived from a restricted number of demographically independent subpopulations (Broughton 2004a:33; Robertson and Cooke 1999). Thus, the same subpopulations of geese likely return annually to the same wintering grounds in the Sacramento Valley. Intensive predation, coupled with their relatively low rates of reproduction (two to five chicks a year), could result in the depression of these restricted subpopulations of geese wintering in the Sacramento Valley. Additionally, it would be difficult to regularly monitor goose populations since they are non-residents. Consequently, humans would likely make no attempt to employ sustainable harvest practices (Alvard 1995). This is further supported by the decimation unregulated market hunting caused on waterfowl populations in central California during the late 19th century (McGowan 1961:364).

Expanding on his study of the declines in the relative proportion of waterfowl and cormorant remains at the Emeryville Shellmound (Broughton 1999), Broughton (2004a) argues that as population densities increased in the San Francisco Bay Area during the late Holocene, multiple high-ranked avian prey (e.g., Anserinae, Phalacrocorax spp., Numenius spp., Limosa spp.) were intensively harvested, resulting in their depression. Using additional data on identified avifaunal remains, Broughton examined diachronic
trends at the Emeryville Shellmound and other mound sites in the area (Broughton et al. 2007) to propose a more fine-grained model of avifauna depression.

As population densities increased in the San Francisco Bay Area during the late Holocene, Broughton (2004a:04) argues that high-ranked avian prey became overexploited and as a result, human populations adopted a wider diet-breadth. That is, populations shifted their economic foci to smaller avifaunas that were less profitable. Broughton uses the proxy measure of body mass to estimate resource rank. Thus, large species of birds are considered high-rank prey items, whereas small species of bird are considered low-rank prey items (Broughton 2004a:33-34).

Using abundance indices derived from the prey-choice model, Broughton calculated the relative abundance of various avian prey types by resource patch. Broughton (2004a:33) argues that geese would have been hunted more frequently in terrestrial patches of grassland and marshland settings, whereas ducks would have been most abundant in aquatic and near shore habitats. First, he examined the waterfowl assemblage of Emeryville, which includes 1,890 identified specimens of 11 species of duck and 1,771 identified specimens of four species of goose. An index of large waterfowl (geese) to small waterfowl (ducks) across the occupation of the site shows an increase in goose specimens in earlier strata, followed by a sharp decline at c.1980 BP and another steep decline at about 950 BP, with the lowest goose abundances recorded around this time (Figure 2.1; Broughton 1999:125; 2004a:07). A second, independent test of resource depression included an index of small geese relative to large geese. If goose patch returns were in decline then hunters would have targeted the largest, most
profitable geese. The index reveals a similar pattern as that between geese and ducks, with a general linear decline in large geese (e.g., *Branta canadensis*) relative to small geese (e.g., *Chen rossii*) over time (Broughton 2004a:35). Broughton argues that an overharvest of goose patches likely resulted in the intensification of the less optimal duck patches that would have been more difficult to access, such as seaducks (Broughton 2004a:36). To examine this, Broughton compared the abundances of terrestrial ducks (*Anas* spp. and *Aythya* spp.) to seaducks (tribe Mergini). Results show a significant linear decline in meriginae ducks relative to other ducks over the strata at Emeryville, suggesting an increase in the relative use of more distant duck patches (Broughton 2004a:36)

Figure 2.1. Distribution of Goose Index by Level, Emeryville Shellmound (Goose Index = $\sum NISP$ anserines/$\sum NISP$ anatids; figure from Broughton 2004a:34).
Broughton also examined trends in summer breeding cormorants as supporting evidence of resource depression. The cormorant assemblage reflects a strong decline in overall cormorant abundance relative to other birds through time—cormorants represent over 40% of the assemblage in earlier deposits and less than 4% in later deposits (Broughton 2004a:40). Since cormorants are particularly sensitive to human predation and often abandon breeding rookeries quickly, behavioral depression should be associated with a decline in the relative abundance of subadult specimens (Broughton 2004a:40). Results of the index of adult cormorants relative to juveniles and chicks shows a general declining trend correlated with the proportion of identified juveniles (Broughton 2004a:40). Broughton attributes this decline to the movement of nesting sites further away from the site in response to disturbances by human predators.

A final, more coarse-grained examination of the shorebird assemblage (NISP = 225), also shows similar trends, with a general decline in the relative abundance of large shorebirds relative to small shorebirds over the Emeryville strata (Broughton 2004a:43-44).

Broughton concludes that paleoenvironmental changes, such as salinity levels and regional precipitation, over the late Holocene in the San Francisco Bay, and to some extent the Arctic waterfowl breeding areas, reveal no direct correlation to patterns in the relative abundance indices (Broughton 2004a:37-38,41-42). This is supported by additional abundance indice data of avifaunal assemblages from five sites in the San Francisco Bay, which reveal similar trends as those noted at Emeryville (Broughton et al. 2007). Broughton and colleagues (2007) also conducted bone density analyses of select
representative birds, such as double-crested cormorant, Canada goose, and four species of ducks, at one of the bay area sites, Yerba Buena (CA-SFR-114). Density mediated attrition was examined to assess the impacts of taphonomy on the observed trends in abundance indices. Although the authors note a strong correlation between element density and NISP in the duck assemblage, no significant trends in bone attrition by depth or over time are noted (Broughton et al. 2007:383). Broughton and colleagues (2007:384-385) also indirectly address the effects density mediated attrition had on the declines in relative cormorant abundance reflected at the Emeryville Shellmound and other Bay area sites. Results reveal cormorant bones are significantly denser than waterfowl bones and thus should be well represented in the assemblage relative to waterfowl taxa. The authors note that although cormorants may be overrepresented relative to the avian bones of lower density in earlier deposits, the fact that they all but disappear in later deposits is not a reflection of taphonomy. Thus, Broughton and others (2007:385) conclude that the effects of density-mediated attrition have not produced the revealed patterns in taxonomic abundances. Instead, harvest pressures caused these resources to be depressed.

A subsequent study of the Emeryville Shellmound (CA-ALA-309) conducted by Simons and colleagues (2002) examined temporal trends in the exploitation of avifaunal assemblages from a more recent excavation at Emeryville and CA-ALA-310 (ca. 350 to 550 BP). A total of over 8,000 avifaunal remains were identified including 41 bird taxa at CA-ALA-309 and 28 taxa at CA-ALA-310. Both avifaunal assemblages show similar results to those identified by Broughton (1999) and are dominated by anseriforms and colonial nesting seabirds. Although compositionally similar, there are some differences in
the interpretation of the results. In both studies, the abundance of ducks decline relative to geese, and cormorants decrease relative to waterfowl over time (Broughton 1999:63; Simons et al. 2002:12). However, Simons et al. (2002) argue that ducks, geese, and colonial nesting birds represent a "co-harvesting" strategy where all species consist of single prey package. These taxa would have been easily taken together, since they occur in the same types of biotic communities at similar times of the year (Simons et al. 2002:09,13-14). However, Broughton (2004a) argues that ducks, geese, and colonial nesting birds represent distinct resource patches. Additionally, Simons and colleagues place a heavier emphasis on the impacts of short and long-term climatic changes, particularly El Niño and drought events, to the representation of the avifaunal record. They conclude that a dual-role of human overhunting and climatic changes caused resource depression (Simons et al. 2002:22).

Summary

In sum, resource depression has been a significant research topic for late Holocene California. The utilization of the various optimality models described above has enabled an empirically-based examination of these phenomena in a variety of archaeological contexts. Optimal foraging theory models and the archaeological studies mentioned, indicate that increased population densities of central place foragers will result in a depression of profitable resources in local patches, resulting in a decline in foraging efficiency with the addition of low profit resources in the diet. The depression of large, profitable migratory waterfowl has been documented in the archaeological record
of other central California sites and the Sacramento Valley sites examined in this study are expected to follow similar trends.

This study closely models Broughton’s (1999, 2004a) research in order to examine changes in the exploitation of migratory waterfowl in the lower Sacramento Valley. This study makes several assumptions. First, prey rank is correlated with body mass and geese are high-ranked. Body mass has generally been accepted as a correlate for prey-rank for prey that exhibit similar escape behaviors and procurement methods. There is a general distinction between the body mass of geese and ducks; in general, geese weigh on average between 1,500 and 4,500 grams, and ducks are smaller, weighing between 300 grams to 1,500 grams (Table 4.4). Second, targeted waterfowl prey were hunted in a fine-grained manner within a single freshwater marsh patch, with no distinction between goose and duck habitats (but see Broughton 1999, 2004a). Third, waterfowl were procured en masse using netting technology. This is supported by the available ethnographic data (see Chapter 3).
The varied physiography, climate, and flora and fauna habitats of the lower Sacramento Valley during the late Holocene had a direct impact on the foraging choices and economic strategies of prehistoric peoples living in the region, including the ethnographic Valley Nisenan. Eighty years of archaeological research in this region has identified a number of temporally distinctive settlement-subistence and socioeconomic patterns spanning the last 5,000 years. Waterfowl were an important, seasonally abundant resource. A review of the life histories of geese, ducks, grebes, and coots, in addition to ethnographic data on procurement methods of these taxa, suggests waterfowl were hunted most efficiently en masse using netting technology.

The lower Sacramento Valley is located in the northern portion of California’s Great Central Valley and includes the Sacramento-San Joaquin Delta. This intermontane valley is bounded by three mountain ranges, the northern Coast Ranges to the west and the northern Sierra Nevada and southern Cascades to the east. The valley contains a myriad of alluvial plains, river channels, sloughs, marshes, and lakebeds and is drained by the southward-flowing Sacramento River. The Sacramento River merges with the westward-flowing Mokelumne and Consumes river drainages at the Sacramento-San Joaquin Delta. Prehistorically, the delta comprised 494,000 acres in a roughly triangular shaped zone that consisted of “a sinuous mosaic of interconnected sloughs, overflow lakes, natural levees, and subtidal islands” (Meyer and Rosenthal 2008:30). The delta
waters drain through a break in the Coast Ranges into the San Francisco Bay and Pacific Ocean. High river flows from snow melt runoff during the winter and spring inundated the Delta with freshwater. Reduced freshwater during the summer and fall caused salt water from the bay to move inland and inundate the Delta (West 1977:4). Historical construction of levees, dikes, and tidal gates beginning in the mid-1880s drained much of the wetlands. In fact, only 3% of historical freshwater emergent wetlands remains today (Whipple et al. 2012:110).

**Biotic Landscape**

The varied physiography of the lower Sacramento Valley and Sacramento-San Joaquin Delta provided prehistoric humans access to a diverse set of biotic communities and food resources (Figure 3.1). The following section briefly describes the major plant and animal communities associated with the biotic communities of the region, emphasizing those resources that were most economically important according to the ethnohistoric record. The taxa mentioned were present during the historic period unless otherwise noted.
Figure 3.1. Historic Vegetation Map (data from Whipple et al. 2012).
River Channel

River channels, although minimally significant in terms of plant resources, provided abundant animal resources, particularly fish. Open channels of fast-moving rivers and larger streams supported lotic fishes such as, hardhead (**Mylophardon conocephalus**), sculpin (**Cottus** spp.), white and green sturgeon (**Acipenser** spp.), Pacific lamprey (**Lampetra lethophaga**), Chinnook salmon (**Oncorhynchus tshawytscha**), and steelhead rainbow trout (**Salmo gairdnerii**). Sacramento sucker (**Catostomus occidentalis**) and western pike-minnow (**Ptchocheilus grandis**) were common in both fast and slow water habitats (Meyer and Rosenthal 2008:36; Schoenherr 1992:516-552).

Avian fauna commonly found in river channels include most diving ducks, such as canvasback (**Aythya valisineria**), ring-necked (**A.collaris**), and ruddy duck (**Oxyura jamaicensis**), as well as some species of sea duck such as, common goldeneye (**Bucephala clangula**), bufflehead (**B. albeola**), and common merganser (**Mergus merganser**) (Garone 2011:30).

Aquatic environments also supported western pond turtle (**Actinemys marmorata**) and populations of freshwater mussel including Rocky Mountain ridged mussel (**Gonidea angulata**), Nuttall’s anadon (**Anadonta nuttaliana**), and western river pearl (**Margaratifera falcata**) (Meyer and Rosenthal 2008:36; Schoenherr 1992:516-552).

Riparian

Riparian woodlands flank the banks of most watercourses within the Central Valley, forming dense, multi-tiered canopies of primarily deciduous woody plant species. These woodlands extend from the banks of rivers and creeks to the edge of the moist soil
zone, and are typically associated with natural levees (Whipple et al. 2012:43).

Predominate riparian vegetation available in the past included: black cottonwood
(*Populus tricarpa*), big leaf maple (*Acer macrophyllum*), California sycamore (*Platanus racemosa*), box elder (*Acer negundo*), Fremont cottonwood (*Populus fremontii*), willow
(*Salix* spp.), valley oak (*Quercus lobata*), interior live oak (*Q. wislizenii*), California
buckeye (*Aesculus californica*), black walnut (*Juglans nigra*), and Oregon ash (*Fraxinus latifolia*). Species found in the understory found closer to the watertable included: wild
grape (*Vitis californica*), wild rose (*Rosa californica*), blackberry (*Rubus vitifolius*),
poison oak (*Toxicodendron diversilobum*), and blue elderberry (*Sambucus mexicana*)
(Schulz 1981:10-12; West 1977:06).

Riparian woodlands are a significant habitat for waterbirds, particularly great blue
heron (*Ardea herodias*), great egret (*Ardea alba*), snowy egret (*Egretta thula*), black-
crowned night heron (*Nycticorax nycticorax*), sandhill crane (*Grus canadensis*), and
double crested cormorant (*Phalacrocorax auritus*), all of which roost there in substantial
colonies (Garone 2011:25). In addition, waterfowl such as wood duck (*Aix sponsa*),
common merganser (*Mergus merganser*) and hooded merganser (*Lophodytes cucullatus*)
nest in the cavities of trees. Other terrestrial birds frequent in this habitat include the
Western yellow-billed cuckoo (*Coccyzus americanus*), numerous passerines (in
particular, blackbirds), owls and raptors, and flickers and woodpeckers.

Mammalian fauna present in this biotic zone include: black-tailed deer
(*Odocoileus hemionus*), badger (*Taxidea taxus*), striped (*Mephitis mephitis*) and spotted
skunk (*Spilogale gracilis*), long-tailed weasel (*Mustela frenata*), mink (*M. vison*), river

**Freshwater Marsh**

Prior to major environmental modifications of the mid-1800s, the Sacramento Valley was characterized by huge tracts of freshwater marsh wetlands (Figure 3.1). Historically there was approximately 365,000 tule-dominant tidal freshwater emergent wetlands within the Delta (Whipple et al. 2012:84). Freshwater marshes characterized the riverine floodplains and basins of the Sacramento Valley as well as the upper estuary of the Delta. Freshwater marshes are low in salinity (0.5 ppt) and are dominated by bulrush or tule (*Schoenoplectus acutus, S. californicus, S. americanus*), cattail (*Typha* spp.), and sedge (*Carex* spp.), rushes (*Juncus* spp.), spikerushes (*Eleocharis* spp.), and reeds (*Phragmites australis*). Floating plants and submergents, such as pondweed (*Potamogeton* spp.), knotweed (*Polygonum* spp.), and yellow pond lilly (*Nuphar polysepalum*) grow in areas of deeper, permanent water (Schulz 1981:10-12; West 1977:07; Whipple et al. 2012:42).

The freshwater marshes are and were in the past the most important habitat for waterfowl, as well as other waterbirds, such as American coot (*Fulica americana*) and grebes. Along with algae, the moist-soil, floating, and submergent plants that grow here provide staple foods, nesting habitat, and cover for waterfowl (Garone 2011:26).
Other common fauna in marsh habitats include muskrat (*Ondatra zibethicus*) and beaver, as well various reptiles, amphibians, and lentic fish species, such as splittail (*Pogonichthys macrolepidotus*), hitch (*Lavinia exilicauda*), thicket chub (*Gila crassicauda*), Sacramento blackfish (*Orthodon microlepidotus*), Sacramento perch (*Archoplites interruptus*), and tule perch (*Hysterocephalus traski*) (Meyer and Rosenthal 2008:36; Schoenherr 1992:516-552).

**Grassland**

Grasslands cover swaths of floodplain lands abutting riparian woodlands and marshlands in the Central Valley. These grasslands, known as the Central Valley prairie, formed a thick mat of annual and perennial bunchgrasses, including: purple needlegrass (*S. pulchra*), nodding needlegrass (*S. cernua*), blue wild rye (*Elymus glaucus*), pine bluegrass (*Poa scabrella*), and deergrass (*Muhlenbergia rigens*) (Schulz 1981:10-12; West 1977:07).

The protein-rich grasses provided various species of geese, particularly for strong grazers such as Ross’s (*C. rossii*) and Canada geese (*Branta canadensis moffitti*), with an important food source. Additionally, various raptors, notably turkey vulture (*Cathartes aura*) and California condor (*Gymnogyps californianus*), doves, quail (*Callepepla californica*), flickers and woodpeckers, and numerous passerine birds would have been present in this habitat (Garone 2011:23).

Seasonal ephemeral wetlands that formed in shallow depressions in claypan or hardpan were also present throughout the grasslands. In the winter, these pools were full of invertebrate fauna, an important source of protein and calcium necessary for migrating
ducks, as well as tundra swans (*Cygnus columbianus*), great egrets, great blue herons, and American avocets (*Recurvirostra americana*) (Garone 2011:23).

Other fauna prominent in these grasslands, included: tule elk (*Cervus elaphus nanodes*), pronghorn (*Antilocapra americana*), jackrabbits (*Lepus californicus*), and coyote (*Canis latrans*) (Boeuy 1995:43; Schoenherr 1992:516-552).

**Valley Woodland**

Extensive oak woodland flanked the foothills along the margins of the Sacramento Valley. Scattered oak woodland was also present throughout the grasslands on the valley floor. Oak woodlands were dominated by valley oak, blue oak (*Quercus douglasii*), coast live oak (*Q. agrifolia*), and interior live oak. Other tree species, including gray pine (*Pinus sabiniana*), Coulter pine (*P. coulteri*), and California buckeye, were present in lesser abundance. The understory of the woodlands was comprised of native bunch and annual grasses including wild rye (*Elymus triticoides*) (Schulz 1981:10-12; West 1977:07).

Avifauna found in oak woodlands were primarily hawks, eagles, doves, quail, flicker, woodpeckers, owls, turkey vulture, and numerous passerine birds.

Archaeological Research

Archaeological research in the lower Sacramento Valley, and in particular the Sacramento-San Joaquin Delta, began in the late 1920’s as avocational archaeologists working at shellmound sites in the San Francisco Bay area recognized the significance of the Delta’s impressive midden mound features. The first monograph of the region, a systematic review of the archaeological record of the Stockton and Lodi areas, was published by Schneck and Dawson in 1929. The following decade witnessed a plethora of archaeological activity as the Sacramento Junior College initiated an extensive program of reconnaissance and salvage excavation throughout the Sacramento Delta and lower Sacramento River valley region. This early work (Heizer 1936; Heizer and Fenenga 1939; Lillard and Purves 1936, Lillard et al. 1939) was heavily focused on burial recovery and the establishment of an assemblage-based chronological framework for the region, a tripartite scheme of Early, Middle, and Late Horizons (Heizer and Fenega 1939; Lillard et al. 1939), later known as the Central California Taxonomic System (CCTS; Beardsley 1948, 1954). The horizons were redefined by Ragir (1972) to incorporate temporal cultural associations and included the Windmiller Culture, Consumes Culture, and Hotchkiss Culture. The Windmiller Culture corresponds to the Early Horizon and was identified at only a few interior valley sites, such as the Windmiller Mound (CA-SAC-107) and Blossom Mound (CA-SJO-68) (Moratto 1984). The Consumes Culture corresponds to the Middle Horizon, and the Hotchkiss Culture with the Late Horizon. The CCTS chronology was later refined and modified with the advent of several other substantial investigations (Bennyhoff and Hughes 1987). The B1 scheme, based primarily
on shell beads found within burial contexts corroborated with radiocarbon assays, obsidian hydration profiles, and artifact types, incorporates chronological periods to address some of the issues of the Horizons (e.g., Bennyhoff and Hughes 1987; Bennyhoff and Frederickson 1994). Groza (2002) conducted a further refinement of the B1 scheme based on 103 well provenienced Olivella shell beads subjected to AMS dating. Known as the Scheme D chronology, this chronology generally corresponds to that of B1 (Bennyhoff and Hughes 1987), but several important discrepancies were noted (see Table 3.1).

Frederickson (1973, 1974, 1994) later restructured the Horizon scheme to reflect more specific regional patterns of the Sacramento Valley not apparent in the Horizon system. This scheme proposed three periods, the Paleoindian, Archaic, and Emergent. Recently, Rosenthal and colleagues (2008) have refined Frederickson’s Archaic scheme to correlate multiple cultural sequences for the region and new radiocarbon data from older sites, such as the Skyrocket site (Groza 2002; LaJeunesse and Pryor 1996; Meyer and Rosenthal 2008). Frederickson’s chronology does not account for complex regional variations of later sites in the region and is most useful for studies of older sites and broader regional patterns.

The Scheme D framework with the calibrated dates provided by Groza (2002) and the Early, Middle, and Late Period terminology is the most consistently used system to categorize and date sites within central California and will be thus be used for this thesis research. Given the issue of marine reservoir effects, (see Hughes and Milliken 2007) this
chronological scheme is merely used as a broad temporal framework in which to examine general trends in the selective efficiency of avian prey.

Table 3.1. Central California Chronology (after Groza [2002:95, Figure 6] and Milliken and Schwitalla [2012:09, Table 1]).

<table>
<thead>
<tr>
<th>Scheme D (cal BP)</th>
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<tr>
<td>Mission Period</td>
<td>180-115</td>
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<tr>
<td>Late Period Phase 2</td>
<td>440-180</td>
</tr>
<tr>
<td>Late Period Phase 1</td>
<td>740-440</td>
</tr>
<tr>
<td>Middle-Late Transition</td>
<td>940-740</td>
</tr>
<tr>
<td>Middle Period</td>
<td>2160-940</td>
</tr>
<tr>
<td>Early-Middle Transition</td>
<td>2450-2160</td>
</tr>
<tr>
<td>Early Period</td>
<td>&gt;5350-2450</td>
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</tbody>
</table>

**Paleoenvironment and Culture**

The following section provides a summary of the major changes in paleoenvironment and prehistory of this region over the Holocene epoch. Current knowledge regarding prehistoric culture change and adaptation in lower Sacramento Valley is derived from the several major excavations detailed above. A reconstruction of the paleoenvironment of the region is significant for understanding the structure and availability of avian (and other) resources, as well as the visibility of the archaeological record. Several methods are used to reconstruct prehistoric environments and analyze climate changes, including geomorphology, pollen profiles, plant macrofossils, tree-ring width data, stable isotope analyses, and faunal studies. These data are typically coarse-grained proxy measures of climate change and caution is warranted when attempting to directly associate environmental changes with the archaeological record (Basgall 1999). However, these data are used here to examine broad, temporal and regional trends.
Paleoenvironmental Reconstructions

*Early to Middle Holocene* (11,500 to 4,000 cal BP)

The early Holocene (11,500 to 7,000 cal BP) marked the development of the Sacramento-San Joaquin Delta. Warmer ambient temperatures melted the continental ice sheets at the end of the Pleistocene, inundating the lower San Francisco Bay and its adjoining drainages leading to a rapid rise in sea level, approximately 80 meters every 1000 years (Meyer and Rosenthal 2008:48; West et al. 2007:15). The rise in sea level led to the development and eastward expansion of the San Francisco Bay estuary.

The middle Holocene (7,000 to 4,000 cal BP) is also characterized by a warm drying trend and is marked by increasing temperatures and decreasing precipitation. Sea level rise slowed, permitting accumulation of sediments and the development of tidal marshes and wetlands along the coast and inland Delta (Atwater 1979). By 6,000 cal BP, the Delta-estuary matured and landforms stabilized, to resemble its historic extent (Atwater and Hedel 1976:10). During this time, marshlands were restricted to a small portion of the lower Sacramento Valley, and may not have extended to the eastern and southern Delta area until the late Holocene, reaching its maximum extent only within the last 1,000 years (Meyer and Rosenthal 2008:55). Sediment deposition was extensive during the middle Holocene resulting in thick layers of peat measuring up to 65 feet in the central Delta (Atwater 1979). These sediments buried much of the older landscape obscuring the earliest archaeological record of the region (Meyer and Rosenthal 2008).
Late Holocene (4,000 to 100 cal BP)

Increased Pacific moisture during the late Holocene marked a return to more mesic conditions with cooler temperatures, increased precipitation, and development of modern vegetation communities (Malamud-Roam et al. 2007; Meyer and Rosenthal 2008:64). The late Holocene is also punctuated by several major ENSO droughts and flooding events (Byrne et al. 2001; Goman and Wells 2000; Malamud-Roam et al. 2006, 2007; Meko et al. 2001).

Shifts in tree-lines, tree-ring chronologies, and isotopic compositions from flood plain and estuary sediments indicate that overall conditions in central California became increasingly arid and saline from ca. 1000 to 800 cal BP, corresponding to the Medieval Climatic Anomaly (MCA) (Byrne et al. 2001; Malamud-Roam et al. 2007). This interval reduced freshwater flow and increased salinity levels, altering biotic communities and availability of some resources. The MCA has been associated with archaeological evidence for extensive resource stress and changes in settlement throughout California (Arnold 1997; Jones et al. 1999; Lightfoot and Luby 2002; Raab and Larson 1997; Schwitalla 2010; Wohlgemuth 2005); however, the overall effects of this climate interval on cultural and behavioral changes are debated (Basgall 1987, 1999; Bettinger 1991; Gamble 2005; True 1990). Following the MCA, was a period of cool and wet conditions known as the Little Ice Age (LIA; ca. 550-200 cal BP) (Byrne et al. 2001; Malamud-Roam et al. 2006, 2007). The LIA resulted in increased precipitation and an influx of salinity into the lower Sacramento Valley. Various short-term flood (1125 to 650 cal BP,
650 to 150 cal BP) and drought events (370 cal BP) occurred during the late Holocene as well (Malamud-Roam et al. 2006, 2007).

Major drought events would have lowered the Sacramento River watershed substantially, potentially impacting the availability of certain resources, including waterfowl. Flood events and extensive depositional events during this period significantly altered the valley during this time. In fact, most valley alluvial sediments are late Holocene in age. The lower reaches of several river channels migrated laterally as sediment deposition increased during these periods (Meyer and Rosenthal 2008:18). As a result, the Sacramento River developed a wide floodplain belt comprising a series of flood basins. Major flood events in the valley caused alluvium to spill beyond the river channel’s banks and into the adjacent floodplain basins, often forming prominent levee ridges and aeolian dunes, particularly along and adjacent to the lower Sacramento River (Meyer and Rosenthal 2008:18). These natural levees and dunes rose two to six meters above the adjacent land and were favored places for settlements prehistorically, since they flooded less frequently than the surrounding flood basins (West 1977:04). These near sea-level flood basins held an estimated four million acres of water during seasonal flood events and remained inundated well into the spring and summer (Garone 2011).

Archaeological Reconstructions

Paleoindian and Lower Archaic (ca. 13,500 to 5,500 BP)

The earliest evidence of human occupation in central California are referred to as the Paleoindian and Lower Archaic periods (Frederickson 1973,1974). Archaeological
sites dated to this period are rare in the lower Sacramento Valley due to the late depositional events detailed above and the low population density and high mobility of people in the region during this time. Paleoindian sites consist of mostly isolated finds of basally thinned and fluted projectiles, similar to Clovis points elsewhere, and are primarily found to the south in the San Joaquin Valley around the lakeshores of Tulare Lake Basin (Wallace and Riddell 1991). Similar to the Paleoindian period, the Lower Archaic is represented by isolated finds of concave base points, stemmed dart points, bia-pointed points, and crescents (Rosenthal et al. 2007:151-152). The site CA-KER-116, located on the ancient shoreline of Lake Buena Vista, has provided the only Lower Archaic dated deposit for the Central Valley. The assemblage recovered at this site is characterized by crescents, stemmed projectile points, an atlatl spur, and battered stone implements along with faunal remains suggesting a generalized pattern of hunting and gathering (Rosenthal et al. 2007:151). Although millingstone is absent from the valley proper, the abundance of these ground stone implements in nearby foothill sites (Skyrocket site, CAL-629/630 and Los Vaqueros site, CCO-696) dated to this period suggests a limited emphasis on small seed and nutcrop exploitation during this time (Rosenthal et al. 2007:152). Regional long-distance movement and trade is evidenced by nonlocal toolstone found at Central Valley sites dated to the Lower Archaic.

*Early Period* (5350 to 2160 cal BP)

The late Holocene shows an abundance of archaeological sites and significant increase in occupation of the Sacramento Valley. The Early Period in the lower
Sacramento Valley is represented by the Windmiller Culture. Archaeological sites in the region dated to this period are mostly located south of the immediate project area in the Sacramento-San Joaquin Delta, and include the Windmiller site (CA-SAC-107; Lillard and Purves 1936), the Blossom Mound (CA-SJO-68; Heizer 1949; Ragir 1972), the McGillivary 1 Mound (CA-SJO-142; Heizer 1949; Lillard et al. 1939), and the Bear Creek site (CA-SJO-112; Olsen and Wilson 1964) (Rosenthal et al. 2007:153).

The archaeological record of this time period reveals a riverine adaptive pattern of increasingly logistically organized foraging strategies, increased regional sedentism, and seasonal movement between the valley and the Sierran foothills (Rosenthal et al. 2007:153). Sites dated to this period are characterized by complex features, trade goods, specialized tools and non-utilitarian artifacts, and faunal and plant remains indicating year round occupations (Rosenthal et al. 2007:155). Subsistence economies were generalized and focused on emerging marshes, riparian forests, and grasslands. Paleobotanical records indicate an increased focus on plant materials, particularly small seeds and some acorns (Wohlgemuth 1996, 2004). Faunal records indicate terrestrial mammals (e.g., black-tailed deer, tule elk, pronghorn, rabbits and hares, rodents, and carnivores) and riverine and marsh animals (e.g., large and small fish, waterbirds, and reptiles) were important resources (Broughton 1994a; Rosenthal et al. 2007:155).

Early Period artifact assemblages reflect the increased reliance on plant remains and diversity of animal resources exploited. Large stemmed and leaf shaped projectile points suggest atlatl use and the emphasis on hunting of large game (Rosenthal et al. 2007). Abundant milling equipment, such as manos and metates and mortars and pestles,
demonstrate the increased reliance on seeds, acorns, and roots and tubers (Basgall 1987). Additionally, new fishing technologies developed, such as gorge hooks, composite bone hooks, and spears, along with abundant fish remains, attesting to the importance of riverine resources, such as fishes (e.g., sturgeon) during this time (Rosenthal et al. 2007:155). Mortuary complexes are characterized by ventrally and dorsally extended burials oriented in a westerly position frequently accompanied by grave goods, including red ochre and quartz crystals. Other technologies developed during this interval, evident in baked clay impressions of fine twisted cordage and twined basketry, basketry awls, and other baked clay objects. Other artifacts attributed to this period include, stone plummets and perforated “pencils”, bird bone tubes, and shell beads of *Haliotis* (types K, Q, S) and *Olivella* (L-series). (Bennyhoff and Hughes 1987; Gifford 1947; Groza 2002; Meyer and Rosenthal 2008; Milliken and Schwitalla 2012; Rosenthal et al. 2007).

**Middle Period** (2160 to 740 cal BP)

The Middle Period, also known as the Upper Archaic (Frederickson 1974; Rosenthal et al. 2007), Berkeley Pattern, or Cosumnes Culture, is characterized by increased population density, lower residential mobility, and pronounced cultural diversity, evidenced by complex and diverse artifact styles and mortuary elements. With the onset of cooler, wetter conditions of the late Holocene, sites are situated upon natural levees along major waterways and are represented by large mounded village sites (Rosenthal et al. 2007:156). Deposits contain extensive accumulations of organic waste material and fire-fractured rock heaps, shallow hearths, rock-lined ovens, house floors,
and mortuary complexes characterized by flexed burials, all indicative of long-term occupation (Beardsley 1948; Lillard et al. 1939). Significant sites dating to this period include the Brazil Mound (CA-SAC-43; Bouey 1995), the Hicks Mound (CA-SAC-60; Lillard et al. 1939), and the two sites used in this thesis research, the King Brown site (CA-SAC-29; Lillard et al. 1939; Olsen 1963) and CA-SAC-15/H (USACE and SAFCA n.d.).

Subsistence economies varied regionally and focused on seasonal items that could be processed in bulk and included resources such as salmon, deer, rabbits, shellfish, and acorns (Rosenthal et al. 2007:156). One of the most pronounced changes that occurred during the Middle Period is a dietary shift to an intensified economy focused on acorns, evidenced by the proliferation of mortar and pestle technology and paleobotanical evidence of increased acorn nutshell remains (Basgall 1987; Wohlgemuth 1996, 2004).

*Olivella* shell bead chronologies of C, D, F, G and M-series have divided the Middle Period into several phases (Phase 1, 2a, 2b, 3, 4, and Middle-Late Transition), representing the profusion and variability of bead types during this period (Bennyhoff and Hughes 1987; Groza 2002; Milliken and Schwitalla 2012). Other artifacts common to this period include concave-base projectile points, minimally shaped cobble mortars and pestles, and a growing emphasis of specialized technologies, such as bone ornaments and tools. Abalone ornaments, bird and mammal bone whistles, baked-clay artifacts, fishtail and asymmetrical spindle-shaped charm stones are also frequently recovered (Bennyhoff and Hughes 1987; Moratto 1984; Rosenthal et al. 2007). Shifts in obsidian use and shell
bead trade that include more coastal sources occur during this interval as well (Rosenthal et al. 2007:147).

**Late Period (740 to 180 cal BP)**

The Late Period, or Emergent (Frederickson 1994; Rosenthal et al. 2007), Augustine Pattern, or Hotchkiss culture, archaeological record is significantly more substantial and comprehensive than other cultural periods with decidedly diversified adaptations and artifact assemblages (Rosenthal et al. 2007:157). The Late Period is divided into several intervals based on *Olivella* shell bead chronologies. In general, Late Period Phase 1 (740 to 440 cal BP) is represented by bead types, M and K-series, and Late Period Phase 2 (440 to 180 cal BP) is represented by E and J-series beads and a proliferation of clam shell disc beads (Bennyhoff and Hughes 1987; Groza 2002; Milliken and Schmitalla 2012).

More intensified economies, larger and denser populations, more pronounced social stratification, and highly developed exchange systems distinguish the Late Period (Moratto 1984:211). Sites are typically large, complex mound villages and hamelets along watercourses. Significant sites dated to this period include: the Johnson Mound (CA-SAC-6; Lillard et al. 1939), the Blodgett site (CA-SAC-267; Johnson 1976), and the Cardinal Mound (CA-SJO-154; Bennyhoff 1994); and the two sites used in this thesis research, the King Brown site (CA-SAC-29) and CA-SAC-15/H (USACE and SAFCA n.d.).

Subsistence economies focused on a diverse array of mammal, fish, bird, and plant foods, with fish and plant harvesting taking an increasingly important role during
this time (Rosenthal et al. 2007:159). Small seeds are relatively more abundant during this time as well (Wohlgemuth 2004). A refined set of fishing technologies suggests an increased reliance on aquatic resources and riverine and marsh habitats.

Trade and social complexity increased during the Late Period. Mortuary complexes are characterized by flexed burials, cremations and pre-interment grave-pit burning, and a differential distribution of grave goods (Moratto 1984:211). Distinctive shell beads of clam, incised *Haliotis* beads, and exotic stone beads were used as exchange items. There is also a proliferation of extralocal raw materials. Artifact assemblages are characterized by small arrow points of the desert and Stockton series, with the introduction of the bow-and-arrow around 1100 to 700 cal BP (Meyer and Rosenthal 2008:71). The fishing tool industry diversified and sites are often found with elaborate and diverse harpoons, bone fish hooks, gorge hooks, and netting. Other artifacts include extensively shaped mortars and pestles, including flat-bottomed mortars, cylindrical pestles, and bi-pointed wooden pestles, pottery (Consumes river brownware), and twined and coiled basketry, suggesting a strong focus on plant resources. Shaped steatite pipes, clay cooking balls, elaborately incised bird bone tubes and whistles are also found in deposits dating to this period (Bennyhoff and Hughes 1987; Frederickson 1974; Meyer and Rosenthal 2008; Moratto 1984; Rosenthal et al. 2007).

*Mission Period* (180 to 115 cal BP)

The Mission Period marked the influx of Spanish missionaries and the incorporation of many indigenous groups in central California into the Spanish Mission

system (1769 to 1833 A.D.). This period witnessed a significant shift in subsistence, trade networks, change in fishing gear, and introduction of a new bead and ornament complex. Indirect influences on Native Californians by these early Europeans included introduced diseases, such as tuberculosis, syphilis, and measles, causing drastic declines in Native populations (Bennyhoff 1977:42). The Plains Miwok reportedly suffered high mortality due to a measles epidemic in 1833 and violent altercations with the influx of Europeans (Bennyhoff 1977; Cook 1955).

**Ethnographic Context**

The study area is located within the ethnographic territory of the Nisenan, or southern Maidu. The Nisenan are a Penutian-speaking group that occupied territory in central California bounded by the Cosumnes and Mokelumne rivers to the south, the Yuba and Feather rivers to north, Sierra Nevada to the West, and Sacramento River to the east (Beals 1933:338-339; Kroeber 1925:391-392). Within this territory lived two distinct cultural groups, the Valley and Foothill Nisenan (Beals 1933:337). The territory of the Valley Nisenan is within the project area boundary within the drainages of the American and Sacramento rivers—extending just south of SAC-29 northward to SAC-15/H (Figure 3.2). There is considerable ethnographic data pertaining to the Foothill Nisenan and nearby Plains Miwok, but very limited information on the Valley Nisenan (Barrett and Gifford 1933; Beals 1933; Bennyhoff 1977; Gifford 1927; Kroeber 1925, 1929; Littlejohn 1928; Loeb 1933; Uldall and Shipley 1966; Voegelin 1942; Wilson 1972; Wilson and Towne 1978). Although Foothill groups and Plains Miwok practiced very
different lifeways than the Valley Nisenan, a distinction stressed by Kroeber (1929) and Beals (1933), general data on these cultures provides a foundation for inferences pertaining to the prehistoric and ethnographic use of the lower Sacramento Valley.

Figure 3.2. Ethnographic Map of Central California (after Bennyhoff 1977, Map 2).

The Valley Nisenan lived in permanent year-round villages situated on low rises along major waterways, such as the Sacramento and American rivers. Communities were organized into autonomous tribelets within a hierarchical patrilineal system (Bennyhoff 1977; Kroeber 1929). Village size ranged from three to fifty dwellings, consisting of semi-subterranean, domed-shaped structures covered within earthen vegetation of tule or grasses (Kroeber 1929). Nisenan peoples had access to a diverse set of resources, and
subsistence activities were scheduled according to the seasonal availability of large harvests of storable resources. Valley groups were particularly focused on riverine resources, such as seeds and fish. Acorns from valley oaks (Quercus lobata) were a staple plant resource for the Valley Nisenan. Important fish resources according to ethnographic data included salmon and lamprey eels. Recent archaeological research suggests other species, such as Sacramento perch, thicktail chub, and Sacramento sucker also played a vital dietary role (Meyer and Rosenthal 2008:72). Terrestrial game were also an important component of the diet, and included black-tailed deer, pronghorn, elk, beaver, black-tailed jackrabbit, cottontail, and ground squirrel, to name a few. Waterfowl were a vital resource to the inhabitants of the valley since they were abundant during the winter when most other resources were scarce (Beals 1933; Kroeber 1925, 1929; Wilson 1972; Wilson and Towne 1978). Other resources such as western pond turtle, freshwater mussel, and grasshopper were also commonly hunted and gathered (Barrett and Gifford 1933:139; Wilson 1972:36). A more thorough review of ethnographic avian subsistence pattern is detailed below.

Bird Resources and Procurement

At the end of the harvest season ceremonies were often held to thank the rains for nourishing the earth, or the black oaks for bearing heavily, or the Canada geese for returning (Barrett and Gifford 1933, cited in Anderson 2005:249).

A variety of birds were procured for food (meat and eggs), feathers, and tools by occupants living in the lower Sacramento Valley. These include waterfowl, water birds such as grebes, coots, cormorants, herons, and various shorebirds, raptors, sandhill
cranes, and woodpeckers, to name a few (Table 5.1). Detailed information on the seasonality, habitat preference, nesting, breeding, and food preferences of the most commonly hunted taxa (ducks, geese, grebes, and coots) of the Sacramento Valley are provided in Appendix A. This section provides a brief description of their life histories focusing on their habitat preferences and escape behaviors. Ethnographic data on procurement and processing techniques are reviewed as well. These data together provide a context in which to examine changes in the archaeofaunal record of this study.

**Pacific Flyway**

The Pacific Flyway, one of four major flyway zones in North America, covers a broad region along the Pacific Coast from Alaska’s northern coast to the southern Gulf of Mexico. Within the Pacific Flyway exists a number of separate radar-identified migration corridors for a variety of waterfowl species (Bellrose 1980:20). In general, most flyway birds migrate seasonally between summer breeding grounds on the coast and interior of Alaska to wintering grounds in the Central Valley of California (Bellrose 1980:20). Significant breeding grounds in Alaska include the Yukon-Kuskokwim River Delta and Yukon flats. Modern estimates suggest that nearly the entire breeding population of cackling geese, tundra swans, 750,000 ducks of various species and 500,000 geese of various species breed there annually (Baldassarre and Bolen 1994:390-391). Similarly, the Central Valley of California, in particular the Sacramento-San Joaquin Delta, hosts large populations of migratory waterfowl species. Approximately 60 percent of the Pacific Flyway waterfowl population and 18 percent of the continental waterfowl
population winters in the Sacramento Valley (Gilmer et al. 1992:442). This includes an average 3.5 million ducks and 0.5 million geese and over 70 percent of the Pacific Flyway’s tundra swan, greater white-fronted goose, snow goose, cackling goose, and northern pintail populations (Baldassarre and Bolen 1994:407-408).

Waterfowl share several similar physiological and behavioral characteristics. Most species migrate bi-annually between summer breeding and wintering areas where they court and form pair bonds (Bellrose 1980). Ducks and geese are also very gregarious during the majority of the year, particularly at wintering and breeding sites, as well as the molting season in which they become flightless (Bellrose 1980). Despite these general commonalities, there are several specific behavioral differences worth noting.

Geese

Five species of native geese are common in the Sacramento Valley: greater white-fronted goose (Anser albi\textit{frons}), snow goose (\textit{Chen caerulescens}), Ross’s goose (\textit{C. rossi}), cackling goose (\textit{Branta hutchinsii}), and Canada goose (\textit{B. canadensis moffitti}). Geese are present in the valley region during the winter months (mid-September to mid-April).

Geese are surface feeders and ground foragers and consume a variety of grains, seeds, grasses, succulents, forbes, sedges and other aquatic vegetation in freshwater marshes and flooded grasslands. In water, they feed by “tipping up,” and submerging their head and neck to graze on aquatic plants and seeds near the surface. On land, they feed by grazing on grasses. They molt and brood near open water in stands of vegetation
and rarely overnight on dry shores. Geese are strong flyers and flush vertically from land or water when startled and are able to gain altitude quickly. They are also capable of diving if provoked. Geese are strong walkers and can run readily in terrestrial habitats. Most adult species weigh between 1,500 to 4,000 grams and live to 15 to 25 years of age. Geese typically have one brood per year with a clutch-size ranging from two to five precocious chicks (Bellrose 1980; Ely and Dzubin 1994; Mowbray et al. 2000, 2002; Ryder and Alisauskas 1994).

Ducks

There are nearly 20 species of resident and migratory ducks native to the Sacramento Valley. Ducks are broadly grouped as dabblers or divers, based on their physiology and diet. Similar to geese, dabblers, such as mallard (Anas platyrhynchos), Northern pintail (A. acuta), and gadwall (A. strepera), feed in shallow waters of marshes, ponds, lakes, rivers, and streams by grazing on aquatic plants and seeds at or near the surface. Divers, such as canvasback (Aythya valisineria), common merganser (Mergus merganser), and lesser scaup (A. affinis), feed in deeper waters of bays, estuaries, lakes, sloughs, ponds, and marshes, where they feed on a variety of resources, including aquatic plants, seeds, insects, invertebrates, algae, and small fish. Dabblers are strong flyers and most flush vertically when startled. Conversely, diving ducks flush by diving underwater.

All taxa are winter migrants except mallard, cinnamon teal (A. cyanoptera), gadwall, northern shoveler (A. clypeata), ruddy duck (Oxyura jamaicensis), wood duck (Aix sponsa), and common merganser, which are either year-round residents or breed in
the valley during the summer season (Sacramento Audubon Society 2011). The most
common and abundant species to the region include, mallard, American wigeon (**A.
americana**), northern pintail, and northern shoveler (Bellrose 1980).

Relative to geese, ducks have a higher fecundity rate with a one-year period to
maturity and large clutch-size, ranging from six to 14 chicks on average. The average
lifespan of a duck is between five and 15 years in the wild, and they weigh between 300
grams to 1,500 grams (Austin and Miller 1995; Austin et al. 1998; Bellrose 1980;
Drilling et al. 2002; Mallory and Metz 1999).

**Coots and Grebes**

There are three species of grebe and one species of coot common to the
Sacramento Valley: Western grebe (**Aechmophorus occidentalis** ), Clark’s grebe (**A.
clarkia**), pied-billed grebe (**Podilymbus podiceps**), and American coot (**Fulica
americana**). Clark’s grebe, pied-billed grebe, and American coot are resident species and
Western grebe is present during the summer breeding months. Grebes and coots prefer
fresh water lakes and marsh habitats. Grebes dive in shallow waters to feed on fish, and
aquatic invertebrates and insects. American coots dive in shallow waters to feed on
aquatic plants, such as sedges, pond-weeds, and algae, but may also forage on terrestrial
grasses and grains. Two other species, horned grebe (**Podiceps auritus**) and eared grebe
(**Podiceps nigricollis**) are rare winter migrants and prefer coastal and bay habitats
(Brisbin and Mowbray 2002; LaPorte et al. 2013; Muller and Storer 1999).
Unlike dabbling ducks, grebes and coots are reluctant to take flight when flushed. Instead, these birds prefer to escape danger by diving underwater or skimming along the surface while flapping their wings to become airborne. Grebes, in particular, are very strong divers and swimmers but are slow on land due to the extreme posterior placement of their feet (McAllister 1963). Coots on the other hand, are fast on land and are adept at walking and running rapidly on land or across water. Both coots and grebes are rarely observed any distance from water and rarely fly except during night migratory flights. On wintering grounds in the Sacramento Valley, coots are observed in large communal roosts in dense stands of cattail and other emergent plants. Grebes roost in loose flocks in open water. Most adult species of grebe weigh between 400 grams to 1,300 grams, and American coot weighs 650 grams. Grebes have an average life span of five to nine years. Coots typically live for four to five years. Coots and grebes average one to two broods per year with a clutch-size ranging from eight to 12 chicks in coots, and two to six chicks in grebes (Brisbin and Mowbray 2002; McAllister 1963; Muller and Storer 1999).

**Ethnographic Procurement**

The great abundance of various types of waterfowl species, as well as their predictable seasonal occurrence, would have provided past communities that lived in the Sacramento Valley with a reliable, robust resource package.

As Whitaker (2012:59) notes, there are scant ethnographic accounts of waterfowl procurement. Waterfowl are reported in ethnohistoric accounts in California, the Great Basin, and the Northwest Coast as being predominately hunted by use of nets and basket
traps, and sometimes hunted with bow-and-arrow utilizing canoes and/or duck decoys
(Barrett and Gifford 1933:186; Curtis 1913:56, 1924:74; 1926:151; Fowler 1992:56-60;
Heizer 1978; Kroeber 1925:410, 1929:263; McKern 1922:249; Olson 1936:50; Suttles
1951:73; Wilson and Towne 1982:09). The Valley Nisenan reportedly used tule decoys,
arrows, and balas along with nets to capture ducks (Wilson and Towne 1982:09) and tule
ducks were frequently used in combination with nets in Northern Paiute communities
(Fowler 1992:58).

Nets were used to ensnare waterfowl, which became tangled in the mesh. The net
was pulled ashore and the birds were disentangled and killed. If there were large numbers
caught, they were processed in-situ, similar to a rabbit drive. Lower catches were
transported and processed back at camp (Fowler 1992:58). Nets were set in different
ways to catch geese, dabbling ducks, and diving ducks, since they have disparate flushing
behaviors.

A large, quickly raised net was effective at taking geese and dabbling ducks,
which flush quickly:

The goose nets, mo’l a’, were set in spring, in a series one behind the other, and
tied to one long rope, with a pole of elderberry—chosen for its lightness—for
each net where the rope crossed it. These were either propped vertically or more
likely laid flat where the geese came to feed on grass. A pull on the rope by
concealed men drew the series of nets (up and) forward and down over the geese.
The duck nets were stretched across water at dusk and the birds caught in them as
they flew at night; they were held by poles at the ends. Men often stayed up to
take the birds out (Kroeber 1929:263).

Ducks that require a long, running start across the surface of the water (such as
those taxa in the Tribe Aythyini and their allies), were netted by placing the net a few feet
above the water to intercept these low-flyers (Fowler 1992:58). Diving seaducks, such as
scaups and buffleheads, were reportedly caught with underwater nets on the Northwest coast. These nets were hidden with seaweed and various plants and dead salmon or other fish were used as bait. The ducks would dive to retrieve the bait and become entangled in the net and drown (Curtis 1913:56; Olson 1936:50; Suttles 1951:73). Similar methods are reported in Yurok ethnographies to capture diving ducks using underwater nets baited with huckleberries (Powers 1925:50).

American coots were driven in late summer and early fall when they were in molt and unable to fly. Northern Paiute ethnography (Fowler 1992) documents the use of linear duck nets to capture coots. These nets were stretched over narrow channels and hunters pushed coots out from emergent vegetation into the net. Once the net was filled, it was dragged to shore and the coots disabled by breaking their legs (since they run very quickly) and killed (Fowler 1992:57-58).

Little information exists on ethnographic waterfowl processing and consumption practices. Detailed information on Northern Paiute processing of coots and waterfowl is documented by Fowler (1992). Once captured in nets and brought ashore, coots were skinned, split lengthwise, the bones were removed, and then hung to dry; they kept this way for a few weeks and were eaten steadily (Fowler 1992:59). Some coots and ducks were also dried for longer-term storage in subsurface pits lined with rye grass and cattail leaves (Fowler 1992:59). Waterfowl were prepared by boiling, roasting, and baking. Large birds, such as swans and geese were pit-roasted. The bird was gutted first, and sometimes skinned or plucked, and placed on the ground over coals. Ducks and coots were also roasted by encasing the entire bird (feathers and all) in a layer of mud and clay.
The heat caused the clay to harden, “sealing in the bird’s succulent juices” (Fowler 1992:60). This similar method of roasting of ducks is reported for Plains Miwok communities as well:

…Wrapping the carcass with mud obtained from special places along stream banks. First, the animal was drawn and the body cavity sewn shut with a small stick of willow or other wood. The animal was then coated with mud—often with the skin still on. After cooking, the animal was removed from the fire, and the mud covering broken off. Waterfowl feathers came away with the mud (Wilson and Towne 1982:36).

It is difficult to determine archaeologically whether birds recovered from the SAC-15/H and SAC-29 assemblages were hunted using the methods described above. Evidence for netting technology in the Sacramento Valley extends to the Early Period, roughly 2,500 years ago. Net weights are abundant in assemblages, especially in the Late Period, and are assumed to be associated with fishing technology. However, these same nets may have also been used to catch many types of prey, including waterfowl. Thus, there was likely no diachronic change in procurement method of waterfowl.

Since the avian taxa examined in this study congregate in large flocks in the valley and are known to have been captured effectively en masse by netting in ethnographic times, it is plausible to assume this occurred similarly in the past. The large abundance of waterfowl remains at the sites and at other sites in the region provides support for this interpretation. Significantly, costly netting techniques do not alter prey-rankings since ducks and geese (and coots) were hunted using the same methods (e.g., Lupo and Schmitt 2002; Ugan 2005a).
Summary

The lower Sacramento Valley has witnessed a plethora of environmental and cultural changes over the last several millennia. With a warming climate and influx of seawater into the Bay estuary over the early and middle Holocene, the Sacramento Valley and Delta stabilized around 6,000 BP. The late Holocene was a time of cool, dry conditions punctuated by droughts and floods. Particularly, the MCA and LIA may have impacted local biotic communities.

Evidence of human occupation in the valley is not robust until after 5,000 BP. Archaeological research focused on the establishment of culture histories until relatively recently. Since then, the focus has shifted to understanding landscape use, human behavior, and subsistence economies. Recent research indicates that there were residential populations living in circumscribed territories within the lower Sacramento Valley. These groups had a varied subsistence economy of game and plants from the surrounding biotic communities of riverine, marshland, oak woodland, riparian, and grasslands. They had complex tool-kits and material culture, practiced elaborate ritual and ceremonials, and exhibited extensive trade-networks with nearby communities, particularly the San Francisco Bay.

Waterfowl were an important resource to prehistoric populations and the ethnographic groups living in the lower Sacramento Valley. Geese, ducks, coots, and grebes were favored bird resources and are found in similar marshland environments throughout the valley. A review of their behaviors and ecology and ethnographic data on
procurement and processing reveal waterfowl were likely effectively taken *en masse* with nets prehistorically.

Based on the ethnographic literature discussed, netting procurement methods appear to have been specialized for each type of avian prey taxa due to differing flushing behaviors. This specialization could have altered prey-rankings. For example, goose nets may have been more labor-intensive than duck-nets, resulting in an overall decline in their ranking. I argue that although there may have been some level of specialization, overall, netting methodology and mode of capture is analogous among all waterfowl examined and would not result in a bias to the method of prey-rankings used for this study.
Chapter 4

ARCHAEOLOGICAL SITES AND METHODOLOGY

The archaeological sites selected for analysis are presented in this chapter as well as the analytical methods used in the collection and analysis of data. Sampling techniques applied in analyses are discussed followed by faunal identification and analysis methodology.

A representative sample from the region is necessary to address changes in the exploitation of avifauna in the lower Sacramento Valley. Archaeological assemblages chosen for sampling met the following criteria:

1) The faunal assemblage is part of a catalogued archaeological collection with provenience, chronological, and descriptive information.

2) The archaeological sites are within analogous site catchments and are located adjacent to the lower Sacramento River. This avoids the potential bias of differential encounter rates with various waterfowl prey, which could confound temporal trends.

3) The archaeological site contains well-dated temporal components spanning the late Holocene based on associated artifacts and/or chronometric data.

4) The faunal assemblage was recovered using 1/8 inch mesh.

5) The faunal sample was recovered from midden contexts.
6) Based on the results from a pilot study, the sampled faunal assemblage should consist of at least 500 identified specimens to be adequate for statistical analyses.

Comprehensive background research, including a literature review, records search, and consultation with various local experts, was conducted in order to delineate appropriate archaeological sites for the study. The results of the background research yielded a suite of potential archaeological sites. Unfortunately, several candidates did not meet one or several of the outlined criteria, severely limiting sampled possibilities.

Selected sites that met all criteria were SAC-29 and SAC-15/H.

Table 4.1. Selection of Archaeological Sites.

<table>
<thead>
<tr>
<th>Site</th>
<th>Environment</th>
<th>Occupation Date</th>
<th>Screen size</th>
<th>Bird NISP</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Col-1</td>
<td>Riverine/Marsh</td>
<td>Proto/Historic</td>
<td>1/8”</td>
<td>5000+</td>
<td>Schulz et al. 1974</td>
</tr>
<tr>
<td>SAC-15</td>
<td>Riverine/Marsh</td>
<td>1200 – 350 cal BP</td>
<td>1/8”</td>
<td>6500+</td>
<td>N/A</td>
</tr>
<tr>
<td>SAC-29</td>
<td>Riverine/Marsh</td>
<td>Middle-Protohistoric</td>
<td>1/8”</td>
<td>4000+</td>
<td>N/A</td>
</tr>
<tr>
<td>SAC-42</td>
<td>Riverine/Marsh</td>
<td>Middle</td>
<td>1/8”</td>
<td>198</td>
<td>Milliken et al. 1995</td>
</tr>
<tr>
<td>SAC-43</td>
<td>Riverine/Marsh</td>
<td>Middle</td>
<td>1/8”</td>
<td>2500+</td>
<td>Bouey 1995</td>
</tr>
<tr>
<td>SAC-56</td>
<td>Riverine/Marsh</td>
<td>Late</td>
<td>1/4”</td>
<td>&lt; 500</td>
<td>N/A</td>
</tr>
<tr>
<td>SAC-65</td>
<td>Riverine/Marsh</td>
<td>535 cal BP</td>
<td>1/8”</td>
<td>MNI = 9</td>
<td>Schulz et al. 1979</td>
</tr>
<tr>
<td>SAC-145</td>
<td>Riverine/Marsh</td>
<td>2020 – 150 cal BP</td>
<td>1/8”</td>
<td>MNI = 24</td>
<td>Simons et al. 1978</td>
</tr>
<tr>
<td>SAC-329</td>
<td>Riverine/Marsh</td>
<td>1090 – 370 cal BP</td>
<td>1/8”</td>
<td>MNI = 14</td>
<td>Soule 1976</td>
</tr>
<tr>
<td>SAC-329</td>
<td>Riverine/Marsh</td>
<td>1090 – 370 cal BP</td>
<td>1/8”</td>
<td>MNI = 14</td>
<td>Soule 1976</td>
</tr>
</tbody>
</table>
First recorded in 1934 by Robert Heizer, the King Brown site (CA-SAC-29) has undergone three phases of investigation. Originally described as a mound measuring 24 meters in diameter by three meters in height, SAC-29 is located approximately one kilometer east of the Sacramento River and seven kilometers downstream from the confluence of the Sacramento and American rivers at the southwestern limit of the ethnographic Valley Nisenan territory. The site is thought to be the remains of a major tribelet center known as Sama (Bennyhoff 1977:124).
Initial archaeological investigation of the site was conducted by the Sacramento Junior College in 1939 under the direction of Dr. J.B. Lillard and Franklin Fenenga (Fenenga 1940; Olsen 1963). Although no subsequent report or location map of excavations was produced, Fenenga noted that excavations consisted of an east-west running trench measuring 60 feet in length and four test units in the northwest portion of the site. Excavations recovered 26 interments in addition to various midden artifacts (Olsen 1963:7-8). Additionally, several specialized studies were published using the artifacts recovered and results suggest occupation dated from the Middle Period through Late Periods (Bennyhoff 1950; Fenenga 1953; Gifford 1947). The collection is currently curated at the Phoebe A. Hearst Museum at University of California, Berkeley.

Students from Sacramento State College conducted the second phase of investigation intermittently between 1954 and 1956 as part of a salvage project directed by Drs. Richard Reeve and Brigham Arnold (Olsen 1963:09). Excavations consisted of nine trenches ranging from five to 10 feet wide and 10 to 70 feet long, subdivided into five-foot by five-foot units and excavated to sterile soil in arbitrary twelve-inch levels. Olsen (1963) reports the site dimensions at the time of excavation as 69 by 125 meters with an estimated volume of 16,000 cubic meters. Of this total volume, the SSC excavated 430 cubic meters and recovered 148 interments, one large structure (a possible dance house), 1,500 projectile points, over 10,000 shell ornaments, 20,000 shell beads, and several thousand bone artifacts (Johnson, n.d.). Olsen’s (1963) M.A. thesis serves as the report for this investigation and concludes that the bulk of the site deposit is late
Middle Period in age. The collection is currently curated at the Archaeological Curation Facility at California State University, Sacramento.

In 1967, prior to the construction of Interstate 5, the Central California Archaeological Foundation (CCAF), under contract with California Department of Parks and Recreation, conducted a salvage excavation of the site under the direction of William Pritchard of Sacramento State College. Excavations consisted of 142 five-foot by five-foot units excavated to sterile soil in arbitrary six-inch levels; the deposit was screened through one-eighth inch mesh. Recovery efforts resulted in a total volume of approximately 360 cubic meters. Excavations recovered 25 interments and a large faunal assemblage—approximately 238 kilograms of material, as well as thousands of lithic, bone, and shell artifacts. Although no report was completed, there have been several specialized studies (Arnold 1969; Craw 2002; Dougherty 1990; Kielusiak 1982). Results of these studies indicate a more substantial Late Period Phase 1 occupation than previously noted. The collection from this phase of work is also curated at the Archaeological Curation Facility at California State University, Sacramento.

Chronological information utilized to assist in the assignment of temporal components of the site derives from various studies (Arnold 1969; Craw 2002; Dougherty 1990; Olsen 1963). No radiocarbon samples are available from the site, so chronology was established from diagnostic bead and projectile point artifacts and obsidian hydration samples. The site includes 61 source-specific obsidian hydration measurements (92% of which are Napa Valley obsidian), and an additional 30 source-specific obsidian artifacts without hydration data and 195 unsourced obsidian hydration measurements (Arnold
1969; Dougherty 1990). A small sample (~20) of the original hydration slides produced by Arnold 1969 was re-measured for verification by Bill Norton at the Obsidian Hydration Lab, Archaeological Research Center. Results suggest the vast majority of original hydration measurements are accurate. Hydration conversion rates for Napa obsidian sourced artifacts were based on those calculated by Rosenthal and colleagues (2006). The conversion formula is:

\[ T = 148.99 \mu^2 \]

A suite of time-sensitive artifacts was recovered from the 1967 investigation, including over 1,000 projectile points and thousands of shell bead artifacts. All available bead and projectile point artifacts from the sampled units (n = 235) were typed in accordance with Bennyhoff and Frederickson (1994), Bennyhoff and Hughes (1987), Milliken and Schwitalla (2012), and Olsen (1963). It should be noted that almost all Middle Period projectile points (Excelsior series) were missing from the collection at the time of analysis but data for these were available in Arnold (1969) and Dougherty (1990).

Artifacts from two loci selected for faunal analysis were analyzed to document chronological discontinuities. Available data includes 44 hydration rim measurements, 73 beads, and 86 projectile points from a cluster of five units in the southwestern portion of the site, and 15 hydration rim measurements, 56 beads, and 20 projectile points from a cluster of three units in the northwestern portion of the site.

The chronological data were used to sort materials into three analytic components representing, Late Period Phase 2, Late Period Phase 1, and the Middle Period. The Late Period Phase 2 deposit is present in only the southwest units and ranges from a depth of 0
to 30 inches. The Late Period Phase 1 deposit is restricted to 30 inches and below in the southwest units and 12 to 24 inches in the northwest units. The lower levels, below 24 inches in the northwest region of the site, contain older deposits dating to the Middle Period.

Figure 4.2. SAC-29 Site Map (adapted from Craw 2002: Figure 5.1).
Figure 4.3. SAC-29 Late Period Phase 1 and 2 Artifacts.
Figure 4.4. SAC-29 Middle Period Artifacts (bottom illustration from Dougherty 1990).
Faunal Sample

The faunal materials analyzed from SAC-29 are a result of the 1967 phase of investigation only. Since no formal report has been written for the collection, the selection of avifaunal remains to sample for analysis was made based on data provided by the collection catalog created by Department of Parks and Recreation in 1993, a database of diagnostic artifact data created by Craw (2002) in preparation for her thesis research, various other theses (Arnold 1969; Dougherty 1990; Olsen 1963), and personal communication (2011) with Marianne Russo and Dr. Jerald Johnson who are currently working with the collection. Additionally, the examination of original field notes and maps was conducted in order to delineate disturbances from human interments. The selection of faunal remains was made by excavation unit using the following criteria:

1) Available field notes and side wall profiles
2) Absence of human interments
3) At least 1,000 g of faunal material
4) Associated diagnostic artifacts and obsidian hydration rim measurements

The majority of the 142 five-foot by five-foot excavation units were excluded from analyses because they either contained human interments or they could not confidently be linked to dated deposits. Consequently, nine units were selected for analysis that met the above criteria.
The sampled units clustered in two areas of the site, the southwest and northwest portions. Available avifauna were analyzed from arbitrary six-inch levels at a depth ranging from surface to 120 inches below surface (Table 4.2). This includes seven levels dated to the Middle Period, five dated to Late Period Phase 1, and five dated to Late Period Phase 2. Some levels were omitted due to mixing of matrix between levels, cataloging errors, lack of associated diagnostic artifacts or obsidian hydration dates and/or bird fauna. After reviewing the chronological data, it was determined that the first two levels (0 to 12) inches in the northwest units exhibited extensive mixing of matrix materials between levels. Bird fauna was not recovered or unavailable from 48 to 54 inches below surface from units S7/W0, S7/W1, and S7/W4. Similarly, avifauna was either not unavailable and/or no associated diagnostic artifacts were recovered for levels 66 to 120 inches below surface from unit N0/W13. Further, during analysis it became evident that fauna from one of the selected units, N1/W12, was erroneously mixed with interment-associated faunas from a unit in another portion of the site. Thus, analyzed avifauna from this unit was excluded from analyses.
Table 4.2. SAC-29 Sample Provenience (Phase 1 and Phase 2 are of the Late Period).

<table>
<thead>
<tr>
<th>Unit</th>
<th>Depth (in)</th>
<th>Component</th>
<th>Sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>S6/W2</td>
<td>00-30</td>
<td>Phase 2</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>30-48</td>
<td>Phase 1</td>
<td>yes</td>
</tr>
<tr>
<td>S7/W0</td>
<td>00-30</td>
<td>Phase 2</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>30-48</td>
<td>Phase 1</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>48-54</td>
<td>Phase 1</td>
<td>no</td>
</tr>
<tr>
<td>S7/W1</td>
<td>00-30</td>
<td>Phase 2</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>30-48</td>
<td>Phase 1</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>48-54</td>
<td>Phase 1</td>
<td>no</td>
</tr>
<tr>
<td>S7/W3</td>
<td>00-30</td>
<td>Phase 2</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>30-42</td>
<td>Phase 1</td>
<td>yes</td>
</tr>
<tr>
<td>S7/W4</td>
<td>00-30</td>
<td>Phase 2</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>30-48</td>
<td>Phase 1</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>48-54</td>
<td>Phase 1</td>
<td>no</td>
</tr>
<tr>
<td>N0/W13</td>
<td>00-12</td>
<td>Mixed</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>12-24</td>
<td>Phase 1</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>24-66</td>
<td>Middle</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>66-120</td>
<td>Indet.</td>
<td>no</td>
</tr>
<tr>
<td>N1/W13</td>
<td>00-12</td>
<td>Mixed</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>12-24</td>
<td>Phase 1</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>24-60</td>
<td>Middle</td>
<td>yes</td>
</tr>
<tr>
<td>N2/W12</td>
<td>00-12</td>
<td>Mixed</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>12-24</td>
<td>Phase 1</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>24-54</td>
<td>Middle</td>
<td>yes</td>
</tr>
</tbody>
</table>

Craw (2002) analyzed faunal remains from four units recovered from these same loci, having employed a similar sampling methodology. As a result, avifauna from three of four units analyzed by Craw, S7/W0, S7/W03 and N1/W13, were reanalyzed by the author. Avifauna (~100 identifiable specimens) from the fourth unit, N2/W10, were not included in any analyses of the present study. The decision to exclude her analysis and reanalyze the avifauna remains from these units was due to her use of differing analysis methodologies and goals of research. The research for this thesis required a greater depth
of analysis of avifaunal remains and a higher quality data set than currently exists for the site.

**CA-SAC-15/H**

The site SAC-15/H was first reported in 1934 by Robert Heizer as a low mound along the Sacramento River. The site is located immediately east of the levee bordering the Sacramento River, approximately 500 meters south of modern Interstate 5, and was formally recorded by Dames and Moore in 1993. Dames and Moore noted the mound as 80 meters in diameter and consisting of dark midden soil with an abundance of freshwater shell and cultural materials. Surface observations suggested the site occupation ranges from the late Middle Period and Phase 1 of the Late Period (USACE and SAFCA n.d.).

More recently, AECOM conducted a major testing and data recovery project of the site in 2008 and 2011 as part of the Natomas Levee Improvement Program (NLIP) prepared for Army Corps of Engineers and Sacramento Regional Flood Control Agency (USACE and SAFCA n.d.). Excavations resulted in seven archaeological test units (TUs) excavated in two site loci (Locus 1 and 3; Figure 4.6). Units were either 1 x 1 meter or 2 x 2 meters in size and were excavated to depths ranging from 1.6 to 2.9 meters below surface. In addition, twenty backhoe trenches, 15 of which received geoarchaeological analysis, were excavated across the site (Meyer and Kaijankoski 2013). Matrix was screened through a mix of quarter-inch, eighth-inch, and sixteenth-inch mesh; flotation samples were screened through finer mesh. The ages of the various stratigraphic units identified in the trenches and units were determined primarily through radiocarbon dating.
of organic materials associated with cultural deposits. Radiocarbon dates were obtained on 91 samples acquired from the site.

Although portions of the site have been disturbed by bioturbation and historical land use activities, the site retains much of its original integrity and systemic context. Based on stratigraphy, radiocarbon evidence, and age-depth relationships identified from geoarchaeological investigations, it appears the site is vertically stratified, and the majority of the archaeological deposits can be tightly associated with spatially discrete strata and temporal components (Meyer and Kaijankoski 2013:16-17). Radiocarbon data reveals an occupation range from 1200 to 350 cal BP (Figure 4.5).

Following Meyer and Kaijankoski (2013:15), the faunal assemblage was divided into two discrete temporal periods, Late Period Phase 1/MLT (350 to 800 cal BP) and late Middle Period (800 to 1200 cal BP). The Late Period component ranges from a depth of 0 to 180 cmbs. The Middle Period component occurs below 180 cmbs.
Faunal Sample

The SAC-15/H faunal materials analyzed for this thesis come from the 2011 NLIP data recovery project only, as the testing phase faunal materials and data were unavailable at the time of writing. Data recovery resulted in the excavation of three units (TU 7, 8, and 9) measuring 2 x 2 meters and a secondary unit of TU 7 (TU 7a) measuring 1 x 2 meters. Depths of these units range between 1.6 and 2.8 m below surface.

The selection of avifaunal remains to sample for analysis was made based on data provided by the collection catalog created by AECOM in 2011, radiocarbon and geoarchaeological data provided by AECOM and Far Western Anthropological Research Group, and personal communication with NLIP project director, Richard Deis, M.A..
Faunal remains for this study derive from excavation unit TU 7/7a only, as it was determined to be the only data recovery unit that contained both Middle and Late Period deposits. No Phase 2 Late Period fauna were available for analysis. Although the uppermost stratum in TU 8 appears to be restricted entirely to Late Period Phase 2, the integrity of this stratum is questionable because it also contained a pipeline and a variety of other historic-era materials.

Unit 7/7a measured 5.52 meters in size and was excavated to a depth of 5 meters, recovering a total of 5.34 m³ of matrix. The unit contained a layer of disturbed deposits at the surface, underlain by a thick sequence of three to four alluvial strata dating to the Late Period. The Middle Late Transition is represented by a complex sequence of cultural strata and intact residential features (Meyer and Kaijankoski 2013). The lower stratigraphic unit dates to the late Middle Period.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Depth (cm)</th>
<th>Date (cal BP)</th>
<th>Sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/7A</td>
<td>0-40</td>
<td>Mixed</td>
<td>no</td>
</tr>
<tr>
<td>7/7A</td>
<td>40-180</td>
<td>350-800</td>
<td>yes</td>
</tr>
<tr>
<td>7/7A</td>
<td>180-280</td>
<td>800-1200</td>
<td>yes</td>
</tr>
</tbody>
</table>

Fauna recovered using one-eighth inch mesh were analyzed from all levels of unit 7/7A from 40 cm to 280 cm for a total of 28 arbitrary 10 cm levels (Table 4.3). The first 40 centimeters were not considered in this study due to the presence of a turbated plow zone. Fauna was not analyzed from features within the unit or any level-bags denoted as disturbed by bioturbation or “wall cleanup” in the data recovery catalog.
Identification Protocol

Both faunal samples were analyzed by the author following the same identification protocol. Avian remains from SAC-15/H were pulled by the author from unsorted faunal material and placed in a separate labeled bag (but kept with the original catalog number). Students in the Department of Anthropology, CSUS, previously sorted all faunal material from SAC-29 by taxonomic class. Thus, bird remains were separated
from other vertebrate classes. Due to the varying experience of students that conducted
the faunal sorting, the author reviewed all fauna from the selected site proveniences for
bird remains. At the time of analysis, previously cataloged specimens were being
resorted, recounted, and reweighed by Marianne Russo in order to identify any NAGPRA
related materials and to correct for various errors with the current catalog of the site
assemblage. As such, no attempt was made to wash, label, or further sort avifaunal
remains; all specimens were left “as-is” and, as with the SAC-15 sample, identifications
were made within level bags.

All avian bone was counted and sorted into generic identifiable and unidentifiable
categories. The identifiable fauna were further identified to skeletal element (portion and
side) and the lowest taxonomic level possible given the condition, available reference
material, and skill of the analyst. Identifications beyond class level were not attempted
for ribs, vertebrae, cuneiforms, scapholunars, and quadrates. Specimens that could not be
assigned to element were excluded from further analyses.

In addition to the typical method of recording element portion (proximal, distal,
proximal shaft, etc.), portion was recorded using the bone zone recording method
provided by Cohen and Serjeantson (1996:109-112). Faunal remains that could be
identified to element but not taxon were size-sorted. Size determinations were based on
average modern bird weight information from the Birds of North America volumes
(Poole 2002) and follow similar categories identified in Serjeantson (2009). Further size
class determinations were made for those specimens assigned to the family Anatidae
(Table 4.4).
Those specimens that strongly resembled a particular genus or species but could not positively be identified as such are noted as “cf.”, or compares favorably with the taxonomic assignment in question. Identifications were made using the comparative collections of the Anthropology and Biology departments housed at California State University, Sacramento. The collection(s) of over 300 avifauna reference specimens contains multiple specimens of almost every taxon needed for the study. Several reference materials were also consulted to aid in the identification process in addition to the examination of multiple specimens per taxon. Specifically, I used diagnostic criteria found in Bovy (2005), Broughton (2004a), Cohen and Serjeantson (1996), Gilbert et al. (1996), Howard (1929), Jangala (2004), Livezey (1996a), Livingston (1988), Oates et al. (2003), and Olsen (1979). Specific identification criteria used to distinguish particular genera and species outside of these references are noted in Appendix A. Anatomical terminology follows Howard (1929) and Serjeantson (2009).

Age at death was recorded for all elements analyzed; age categories recorded include adult, sub-adult, or juvenile. Juvenile specimens were very porous, small in size, and lack cortical bone. Sub-adult specimens were full-size, fused, and only slightly porous. Adult bones exhibited complete ossification. When present, modifications were recorded for each specimen. Types of cultural and non-cultural modifications recorded include: processing marks, degree of thermal alteration, animal gnaw marks, and weathering (following Behrensmeyer 1978).
Table 4.4. Bird Size Categories (average weight data from Poole 2002).

<table>
<thead>
<tr>
<th>Size Class</th>
<th>General Avian Birds</th>
<th>General Avian Weight (g)</th>
<th>Duck Birds</th>
<th>Duck Weight (g)</th>
<th>Goose Birds</th>
<th>Goose Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very small</td>
<td>&lt;150</td>
<td>Passerines, Northern Flicker, Virginia Rail</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>150-600</td>
<td>Ducks (small), Snowy Egret, American Coot</td>
<td>300-600</td>
<td>Teals, Bufflehead, Ruddy Duck</td>
<td>1500-2200</td>
<td>Ross's Goose, Brant, Cackling Goose</td>
</tr>
<tr>
<td>Medium</td>
<td>600-1000</td>
<td>Ducks (medium-large), Gulls, Common Raven</td>
<td>600-900</td>
<td>Hooded Merganser, Gadwall, Northern Shoveler</td>
<td>2200-3500</td>
<td>Greater White-fronted Goose, Snow Goose</td>
</tr>
<tr>
<td>Large</td>
<td>1000-5000</td>
<td>Geese, Great Blue Heron, Turkey Vulture</td>
<td>900-1500</td>
<td>Mallard, Canvasback, Common Merganser</td>
<td>3500-4500</td>
<td>Canada Goose</td>
</tr>
<tr>
<td>Very Large</td>
<td>&gt;5000</td>
<td>Tundra Swan, Sandhill Crane, California Condor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Counting Measures: NISP and MNI

All specimens were counted in order to provide a basic number of specimens (NISP); however, only those specimens identified to specific element and taxon are used in statistical analyses. The number of identified specimens (NISP) is the most commonly utilized measurement in zooarchaeology. Its use has several inherent weaknesses related to differential preservation, recovery, cultural processing, intertaxonomic differences in the frequency of elements, its use as an ordinal scale measurement, and interdependence of skeletal remains (Lyman 2008:29), the latter of which is the most severe (Grayson 1979, 1984). Many of these issues, particularly the issue of interdependence, may be resolved by calculating the minimum number of individuals (MNI). However, MNI has its own set of weaknesses for use in zooarchaeological analyses (see Lyman 2008:45). The most problematic is that MNI varies depending on how specimens are aggregated. It is has been shown in several case studies that MNI is dependent on NISP, making the computation of MNI superfluous in most instances (Grayson 1979; Lyman 2008:70). Minimum number of individual estimates were not calculated for this study (but see Appendix B for analysis data).
RESULTS AND DISCUSSION

Data for taxonomic composition, relative abundance, and taphonomic conditions from the SAC-29 and SAC-15/H avifaunal samples are reviewed in this chapter in order to assess waterfowl resource depression in the Sacramento Valley. Changes in regional environmental conditions are discussed relative to changes in assemblage composition. Results are compared to Broughton’s (1999, 2004a) Emeryville Shellmound avifaunal research to provide a broader, regional perspective.

CA-SAC-29 Avifaunal Assemblage

The analyzed portion of the SAC-29 assemblage contained 4,486 avifaunal specimens of which 2,408 (54%) were identified to a taxonomic level below class, representing 18 genera in 12 families (Table 5.1). Waterfowl dominate the assemblage, particularly ducks. Species of dabbling duck are more frequent than diving species. Rails, particularly *Fulica americana* (American coot), are also quite common. Various other water birds and terrestrial birds are present in trace amounts. The distribution of identified taxa among temporal periods is presented in Table 5.2. Juvenile and subadult bones were uncommon (NSP = 162; 4%). Identification of avian juvenile and subadult bones posed a significant challenge and only 31% could confidently be assigned to a taxonomic level below class. Subadult specimens identified represent mostly resident
species of Ardeidae (44%), anatids (21%), passerines (15%), and *Fulica americana* (10%) (Table 5.3).

**SAC-15/H Avifaunal Assemblage**

The analyzed portion of the SAC-15/H assemblage contained 1,907 avifaunal specimens of which 788 (41%) were identified to a taxonomic level below class, representing 17 genera in 10 families (Table 5.1). Similar to SAC-29, the assemblage consists of mostly waterfowl dominated by ducks. Diving and dabbling ducks occur in equal abundance. Grebes are much more common in this assemblage than at SAC-29. American coots are also frequent. Other water birds occur in trace amounts, but less than are present in the SAC-29 assemblage. Conversely, terrestrial birds are more common in this assemblage at SAC-29, but are relatively low in abundance overall. The distribution of identified taxa among temporal periods is presented in Table 5.2. Juvenile and subadult bones were also uncommon at SAC-15/H (NSP = 49; 3%). Due to the difficulty of identification of avian juvenile and subadult bones, only 30% could confidently be assigned to a taxonomic level below class. Subadult specimens identified represent mostly resident species of grebes (53%), anatids (20%), herons (13%) and passerines (13%) (Table 5.3).
<table>
<thead>
<tr>
<th>TAXON</th>
<th>SAC-15/H</th>
<th>SAC-29</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anserinae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anserinae – small</td>
<td>57</td>
<td>118</td>
</tr>
<tr>
<td>Anserinae – medium</td>
<td>76</td>
<td>161</td>
</tr>
<tr>
<td>cf. Anserini</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Anser albifrons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cf. Branta bernicla or B. hutchinsii</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. canadensis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cf. B. canadensis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anatinae</td>
<td>57</td>
<td>224</td>
</tr>
<tr>
<td>Anatinae – small</td>
<td>53</td>
<td>210</td>
</tr>
<tr>
<td>Anatinae – medium</td>
<td>60</td>
<td>170</td>
</tr>
<tr>
<td>Anatinae – large</td>
<td>132</td>
<td>340</td>
</tr>
<tr>
<td>cf. Anatinae</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Anatini</td>
<td>24</td>
<td>23</td>
</tr>
<tr>
<td>Anas spp.</td>
<td>14</td>
<td>164</td>
</tr>
<tr>
<td>A. platyrhynchos</td>
<td>6</td>
<td>39</td>
</tr>
<tr>
<td>Aythya spp.</td>
<td>14</td>
<td>80</td>
</tr>
<tr>
<td>Mergini</td>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>Mergus merganser</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>cf. M. merganser</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Bucephola albeola</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Oxyura jamaicensis</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>Podicipedidae</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Podilymbus podiceps</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>cf. P. podiceps</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Aechmorhophorus sp.</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Phalacrocorax auritus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelecaniformes</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Ardeidae</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Ardea spp.</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>A. Herodias</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>cf. A. Herodias</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Accipitriformes</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Cathartes aura</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>TAXON</td>
<td>SAC-15/H</td>
<td>SAC-29</td>
</tr>
<tr>
<td>-------</td>
<td>----------</td>
<td>--------</td>
</tr>
<tr>
<td>Accipitridae</td>
<td>Hawks</td>
<td>2</td>
</tr>
<tr>
<td><em>Buteo</em> spp.</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td><em>Haliaeetus leucocephalus</em> or <em>Aquila chrysaetos</em></td>
<td>Bald Eagle or Golden Eagle</td>
<td>2</td>
</tr>
<tr>
<td><em>Falco sparverius</em></td>
<td>American Kestrel</td>
<td>2</td>
</tr>
<tr>
<td>Gruiformes</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Rallidae</td>
<td>Rail</td>
<td>1</td>
</tr>
<tr>
<td><em>Fulica americana</em></td>
<td>American Coot</td>
<td>85</td>
</tr>
<tr>
<td>cf. <em>F. americana</em></td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>cf. <em>Grus canadensis</em></td>
<td>Sandhill Crane</td>
<td>1</td>
</tr>
<tr>
<td>Charadriiformes</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Strigidae</td>
<td>Owl</td>
<td>-</td>
</tr>
<tr>
<td>Picidae</td>
<td>Woodpecker</td>
<td>-</td>
</tr>
<tr>
<td><em>Colaptes</em> spp.</td>
<td>Flicker</td>
<td>1</td>
</tr>
<tr>
<td>Passeriformes</td>
<td>Perching birds</td>
<td>30</td>
</tr>
<tr>
<td>Corvidae</td>
<td>Crow, Jay, Magpie</td>
<td>1</td>
</tr>
<tr>
<td><em>Corvus brachyrhynchos</em></td>
<td>American Crow</td>
<td>6</td>
</tr>
<tr>
<td><em>C. corax</em></td>
<td>Common Raven</td>
<td>1</td>
</tr>
<tr>
<td>Aves</td>
<td>Bird</td>
<td>138</td>
</tr>
<tr>
<td>Aves-very small</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>Aves-small</td>
<td>277</td>
<td>391</td>
</tr>
<tr>
<td>Aves-medium</td>
<td>507</td>
<td>747</td>
</tr>
<tr>
<td>Aves-large</td>
<td>183</td>
<td>500</td>
</tr>
<tr>
<td>Aves-very large</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td><strong>TOTAL NISP</strong></td>
<td>788</td>
<td>2406</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>1907</td>
<td>4486</td>
</tr>
</tbody>
</table>
Table 5.2. NISP and %NISP per Avian Type by Site and Temporal Period.

<table>
<thead>
<tr>
<th></th>
<th>SAC-15/H</th>
<th></th>
<th>SAC-29</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Middle Period</td>
<td>Late Period</td>
<td>Middle Period</td>
<td>Late Period</td>
</tr>
<tr>
<td></td>
<td>NISP</td>
<td>%NISP</td>
<td>NISP</td>
<td>%NISP</td>
</tr>
<tr>
<td>Geese</td>
<td>92</td>
<td>29%</td>
<td>93</td>
<td>20%</td>
</tr>
<tr>
<td>Dabbling ducks</td>
<td>17</td>
<td>5%</td>
<td>27</td>
<td>6%</td>
</tr>
<tr>
<td>Diving ducks</td>
<td>35</td>
<td>11%</td>
<td>9</td>
<td>2%</td>
</tr>
<tr>
<td>Indet. ducks</td>
<td>108</td>
<td>34%</td>
<td>202</td>
<td>43%</td>
</tr>
<tr>
<td>Rails</td>
<td>31</td>
<td>10%</td>
<td>58</td>
<td>12%</td>
</tr>
<tr>
<td>Grebes</td>
<td>22</td>
<td>7%</td>
<td>34</td>
<td>7%</td>
</tr>
<tr>
<td>Other waterbirds</td>
<td>7</td>
<td>2%</td>
<td>8</td>
<td>2%</td>
</tr>
<tr>
<td>Terrestrial birds</td>
<td>5</td>
<td>2%</td>
<td>40</td>
<td>8%</td>
</tr>
<tr>
<td>Total</td>
<td>317</td>
<td>100%</td>
<td>471</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 5.3. Subadult NISP (includes subadult and juvenile specimens).

<table>
<thead>
<tr>
<th>Taxon</th>
<th>SAC-15/H</th>
<th></th>
<th>SAC-29</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Middle Period</td>
<td>Late Period</td>
<td>Middle Period</td>
<td>Late Period</td>
</tr>
<tr>
<td>Anatidae</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Anatinae</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Anas spp.</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Podicipedidae</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Podilymbus podiceps</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Aechemorphous sp.</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Phalacrocorax auritus</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Ardeidae</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Ardea spp.</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Gruiformes</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Fulica americana</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Strigidae</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Corvidae</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Corvus brachyrhynchos</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Passeriformes</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>11</td>
<td>29</td>
<td>19</td>
</tr>
</tbody>
</table>
**Taxonomic Diversity**

The taxonomic composition of a faunal assemblage is often a function of sample size and may not reflect behavioral decisions such as prey-choice (Baxter 2001; Grayson 1978, 1984; Lyman 2008). In order to gain a better understanding of the taxonomic composition of the sampled avifaunas and to examine sample size effects further, two diversity measures, richness and evenness, were calculated. Richness and evenness values by component and site are provided in Table 5.4.

Taxonomic richness refers to the range of taxa present in an assemblage and is obtained by tallying the number of taxa (NTAXA; Lyman 2008:143) at the genus level (Note: Charadriiformes and Strigidae are also included in NTAXA calculations since no specimens were identified to genera in this order and family). The SAC-15/H sample has a taxonomic richness of 18, and the SAC-29 sample has a taxonomic richness of 19 (Table 5.4). As Figure 5.1 illustrates, both samples appear to reach redundancy in richness after a random sample of 140 specimens. As a result, these samples can be compared directly (Lepofski and Lertzman 2005; Lyman and Ames 2004). Regression analysis reveals that taxonomic richness is comparable between the two assemblages and there is no significant relationship with sample size ($r^2 = 0.27$, $p > 0.37$).
Table 5.4. Taxonomic Counts and Diversity Values by Temporal Period.

<table>
<thead>
<tr>
<th>TAXON</th>
<th>SAC-15/H</th>
<th></th>
<th>SAC-29</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Middle</td>
<td>MLT/Late 1</td>
<td>Total</td>
<td>Middle</td>
<td>Late 1</td>
<td>Late 2</td>
<td>Total</td>
</tr>
<tr>
<td>Anser sp.</td>
<td>- 3</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Branta sp.</td>
<td>- 4</td>
<td>4</td>
<td>18</td>
<td>21</td>
<td>12</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>Anas sp.</td>
<td>6 14</td>
<td>20</td>
<td>82</td>
<td>49</td>
<td>72</td>
<td>203</td>
<td></td>
</tr>
<tr>
<td>Aythya sp.</td>
<td>11 3</td>
<td>14</td>
<td>41</td>
<td>17</td>
<td>22</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Bucephala sp.</td>
<td>1  -</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Mergus sp.</td>
<td>5  -</td>
<td>5</td>
<td>13</td>
<td>8</td>
<td>17</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Oxyura sp.</td>
<td>5  3</td>
<td>8</td>
<td>9</td>
<td>3</td>
<td>5</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Podilymbus sp.</td>
<td>12 20</td>
<td>32</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Aechmorpus sp.</td>
<td>3  6</td>
<td>9</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Phalacrorcorax sp.</td>
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<td>7</td>
<td>7</td>
<td>6</td>
<td>12</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Ardea sp.</td>
<td>- 1</td>
<td>1</td>
<td>22</td>
<td>5</td>
<td>5</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Cathartes sp.</td>
<td>-  -</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Buteo sp.</td>
<td>-  -</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Haliaeetus/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aquila sp.</td>
<td>2  -</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Falco sp.</td>
<td>-  2</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Fulica sp.</td>
<td>31 57</td>
<td>88</td>
<td>182</td>
<td>95</td>
<td>65</td>
<td>342</td>
<td></td>
</tr>
<tr>
<td>Grus sp.</td>
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<td>1</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Charadriiformes</td>
<td>1  2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Strigidae</td>
<td>-  -</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>2</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Colaptes sp.</td>
<td>1  -</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Corvus sp.</td>
<td>-  7</td>
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<td>1</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Unidentified</td>
<td>582 1117</td>
<td>1699</td>
<td>1783</td>
<td>842</td>
<td>1004</td>
<td>3629</td>
<td></td>
</tr>
<tr>
<td>Total NISP</td>
<td>84 124</td>
<td>208</td>
<td>404</td>
<td>222</td>
<td>231</td>
<td>857</td>
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</tr>
<tr>
<td>Total Specimens</td>
<td>666 1241</td>
<td>1907</td>
<td>2187</td>
<td>1064</td>
<td>1235</td>
<td>4486</td>
<td></td>
</tr>
<tr>
<td>Richness (NTAXA)</td>
<td>12 14</td>
<td>18</td>
<td>18</td>
<td>15</td>
<td>15</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Evenness (1/D)</td>
<td>5.45 3.95</td>
<td>4.26</td>
<td>3.84</td>
<td>4.04</td>
<td>5.12</td>
<td>4.31</td>
<td></td>
</tr>
</tbody>
</table>
There also exists a diachronic shift in taxonomic richness. At SAC-15/H, richness increases from 12 in the Middle Period to 14 later in the MLT/Late Phase 1 period (Table 5.4). Conversely, richness declines from 18 in the Middle Period to 15 in both later periods at SAC-29. This suggests diet-breadth of avian taxa increased at SAC-15/H but decreased at SAC-29. However, this difference is likely a result of the small sample size among temporal periods at SAC-15/H (Middle Period NISP = 84, MLT/Late I NISP = 124) (Table 5.4, Figure 5.1). When temporal units are combined among assemblages to account for sample size effects, the Middle period has a richness of 20, the MLT/Phase 1 period has a richness of 17, and the Late Phase 2 period has a richness of 15, showing a general narrowing of avian diet-breadth over time (Table 5.5).
Table 5.5. Aggregated Taxonomic Counts and Diversity Values by Temporal Period (data from table 5.4).

<table>
<thead>
<tr>
<th>TAXON</th>
<th>Middle</th>
<th>Late 1</th>
<th>Late 2</th>
<th>Total NISP</th>
<th>Middle</th>
<th>Late 1</th>
<th>Late 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anser sp.</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>488</td>
<td>346</td>
<td>231</td>
<td></td>
</tr>
<tr>
<td>Branta sp.</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>346</td>
<td>17</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Anas sp.</td>
<td>6</td>
<td>14</td>
<td>20</td>
<td>231</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aythya sp.</td>
<td>11</td>
<td>3</td>
<td>14</td>
<td>203</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bucephala sp.</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>80</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mergus sp.</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxyura sp.</td>
<td>5</td>
<td>3</td>
<td>8</td>
<td>182</td>
<td>95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podilymbus sp.</td>
<td>12</td>
<td>20</td>
<td>32</td>
<td>342</td>
<td>65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aechmorphorus sp.</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fulica sp.</td>
<td>31</td>
<td>57</td>
<td>88</td>
<td>754</td>
<td>200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TAXON</th>
<th>Middle</th>
<th>Late 1</th>
<th>Late 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTAXA</td>
<td>8</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>1/D</td>
<td>4.33</td>
<td>3.14</td>
<td>3.59</td>
</tr>
</tbody>
</table>

However, a closer inspection of richness reveals that the addition of very rare taxa are driving changes in the richness values. These rare taxa are economically insignificant species, such as passerines and raptors, and are unrelated to the questions of diachronic changes in waterfowl exploitation addressed in this thesis (Table 5.4). When these rare taxa are removed, richness values are identical among sites and temporal periods with no significant relationship with sample size ($r^2 = 0.64, p > 0.10$) (Table 5.6).

Table 5.6. Taxonomic Counts and Diversity Values of Waterfowl Genera Used in Abundance Indices by Temporal Period. Adjusted Residuals of SAC-15/H Totals from $\chi^2$ test: *p < 0.01.

<table>
<thead>
<tr>
<th>TAXON</th>
<th>SAC-15/H</th>
<th>SAC-29</th>
<th>Adj. Res.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anser sp.</td>
<td>-</td>
<td>5</td>
<td>+0.17</td>
</tr>
<tr>
<td>Branta sp.</td>
<td>-</td>
<td>18</td>
<td>-2.38*</td>
</tr>
<tr>
<td>Anas sp.</td>
<td>6</td>
<td>82</td>
<td>-4.59*</td>
</tr>
<tr>
<td>Aythya sp.</td>
<td>11</td>
<td>41</td>
<td>-1.22</td>
</tr>
<tr>
<td>Bucephala sp.</td>
<td>1</td>
<td>-</td>
<td>+0.60</td>
</tr>
<tr>
<td>Mergus sp.</td>
<td>5</td>
<td>13</td>
<td>-1.35</td>
</tr>
<tr>
<td>Oxyura sp.</td>
<td>5</td>
<td>9</td>
<td>+1.58</td>
</tr>
<tr>
<td>Podilymbus sp.</td>
<td>12</td>
<td>5</td>
<td>+10.45*</td>
</tr>
<tr>
<td>Aechmorphorus sp.</td>
<td>3</td>
<td>1</td>
<td>+4.24*</td>
</tr>
<tr>
<td>Fulica sp.</td>
<td>31</td>
<td>182</td>
<td>+0.60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TAXON</th>
<th>SAC-15/H</th>
<th>SAC-29</th>
<th>Adj. Res.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total NISP</td>
<td>74</td>
<td>356</td>
<td>754</td>
</tr>
<tr>
<td>NTAXA</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>1/D</td>
<td>4.33</td>
<td>3.02</td>
<td>3.37</td>
</tr>
</tbody>
</table>
Richness suggests comparable numbers of waterfowl taxa were exploited at both SAC-15/H and SAC-29, but provides no information regarding species abundance. Evenness measures provide a means of examining for trends in the dominance of a particular taxon. The Simpson’s Index (D) was used to calculate evenness. This measure is particularly sensitive to the dominance of a single taxon within an assemblage (Lyman 2008:197). Since Anatidae comprise over 70% of identified avian remains of both SAC-15 and SAC-29, this is the most appropriate measure. The reciprocal of Simpson’s index (1/D) calculates the probability that two specimens drawn from a finite community will belong to the same species. The equation for the reciprocal of Simpson’s index is:

$$D = \sum \left( \frac{n_i(n_i - 1)}{N(N - 1)} \right)$$

Where $n_i$ is the number of specimens of the $i$th taxon, and $N$ is the total number of specimens of all taxa represented (Magurran 1988). The more evenly specimens are distributed across taxa, the larger the value of the index. As 1/D decreases, the more the assemblage is dominated by a single taxon (Lyman 2008:197). The reciprocal of Simpson’s index values were computed using a Microsoft Excel program developed by Jacob L. Fisher, following examples outlined in Lyman (2008:192) and Magurran (1988:145-149).

The avifauna assemblages at both SAC-15/H and SAC-29 have low evenness values and are dominated by waterfowl—particularly ducks, coots, and grebes (Table 5.4). A closer examination of the two waterfowl assemblages reveals a significantly disparate pattern in the frequency of several waterfowl taxa among assemblages ($\chi^2 = 150.10$, $p < 0.01$, df = 9) (Table 5.6). *Fulica americana* are common in both assemblages,
however, grebes, particularly, *Podilymbus podiceps*, are significantly more dominant at SAC-15/H. Similarly, species of *Anas* and *Branta* are significantly more abundant at SAC-29. Evenness varies slightly through time at both sites as well, and the changes in evenness values do not appear to be a result of sample size effects ($r^2 = 0.34$, $p < 0.30$) (Table 5.6). Specifically, there is a significant decrease in diving ducks (*Merus* sp. and *Aythya* sp.) from the Middle to Late Period at SAC-15/H ($\chi^2 = 25.90$, $p < 0.01$, df = 9) (Figure 5.2). Conversely, at SAC-29 there is both a significant increase (*Mergus* sp.) and decrease (*Fulica* sp.) in diving ducks and a decrease in dabbling ducks (*Anas* sp.) over time (Figure 5.3).

![Figure 5.2. %NISP per Waterfowl Genera by Temporal Period, SAC-15/H (data from Table 5.6).](image-url)
In sum, the results of the tests of diversity of the SAC-15/H and SAC-29 avifauna assemblages reveal generally similar taxonomic structuring but significant differences in the abundances of a few genera. The avifaunal assemblages are comparably rich in the number of taxa present—save a few rare birds, such as crows and eagles, which had significant ceremonial use but were of little economic importance—and are dominated by *Anas* sp., *Fulica americana*, and *Podilymbus podiceps*. Several reasons could account for the dominance of these particular taxa. Over 70% of both avifaunal assemblages are represented by anatid remains, but only one genus, *Anas* sp., is dominant at SAC-29 (and to a lesser extent at SAC-15/H). The underrepresentation of anatids in the evenness measures is likely a result of differential identifiability. The difficulty of identifying anatids to genus (and species) is well-known (Grayson 1973; Howard 1929; Woolfenden 1961). Seasonality may have also structured the avifauna assemblages. The dominant

![Bar chart showing %NISP per Waterfowl Genera by Temporal Period, SAC-29 (data from Table 5.6).](image)
taxon among both sites, *Fulica americana*, are resident species and were thus exploitable year-round. Their continued availability may have resulted in their dominance relative to other migratory waterfowl. The abundance of *Podilymbus podiceps* remains at the SAC-15/H (NISP = 32, 17%) compared to the low representation of these at SAC-29 (NISP = 5; 0.6%) may relate to a divergence in local habitat exploitation or the low availability of pied-billed grebes within the foraging radius of SAC-29 (see Figure 5.12). Variation in the abundances of the various diving and dabbling duck species over time may also be a reflection of changes in site seasonality or changes to specific local habitats within foraging radii and are difficult to interpret with the limited regional avifaunal assemblage data presented here. Future research will thus need to incorporate more avifaunal data to fully unravel these fine-grained trends in taxonomic diversity.

These minor differences although interesting to note, do not retract from the ability to use the two sampled avifaunal assemblages to evaluate diachronic changes in relative abundance. Significantly, the statistical tests presented here reveal that patterns in taxonomic composition are not driven by variations in sample size.

**Relative Abundance**

Although a variety of avifauna was identified the following analyses of relative abundance focus on taxa from three families: Anatidae, Rallidae (i.e., *Fulica americana*) and Podicipedidae (Table 5.7). Included in all small waterfowl computations are specimens identified as Podicipedidae and *F. americana*. Although technically within the families of herons and rails, respectively, their remains were commonly identified at both
faunal assemblages. These small to medium duck-sized birds are behaviorally similar to most species of diving duck and are often found foraging in small flocks among ducks in freshwater marsh and riverine environments. Similar to ducks, their small relative body mass makes them a low-ranked waterfowl prey.

Table 5.7. NISP of Large and Small Waterfowl used in Abundance Indices.

<table>
<thead>
<tr>
<th></th>
<th>Large Waterfowl</th>
<th>Small Waterfowl</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anserinae</td>
<td>Anatinae</td>
<td>Podicipedidae</td>
</tr>
<tr>
<td>SAC-15/H</td>
<td>185</td>
<td>398</td>
<td>56</td>
</tr>
<tr>
<td>SAC-29</td>
<td>519</td>
<td>1317</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td>704</td>
<td>1715</td>
<td>80</td>
</tr>
</tbody>
</table>

Two methods are typically used to derive measures of prehistoric resource depression in archaeofaunas: quantitative trends in the relative abundances of profitable prey (typically measured by body size), and demographic indicators of harvest pressure. This study only uses the first method to investigate anthropogenic impacts to waterfowl populations in the Sacramento Valley due to the near absence of identified subadult bones in the sample (Table 5.3).

Changes in the relative abundances of taxa across dated deposits are used to monitor changes in foraging diet and behavior. Specifically, the prey choice model predicts that profitable or high-ranked prey will be preferentially selected over less profitable or low-ranked prey, regardless of the abundance of the latter. As the encounter rates with profitable taxa decrease, due to environmental changes or overhunting by humans, other prey are added to the diet. Therefore, a decrease in the abundance of profitable prey species in dated archaeological deposits should be a measure of the
declines in the encounter rate or density of those species in the surrounding environment (Broughton 1999). Discussed more thoroughly elsewhere (Chapter 2), profitability for this study is correlated with prey body mass; this is supported by empirical data derived from ethnographic and experimental faunal studies. Thus, larger species are more susceptible to resource depression since they are hunted more intensively. For this study, Anserinae are considered more profitable than other anatids (and grebes and coots) and should decline in relative abundance to these other taxa over time. This is exacerbated by the fact that Anserinae can be considered $K$-selected species, as they exhibit longer lifespans, delayed sexual maturity, and produce less offspring than smaller waterfowl species (Table A-2).

A critical aspect not accounted for in the prey-choice model is prey spatial distribution. Instead, a corollary optimal foraging model, the patch-choice model, assumes that prey are distributed evenly in “patches” in the environment and encountered randomly within each patch. Thus, variation in patch use can also dictate prey choice. This study examines differentially ranked prey (waterfowl) in a single resource patch or “hunt type”. In the Sacramento Valley, most duck and goose species are found together in similar environments, predominately the extensive marshy wetlands emanating from the Sacramento-San Joaquin Delta. Although geese also forage in flooded grasslands at wintering sites, and some species of ducks (e.g., mergansers) forage primarily in riverine environments, it is suggested that most of the represented taxa (including grebes and coots) wintering in the area would have been hunted together in freshwater marshland or marsh-border settings. This is further supported by the fact that several of the geese
identified in the sample are *Anser albifrons* (NISP = 14), likely of the subspecies “Tule Goose” (*A. a. gambelli*) which forages almost exclusively in freshwater marshes to graze on various emergent plants, and historically wintered in the Sacramento Valley in abundance (Deuel and Takekawa 2008:75). Thus, according to the prey-choice model, geese are considered a high-ranked prey item due to their large body mass and resource depression should be signaled by declines in their relative abundance within the study samples.

I use a modified form of the goose index developed by Broughton (2004a) to incorporate two additional taxa into the equation (Podicipedidae and *F. americana*). This index was computed by arbitrary level and analytical component for each of the two sites sampled. The modified goose index used is:

\[
\frac{\sum \text{NISP Large Waterfowl}}{\sum \text{Large + Small Waterfowl}}
\]

Where the sum of the NISP of large-sized waterfowl (Anserinae) is divided by the sum of the NISP of all waterfowl. Small-sized waterfowl include species of Anatinae, Podicipedidae, and *Fulica americana*.

At SAC-29 there is a general decline in the goose index at both the arbitrary depth and dated component level, suggesting a decrease in the relative abundance of geese from c. 2500 to 200 BP \( (r^2 = 0.60, p <0.01) \) (Figure 5.4). This is a strong gradual trend and differs somewhat to the one observed at the Emeryville Shellmound assemblage in
nearby San Francisco dated to c. 2600 to 700 BP, which produced a much sharper decline in the goose index over the strata of the site (Figure 2.1).

![Goose Index by level, SAC-29](image)

Figure 5.4. Distribution of the Goose Index by level, SAC-29 (level 1 is the youngest and level 16 is the oldest). The simple best-fit regression line is shown to assist with identifying trends in goose relative abundance.

Since abundance indices are ratio-based measures they do not account for the effects of sample size. The NISP values of geese and ducks vary significantly across the SAC-29 and SAC-15/H unit levels. To control for variations in sample size, a Cochran’s test of linear trends was computed (Cannon 2001; Zar 1996). This non-parametric statistical test weights abundance values by their associated sample size. Chi-square values are divided into two parts, linear trend and departure from the linear trend. The $\chi^2_{trend}$ measures the extent that a sample varies from a linear trend. In this case, a
significant trend represents a significant correlation between relative abundance and time, accounting for sample size. The $\chi^2_{\text{departure}}$ measures the “noise” in the variability of the proportions of the sample. A significant departure indicates that there is something other than a linear correlation causing proportions to vary among samples (Cannon 2001; Zar 1996). All chi-square tests of significance were computed using Michael Cannon’s (2001) Excel macro program (Accessed October 2012: http://home.utah.edu/~u0577421/). Adjusted residuals were computed in the macro Excel program and provide a means of identifying sources of significance across data sets. Adjusted residuals greater in value than 1.96 are considered to be significant at the 95% confidence level.

The Cochran’s test of linear trends reveals a significant linear decline in the goose index across the Middle to Late Periods at SAC-29 (Level: $\chi^2_{\text{trend}} = 19.53$, df = 1, $p < 0.01$; $\chi^2_{\text{departure}} = 9.88$, df = 14, $p < 0.77$); Temporal component: $\chi^2_{\text{trend}} = 16.04$, df = 1, $p < 0.01$; $\chi^2_{\text{departure}} = 0.63$, df = 1, $p < 0.43$). As is evident in Table 5.8, there is an increase in negative adjusted residuals through the depth of the site, where the frequency of geese to that of ducks is less than expected. At the 95% confidence level, the linear trend is driven by relative abundances of only one excavation level per temporal period; multiple excavation levels significant at the 65% confidence level (adjusted residual values larger than 1.00) confirm the same directionality across time (Table 5.8).
Table 5.8. Abundance Indices by Level and Temporal Period, SAC-29. Index= ∑(NISP Anserinae + NISP Anatinae[+Podipedidae+*Fulica americana*]). Adjusted residuals of NISP Goose from $\chi^2$ test: *p < 0.01.

<table>
<thead>
<tr>
<th>Level</th>
<th>NISP Goose</th>
<th>NISP Duck</th>
<th>NISP Total</th>
<th>Index</th>
<th>Adj. Res.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Period, Phase 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>62</td>
<td>72</td>
<td>0.14</td>
<td>-1.97*</td>
</tr>
<tr>
<td>2</td>
<td>14</td>
<td>75</td>
<td>89</td>
<td>0.16</td>
<td>-1.78</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>79</td>
<td>104</td>
<td>0.24</td>
<td>+0.12</td>
</tr>
<tr>
<td>4</td>
<td>31</td>
<td>141</td>
<td>172</td>
<td>0.18</td>
<td>-1.78</td>
</tr>
<tr>
<td>5</td>
<td>26</td>
<td>101</td>
<td>127</td>
<td>0.20</td>
<td>-0.85</td>
</tr>
<tr>
<td>Late Period, Phase 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>17</td>
<td>71</td>
<td>88</td>
<td>0.19</td>
<td>-0.96</td>
</tr>
<tr>
<td>7</td>
<td>39</td>
<td>130</td>
<td>169</td>
<td>0.23</td>
<td>-0.16</td>
</tr>
<tr>
<td>8</td>
<td>14</td>
<td>85</td>
<td>99</td>
<td>0.14</td>
<td>-2.26*</td>
</tr>
<tr>
<td>9</td>
<td>39</td>
<td>124</td>
<td>163</td>
<td>0.24</td>
<td>+0.11</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>22</td>
<td>30</td>
<td>0.27</td>
<td>+0.40</td>
</tr>
<tr>
<td>Middle Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>29</td>
<td>101</td>
<td>130</td>
<td>0.22</td>
<td>-0.35</td>
</tr>
<tr>
<td>12</td>
<td>74</td>
<td>209</td>
<td>283</td>
<td>0.26</td>
<td>+1.09</td>
</tr>
<tr>
<td>13</td>
<td>84</td>
<td>232</td>
<td>316</td>
<td>0.27</td>
<td>+1.36</td>
</tr>
<tr>
<td>14</td>
<td>61</td>
<td>129</td>
<td>190</td>
<td>0.32</td>
<td>+2.90*</td>
</tr>
<tr>
<td>15</td>
<td>36</td>
<td>86</td>
<td>122</td>
<td>0.30</td>
<td>+1.65</td>
</tr>
<tr>
<td>16</td>
<td>12</td>
<td>36</td>
<td>48</td>
<td>0.25</td>
<td>+0.23</td>
</tr>
</tbody>
</table>

A similar pattern is evident in the goose index at SAC-15/H, although there is a fair amount of statistical “noise.” Due to the limited number of waterfowl remains per 10 cm excavation level at SAC-15/H, avifaunal data was aggregated into levels of 20 cm. The last two 10 cm levels (23 and 24) resulted in null values and were excluded from further analyses. There is a steep decline in the goose index from levels 22 to 16 (250 to 190 cmbs) followed by a spike in the goose index at level 8 (100 to 120 cmbs), dating to the MLT ($r^2 = 0.50$, p < 0.02) (Figure 5.5). A closer look at the uncalibrated radiocarbon dates from level 8 shows a discrete reversal in the order of the dates, which go from 530 BP at 120 cmbs to 680 BP at 100 cmbs. This is likely due to an ash dump feature at
this provenience (USACE and SAFCA n.d.). Hence, the statistical noise is likely related to complex feature deposits, not variation in foraging decisions. A Cochran’s test of linear trends confirms that, overall, there is a significant linear decline over the depth of the deposit (Level: $\chi^2_{\text{trend}} = 5.15$, df = 1, $p < 0.02$; $\chi^2_{\text{departure}} = 5.07$, df = 9, $p < 0.82$; Temporal Component: $\chi^2_{\text{trend}} = 6.25$, df = 1, $p < 0.01$). Again, there is an increase in negative adjusted residuals from the Middle to Late Periods, where the frequency of geese to that of ducks is less than expected (Table 5.9).

Figure 5.5. Distribution of the Goose Index by level, SAC-15/H (level 2 is the youngest and level 24 is the oldest). The simple best-fit regression line is shown to assist with identifying trends in goose relative abundance. The last level was excluded from the sample due to null values.
Table 5.9. Abundance Indices by Level and Temporal Period, SAC-15/H. Index = \( \sum (\text{NISP Anserinae} + \text{NISP Anatinae} + \text{NISP Podicipedidae} + \text{NISP F. americana}) \). Adjusted residuals of NISP Goose from \( \chi^2 \) test: \(^*p < 0.01\).

<table>
<thead>
<tr>
<th>Level</th>
<th>NISP Goose</th>
<th>NISP Duck</th>
<th>NISP Total</th>
<th>Index</th>
<th>Adj. Res.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>31</td>
<td>38</td>
<td>0.18</td>
<td>-1.04</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>29</td>
<td>38</td>
<td>0.24</td>
<td>-0.28</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>29</td>
<td>37</td>
<td>0.22</td>
<td>-0.57</td>
</tr>
<tr>
<td>8</td>
<td>13</td>
<td>29</td>
<td>42</td>
<td>0.31</td>
<td>+0.82</td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td>35</td>
<td>44</td>
<td>0.20</td>
<td>-0.81</td>
</tr>
<tr>
<td>12</td>
<td>30</td>
<td>115</td>
<td>145</td>
<td>0.21</td>
<td>-1.51</td>
</tr>
<tr>
<td>14</td>
<td>17</td>
<td>62</td>
<td>79</td>
<td>0.22</td>
<td>-0.88</td>
</tr>
<tr>
<td>Middle Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>12</td>
<td>34</td>
<td>46</td>
<td>0.26</td>
<td>+0.08</td>
</tr>
<tr>
<td>18</td>
<td>23</td>
<td>55</td>
<td>78</td>
<td>0.29</td>
<td>+0.84</td>
</tr>
<tr>
<td>20</td>
<td>30</td>
<td>59</td>
<td>89</td>
<td>0.34</td>
<td>+1.87</td>
</tr>
<tr>
<td>22</td>
<td>27</td>
<td>60</td>
<td>87</td>
<td>0.31</td>
<td>+1.24</td>
</tr>
</tbody>
</table>

The tests of relative abundance suggest profitable, high-return resources of geese declined in relative abundance from the Late to Middle Periods during the occupations of SAC-29 and SAC-15/H. Although a similar trend is apparent in both assemblages, several factors other than harvest pressure could be influencing the data. Taphonomy, significantly bone survivorship, may be differentially impacting the waterfowl assemblages, thereby biasing results. Additionally, climate changes over the Middle to Late Period may have altered waterfowl food availability, restricting encounter rates with profitable waterfowl.

**Skeletal Part Representation and Taphonomy**

Although the sample data suggests a decline in the relative abundance of geese over time at both SAC-29 and SAC-15/H, it is possible that factors other than hunting
pressure could be causing this trend. In particular, taphonomic issues such as differential survivorship may be biasing the assemblage.

**Relative Skeletal Abundance**

Variations in the frequency of represented skeletal parts in an assemblage can be a signal of cultural processing and/or post-depositional taphonomy. Relative skeletal abundance (RSA) was calculated for Anserinae and Anatinae only, excluding Podicipedidae and *Fulica americana* due to the lack of bone density data available for those taxa. Following a similar method as Bovy (2002), I normed NISP (NNISP, %NNISP) values for four avian anatomical portions to examine the ratio of observed to expected goose and duck elements in the assemblages (Table 5.10). The norming of the NISP values corrects for the fact that some of the anatomical portions have more elements than others.

Various hypotheses have been proposed to explain the disproportionate numbers of avian elements at archaeological sites, particularly the high frequency of wing elements commonly noted in avifaunal assemblages (see Bovy 2002 for review). These hypotheses attempt to determine whether skeletal element representation can be attributed to cultural or natural factors. Bovy (2002) found that the preponderance of wing elements (over 90%) at avifauna assemblages at various sites along the Northwest Coast was not a result of density-mediated attrition. Instead, these assemblages appear to be deposited as a result of human processing and consumption techniques, tool manufacture, or scavenging damage (Bovy 2002:976).
Table 5.10. Avian Elements Included in Relative Skeletal Abundance (adapted from Bovy 2002, Figure 2).

<table>
<thead>
<tr>
<th>Portion</th>
<th>Element (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skull/Axial</td>
<td>Skull (1)</td>
</tr>
<tr>
<td></td>
<td>Hemi-mandible (2)</td>
</tr>
<tr>
<td></td>
<td>Hemi-innominate (2)</td>
</tr>
<tr>
<td>Pectoral Girdle</td>
<td>Furcula (1)</td>
</tr>
<tr>
<td></td>
<td>Coracoid (2)</td>
</tr>
<tr>
<td></td>
<td>Scapula (2)</td>
</tr>
<tr>
<td></td>
<td>Sternum (1)</td>
</tr>
<tr>
<td>Wing</td>
<td>Humerus (2)</td>
</tr>
<tr>
<td></td>
<td>Radius (2)</td>
</tr>
<tr>
<td></td>
<td>Ulna (2)</td>
</tr>
<tr>
<td></td>
<td>Carpometacarpus (2)</td>
</tr>
<tr>
<td></td>
<td>Phalanx 1, Digit 2 (2)</td>
</tr>
<tr>
<td></td>
<td>Pollex (2)</td>
</tr>
<tr>
<td>Leg</td>
<td>Femur (2)</td>
</tr>
<tr>
<td></td>
<td>Tibiotarsus (2)</td>
</tr>
<tr>
<td></td>
<td>Tarsometatarsus (2)</td>
</tr>
</tbody>
</table>

In contrast to Bovy’s findings in Northwest Coast avifaunal assemblages, element portions are relatively evenly represented at both SAC-15/H and SAC-29 avifaunal assemblages, except for the pectoral girdle, which is higher in frequency (SAC-15/H: 1/D = 3.42; SAC-29: 1/D = 3.74) (Figures 5.6 and 5.7). This differential distribution of skeletal parts is potentially a result of density-mediated attrition.
Figure 5.6. Relative Skeletal Abundance, SAC-29 (showing the frequency distribution of normed skeletal parts of duck and goose).

Figure 5.7. Relative Skeletal Abundance, SAC-15/H (showing the frequency distribution of normed skeletal parts of duck and goose).
Density Mediated Attrition

Taphonomic processes have the potential to obscure and bias the results and interpretations of an archaeofaunal assemblage. The frequency and type of skeletal elements represented in an archaeofaunal assemblage can inform researchers about various cultural processes, but they may also be a result of post-depositional processes. In particular, revealed patterns in the variation of taxonomic abundances consistent with resource depression could merely be a result of differential preservation altering assemblage composition, not actual behavioral decisions (Fisher 2010; Ugan 2005b). In order to mitigate this, methods to assess for differential survivorship were applied to the sampled avian faunal assemblages.

The survivorship of certain skeletal elements in the archaeological record may be affected by their bone density and exposure time in sediments. It can be argued that older deposits will likely have fewer less-dense specimens compared to more recent deposits.

Unfortunately, the data on density-mediated attrition for birds is limited. Using Broughton and colleagues’ (2007) data on the bone density of elements of duck and goose species (Branta canadensis, Anas acuta, A. sterna, and A. platyrhynchos), the average mean volume-density value (bone mineral content/volume) for skeletal elements was compared statistically to those represented in the assemblage (Table 5.11). Two considerations must be taken into account when reviewing the results: 1) bone density values were derived from scans for entire elements instead of linear scan sites on the densest region of elements (Lam et al. 2003); and 2) the duck specimens examined
exhibit highly variable density values. Regardless, the data provide a baseline to examine trends in the differential element composition of the sampled assemblages.

Table 5.11. Anatid Bone Volume Density Values (adapted from Broughton et al. 2007:382-383). *Average element volume densities of four different species of Anatinae.

<table>
<thead>
<tr>
<th>Element</th>
<th>Volume density</th>
<th>Branta canadensis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anatinae*</td>
<td></td>
</tr>
<tr>
<td>Cranium</td>
<td>0.37</td>
<td>0.24</td>
</tr>
<tr>
<td>Dentary</td>
<td>0.41</td>
<td>0.63</td>
</tr>
<tr>
<td>Sternum</td>
<td>0.20</td>
<td>0.27</td>
</tr>
<tr>
<td>Furculum</td>
<td>0.39</td>
<td>0.46</td>
</tr>
<tr>
<td>Scapula</td>
<td>0.48</td>
<td>0.60</td>
</tr>
<tr>
<td>Coracoid</td>
<td>0.53</td>
<td>0.42</td>
</tr>
<tr>
<td>Humerus</td>
<td>0.52</td>
<td>0.55</td>
</tr>
<tr>
<td>Ulna</td>
<td>0.49</td>
<td>0.48</td>
</tr>
<tr>
<td>Radius</td>
<td>0.34</td>
<td>0.71</td>
</tr>
<tr>
<td>Carpometacarpus</td>
<td>0.57</td>
<td>0.57</td>
</tr>
<tr>
<td>Synsacrum</td>
<td>0.26</td>
<td>0.25</td>
</tr>
<tr>
<td>Femur</td>
<td>0.33</td>
<td>0.38</td>
</tr>
<tr>
<td>Tibiotarsus</td>
<td>0.45</td>
<td>0.52</td>
</tr>
<tr>
<td>Tarsometatarsus</td>
<td>0.31</td>
<td>0.40</td>
</tr>
</tbody>
</table>

A Spearman’s rho correlation test was calculated to compare the ranked frequencies of elements against bone density values for the Middle and Late Periods at both sites. Spearman’s rho is calculated by comparing the relationship of ranks of variables within sample sets. The equation for Spearman’s rho is:

\[ r_s = 1 - \frac{6 \sum D^2}{N^3 - N} \]

Where D is the difference between the rank order values for two variables, and N is the number of samples.
The examination of element density and frequency indicates that bone survivorship is significantly affecting the duck assemblages of both SAC-15/H and SAC-29 but not the goose assemblages (Figures 5.8 – 5.11). Geese element abundance is not influenced by bone density in the Middle Period assemblage (SAC-15/H: $r_s = 0.39$, $p > 0.09$; SAC-29: $r_s = 0.13$, $p = 0.33$) or Late Period assemblage (SAC-15/H: $r_s = 0.28$, $p = 0.17$; SAC-29: $r_s = 0.10$, $p = 0.37$). Conversely, duck assemblages dated to the Middle Period (SAC-15/H: $r_s = 0.74$, $p < 0.01$; SAC-29: $r_s = 0.49$, $p < 0.04$) and Late Period (SAC-15/H: $r_s = 0.78$, $p < 0.01$; SAC-29: $r_s = 0.64$, $p < 0.01$) are impacted by density-mediated attrition.

![Graph](image.png)

Figure 5.8. Relationship between Normed Element NISP and Density, SAC-29 Middle Period.
Figure 5.9. Relationship between Normed Element NISP and Density, SAC-29 Late Period.

Figure 5.10. Relationship between Normed Element NISP and Density, SAC-15/H Middle Period.
In sum, a decline in the relative abundance of geese over the Middle to Late Period is evident at both SAC-15/H and SAC-29, with a more marked trend at SAC-29. The taxonomic composition of both avifaunal assemblages is strikingly similar and diversity measures reveal comparable richness and evenness values. Further, both assemblages have analogous taphonomic patterning, evidenced by the tests of relative skeletal abundance and density mediated attrition.

Evidence of extensive weathering and carnivore attrition were extremely low for both avifaunal assemblages; however, the analysis of density-mediated attrition suggests that duck assemblages are suffering from taphonomic biases. As a result, goose NISP may be underestimated by the goose indices. Broughton and colleagues (2007:383) also noted the influence of bone density on duck assemblages at the Yerba Buena (CA-SFR-114) avifaunal assemblage, but found no significant correlation between duck element

Figure 5.11. Relationship between Normed Element NISP and Density, SAC-15/H Late Period.
densities and site depth. Similarly, bone survivorship is acting comparably on both Middle and Late Period duck assemblages at SAC-15/H and SAC-29, with no differences across time. Consequently, the taphonomic bias is not correlated with diachronic changes in the goose indices and is thus not significantly biasing patterns in resource depression.

Although the prey-choice model used in this study focuses on human-induced resource depression, other factors can cause changes in the natural abundances of bird species. Specifically, climatic change can alter habitat structure creating variation in the encounter rates and availability of profitable waterfowl taxa. The next section reviews the available climate correlates for the time periods in question during the late Holocene (i.e., the Middle to Late Periods). Additional data from studies of resource depression across the immediate region are presented as well.

**Possible Effects of Climate Change**

Prior to significant Euro-American modification to the Sacramento Valley (ca. 100 BP), the local environment was characterized by freshwater wetlands surrounding riverine and lacustrine habitats, flanked by grasslands and woodlands (Whipple et al. 2012:110). Most goose species forage in wetland or grassland habitats and roost in wetlands and open water. As previously discussed, this study assumes goose populations hunted at SAC-15/H and SAC-29 wintered in the extensive shallow wetland habitats immediately surrounding the sites (Figure 5.12).

Wetlands were dominated by marshes filled with tule (*Scirpus* spp.) and other emergent vegetation, important food sources to wintering geese. Changes in the
availability of these foods could account for declines in goose abundances in the archaefanunal record. In addition to the potential effects of changing climate on food availability at wintering sites in the valley, climate change may have also caused dramatic impacts to populations of geese at their Arctic breeding sites in Canada and Alaska. Paleoenvironmental changes in the Sacramento Valley over the late Holocene were discussed in some detail in Chapter 3. The purpose here is to address specific climate trends as they correlate to shifts in waterfowl relative abundance. Could observed trends in resource depression be a result of climate change? A review of documented effects of climate changes to bird populations is followed by an attempt to surmise any major climate-driven events that may account for the changes observed in the archaefanunal record.
Figure 5.12. Historic Habitat Distribution within Foraging Radii, SAC-15/H and SAC-29 (habitat data from Whipple et al. 2012).
The effects of short-term (annual or decadal) and long-term (decades or millennia) climate change on bird behavior, physiology, genetics, ecology, and evolution is a major research objective of biologists and ecologists worldwide (Moller et al. 2010). Most birds migrate between breeding grounds in temperate or Arctic regions and wintering grounds in tropic or subtropical regions (Newton 2008; Saether and Engen 2010:192). Several studies of long-distance migrants have illustrated that climatic variation at wintering grounds, breeding grounds, or during migration have caused substantial changes to the geographic ranges and distribution, population dynamics, and timing of migration and reproduction of bird species (Moller et al. 2010). Specifically, current increased global temperatures have extended northern range limits of many birds (Böhning-Gaese and Lemoine 2004; Root 1988). Warmer temperatures have also resulted in the mismatching of breeding timing and migration and food availability altering egg-laying and hatching dates, and clutch sizes (Both and Visser 2001; Boyd and Madsen 1997; Ludwig et al. 2006; Moss et al. 2001; Root et al. 2003; Visser 2008; Visser et al. 2004, 2009). Similarly, seabirds are particularly susceptible to ENSO climatic events, particularly El Niño warming trends. El Niño events have been directly correlated to seabird breeding failures and major die-offs (Ainley and Boekelheide 1990; Ainley et al. 1988; Bertram et al. 2001; Briggs et al. 1984; Duffy 1993; Duffy et al. 1988; Hedd et al. 2002; Kitaysky and Golubova 2000; Springer et al. 1999).

Fluctuations in temperature change also alter precipitation patterns, which has major consequences for bird populations (Bean 1989). It is well documented that waterfowl populations closely track periods of precipitation (Butler and Taylor
2005:1107). Several biological studies of waterfowl populations in North America and Australia demonstrate that waterfowl, which breed in shallow wetlands, often postpone breeding or move to other regions during years of drought or flood conditions (Batt et al. 1989; Bethke and Nudds 1995; Boyd 1962; Boyd and Madsen 1997; Davies and Cooke 1983; Inkley et al. 2004; Norman and Nichols 1991; Sorenson et al. 1998; Smith 1970; Zockler and Lysenko 2000).

Simons and colleagues’ (2002) study of Bay Area avifaunal assemblages noted the significance of climate changes in shaping relative abundance trends. At Emeryville Shellmound (ALA-309/310) in San Francisco, relative duck abundance was observed to be at its lowest percentage ratio between approximately 1100 and 1300 BP (Simons et al. 2002:12). This time period corresponds with the MCA of prolonged drought conditions, resulting in low saline and nutrient inflow from the Delta and greater Bay Estuary (Ingram 1998). Simons and colleagues (2012:12) suggest diving duck populations were severely impacted by these drought conditions, resulting in population reductions. An observed rebound in cormorant remains during this interval provides support for this conclusion, as it indicates a shift to the intensification of other resource patches during this time (Simons et al. 2002:12). Simons and colleagues (2012:13) also note that geese attain their lowest relative abundance ratios between 350 and 550 years ago, corresponding to a shift to the wetter conditions of the LIA. As noted above, reproductive success of waterfowl is positively correlated with summer temperatures and an increase in wet conditions would have resulted in highly unfavorable conditions at Arctic breeding grounds (Boyd 1962; Boyd and Madsen 1997; Zockler and Lysenko 2000). Increased
moisture during the LIA may have led to delays in the annual breeding cycle of waterfowl, possibly reducing nesting density, clutch size, and hatchlings. Simons and colleagues (2012:13) thus suggest the onset of the LIA likely yielded lower populations of geese during this time, restricting their abundance and availability to prehistoric foragers of the Bay Area.

A review of the paleoclimate record of the Sacramento Valley reveals similar trends in climate change. During the past 2,500 years, climate has shown a gradual trend towards cooling and drying punctuated by droughts and flooding events (Byrne et al. 2001; Goman and Wells 2000; Malamud-Roam et al. 2006, 2007; Meko et al. 2001). Paleobotanical and isotopic data from flood plain and estuary sediments indicate that overall conditions in central California became increasingly arid and saline from ca. 1000 to 800 cal BP, corresponding to the Medieval Climatic Anomaly (Byrne et al. 2001; Malamud-Roam et al. 2006, 2007). Drought conditions reduced freshwater flow and caused marshes to shift to support more salt-tolerant species. After that time, the Little Ice Age (ca. 550-200 cal BP) brought cool and wet conditions, dramatically lowering salinity levels (Byrne et al. 2001; Malamud-Roam et al. 2006, 2007). Based on the available data, it appears that after approximately 800 BP (corresponding roughly to the onset of the Late Period), there were changes in environmental conditions that may correspond with prehistoric dietary changes.

A lack of fine-grained temporal resolution in the faunal samples obviously complicates attempts to correlate faunal changes with shifts in environmental changes. However, some general trends may be useful to examine. Dabbling ducks and geese have
similar diets and feed in shallow waters of freshwater marshlands or forage on grassland vegetation, making them sensitive to flooding. Conversely, diving ducks have diets of mainly fish, insects, and crustaceans, and typically prefer deeper stands of marshland or riverine habitats. These taxa are likely more sensitive to drought conditions, and may potentially flourish in very wet years (e.g., LIA). If environment was changing as suggested, then the availability of diving ducks should be low during the MCA and high during the wetter interval after 800 BP. On the other hand, geese and dabbler availability should reflect a similar response to environmental conditions, with population restrictions after 800 BP, corresponding to wetter, flooded conditions locally.

Results of changes of goose, dabbling duck, and diving duck NISP values before and after 800 BP conflict with the proposed patterns in paleoenvironment (Table 5.12). There appears to be no change in diving duck abundance with the onset of more favorable diving duck conditions after 800 BP. As proposed, geese and dabblers should respond similarly to changes in environment. However, geese occur in lower than expected frequencies during the Late Period and dabblers occur in higher than expected frequencies ($\chi^2 = 12.68$, $p < 0.01$). The fact that their relative abundances do not correlate suggests that climate changes are likely not driving the trends in the data. Further support for this is Broughton’s (2004a:38) examination of paleoclimate data of the San Francisco Bay in which significant linear changes in salinity or precipitation that would have impacted goose wintering or breeding habitats over the late Holocene were not correlated with changes in the avifaunal record.
Table 5.12. NISP of Geese, Dabblers, Divers by Temporal Period (Dabblers = Anas spp.; Divers = Aythya spp. Mergini, Oxyura spp., Podicipedidae, and Fulica americana). NISP values include data from both SAC-15/H and SAC-29. Middle Period adjusted residuals from $\chi^2$.

<table>
<thead>
<tr>
<th></th>
<th>Middle Period</th>
<th>Late Period</th>
<th>Adj. Res.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geese</td>
<td>388</td>
<td>316</td>
<td>-2.90</td>
</tr>
<tr>
<td>Dabblers</td>
<td>115</td>
<td>155</td>
<td>+3.00</td>
</tr>
<tr>
<td>Divers</td>
<td>349</td>
<td>349</td>
<td>+0.66</td>
</tr>
</tbody>
</table>

Discussion

The prey-choice model employed to test for resource depression assumes that all waterfowl will be hunted in a fine-grained matter within a single patch (freshwater marsh). Resource depression should thus be signaled by a decline in the frequency of profitable (goose) waterfowl taxa over time. Results show a decline in the relative abundance of geese to that of ducks over the Middle to Late Periods at both SAC-15/H and SAC-29, with the strongest trend evident at SAC-29. The taxonomic composition of both avifaunal assemblages is very similar and the two samples have comparable richness and evenness values (although significant differences exist in the frequency of some waterfowl genera). This suggests that prehistoric occupants at both sites were foraging for comparable avian resources overall. Both assemblages have analogous taphonomic patterning as is evidenced by the tests of relative skeletal abundance and density mediated attrition. Bone survivorship is comparatively low in duck assemblages at both sites and across the depth of each site; however, there are no significant differences in survivorship across time.

A climate explanation for the declines in relative goose abundance is not well supported by the paleoclimate data and changes in the frequency of waterfowl that prefer
differing environmental conditions. Additional research (Broughton 2004a) of waterfowl exploitation in the San Francisco Bay during a similar time interval has also shown no correlation between diachronic changes in waterfowl abundances and climate change.

Other recent studies have shown the impacts of technological changes on diet, particularly the introduction of the bow and arrow to the region around 1100 to 700 cal BP (Wake 2012; Zelazo 2013). Although waterfowl were hunted using various methods ethnographically (see Chapter 3), including bow and arrow, the vast majority of evidence supports the use of netting technology as the most effective procurement method.

Evidence for the use of nets extends to the Middle Period in the region. Although netting was not used exclusively and the bow and arrow may have aided the hunting of waterfowl in some instances, this is unlikely to cause major changes in taxonomic abundance, particularly since ducks and geese were hunted similarly.

There is little doubt that human overhunting played a role in shaping late prehistoric diet in central California. In fact, most applications of foraging theory to studies of resource depression have detected, to at least some degree, prehistoric harvest pressures on prey populations (Grayson 2001). Broughton (1999, 2004a) provides strong evidence for the decline in profitable avian prey through his study of Emeryville avifaunas. The declines in geese relative to ducks are striking, and he provides robust evidence to support his hypothesis of avian depression with the examination of prey age structures and bone part representation of cormorant remains (Broughton 2004a:39-41).

Unfortunately, it was not possible to assess demographic structure for the current study, which obviates possible supportive evidence for human overhunting. However,
based on the trends examined in this study and regional comparisons of avifaunas, mammals, and fish resources, it seems extremely likely that human harvesting played a significant role in dietary changes at SAC-15/H and SAC-29.
Analyses of faunal assemblages from archaeological sites across California document clear evidence of long-term resource depression in terrestrial and sea mammals, colonial nesting birds, shellfish, and fish resources. However, there has been limited research on prehistoric anthropogenic impacts to waterfowl populations regionally. Broughton’s (2004a) analysis of avian depression at the Emeryville Shellmound in San Francisco is used as a model to examine diachronic trends in the prehistoric exploitation of migratory waterfowl in the lower Sacramento Valley.

Tests of avian depression included abundance indices derived from the prey choice model. The prey-choice model employed assumed that all waterfowl were hunted in a fine-grained matter within a single patch (freshwater marsh) and were procured en masse with netting technology. Resource depression should thus be signaled by a decline in the frequency of profitable waterfowl taxa over time. Prey body mass is used as a proxy measure of profitability or prey-rank. Abundance indices measured the abundance of large waterfowl (geese) remains relative to small waterfowl (ducks) remains over the Middle and Late Periods (ca. 2500 – 200 BP) at two sites, SAC-15/H and SAC-29, located in similar habitats along the Sacramento River. The taxonomic composition, taphonomy, and paleoclimatic context of these assemblages were reviewed in order to
provide clarification on observed trends in relative abundance and evidence for avian resource depression.

Results reveal waterfowl were an important resource to prehistoric populations living in the lower Sacramento Valley. Measures of taxonomic diversity suggest foragers focused their exploitation efforts on a variety of similar, economically significant waterfowl and waterbird taxa at both SAC-15/H and SAC-29. In particular, geese, diving and dabbling ducks, coots, and grebes were favored bird resources. Limited abundances of terrestrial taxa were recovered and likely relate to ceremonial use (e.g., clothing and tools).

The abundance indices show a decline in the frequency of geese to ducks over the Middle to Late Periods at both SAC-15/H and SAC-29. These results are highly suggestive of resource depression. An examination of taphonomy further supports the abundance indice results. Although duck assemblages appear to be suffering from taphonomic biases, no diachronic changes affecting goose indices were noted.

A review of the biological literature has shown that significant climatic changes can have dramatic impacts to migratory waterfowl population. Other researchers (Simons et al. 2002), have interpreted diachronic changes in avian abundances as a result of long-term environmental changes. However, a climate explanation for the declines in relative goose abundance at SAC-15/H and SAC-29 is not well supported by the paleoclimate data. Limited fine-grained temporal resolution in the faunal samples made correlations in faunal changes with shifts in environmental conditions difficult. General trends in drought (e.g., MCA) and flood intervals (e.g., LIA) were not correlated to changes in the
preferred waterfowl habitats among diving ducks, dabbling ducks, and geese. This study also rules out changes in technology as a possible causal factor for the observed trends in avian depression. Waterfowl were most effectively hunted en masse with nets and evidence for nets is present throughout both the Middle and Late Periods.

Although it is assumed exploitation depression is most responsible for these observed trends, behavioral and/or micro-habitat depression may have also played a major role. Behavioral and micro-habitat depression have been noted as a causal factor in the appearance of similar trends in resource depression of prey faunas elsewhere (Bovy 2007b; Hildebrandt and Jones 1992, 2002; Whitaker 2010). However, behavioral/micro-habitat depression is unlikely to have resulted in changes to waterfowl availability in the lower Sacramento Valley since these behaviors are most typified of breeders, in which birds become highly sensitive to predation on young. All goose species present in the Sacramento Valley are winter migrants, and would thus not enact the same defensive mechanisms observed at their Arctic breeding grounds.

This research has furthered our understanding of waterfowl exploitation within the economy of prehistoric peoples of the lower Sacramento Valley. Results and interpretations derived from this study add to the relative dearth of data related to trends in past subsistence strategies of the lower Sacramento Valley. Additionally, the examination of prey-choice variation within a single prey patch/hunt type, of prey with similar escape behaviors, micro-habitats, and seasonal patterns, represents a robust application of the resource depression model. Lastly, this research provides data on prehistoric human impacts to migratory waterfowl, which has far-reaching applications to
other studies archaeological and non-archaeological (e.g., wildlife management policies and practices).
APPENDIX A: DESCRIPTIVE SUMMARY
DESCRIPTIVE SUMMARY

The descriptive summary below provides a list of the taxa and elements represented in the sampled assemblages and the criteria used to identify them. Modern range distributions, habitats, pertinent archaeological information, and clarification of particular identification procedures, when necessary, are also discussed. Avifauna life histories and distribution and range data are summarized from the Birds of North America Online, which builds on the initial 18-volume printed series, The Birds of North America (Poole 2002). The Birds of North America, a joint collaboration between the American Ornithologists’ Union, the Cornell Laboratory of Ornithology, and the Academy of Natural Sciences, provides detailed scientific and life history information for all 716 species of breeding birds in North America. Additional resources consulted, include Baldassarre and Bolen (1994), Bellrose (1980), and the Sacramento Audubon Society (2011). Taxonomic names follow the most recent version of the American Ornithologists’ Union check-list and its supplements (54th supplement published 2013; original publication 1998).

Identification Protocol

Faunal samples from SAC-15/H and SAC-29 were analyzed by the author following the same identification protocol. All avian bone was counted and sorted into generic identifiable and unidentifiable categories. The identifiable fauna were further identified to skeletal element (portion and side) and the lowest taxonomic level possible.
given the condition, available reference material, and skill of the analyst. Identifications beyond class level were not attempted for ribs, vertebrae, cuneiforms, scapholunars, and quadrates. Specimens that could not be assigned to element were excluded from further analyses.

In addition to the typical method of recording element portion (proximal, distal, proximal shaft, etc.), portion was recorded using the bone zone recording method provided by Cohen and Serjeantson (1996:109-112). Faunal remains that could be identified to element but not taxon were size-sorted. Size determinations were based on average modern bird weight information from Birds of North American Online (Accessed September 2011, http://bna.birds.cornell.edu/), and follow similar categories identified in Serjeantson (2009). Further size class determinations were made for those specimens assigned to the family Anatidae (Table A-1).
Table A-1. Bird Size Categories (weight data from Poole 2002).

<table>
<thead>
<tr>
<th>Size Class</th>
<th>General Avian Weight (g)</th>
<th>Birds</th>
<th>Duck Weight (g)</th>
<th>Birds</th>
<th>Goose Weight (g)</th>
<th>Birds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very small</td>
<td>&lt;150</td>
<td>Passerines, Northern Flicker, Virginia Rail</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>150-600</td>
<td>Ducks (small), Snowy Egret, American Coot</td>
<td>300-600</td>
<td>Teals, Bufflehead, Ruddy Duck</td>
<td>1500-2200</td>
<td>Ross's Goose, Brant, Cackling Goose</td>
</tr>
<tr>
<td>Medium</td>
<td>600-1000</td>
<td>Ducks (medium-large), Gulls, Common Raven</td>
<td>600-900</td>
<td>Hooded Merganser, Gadwall, Northern Shoveler</td>
<td>2200-3500</td>
<td>Greater White-fronted Goose, Snow Goose</td>
</tr>
<tr>
<td>Large</td>
<td>1000-5000</td>
<td>Geese, Great Blue Heron, Turkey Vulture</td>
<td>900-1500</td>
<td>Mallard, Canvasback, Common Merganser</td>
<td>3500-4500</td>
<td>Canada Goose</td>
</tr>
<tr>
<td>Very Large</td>
<td>&gt;5000</td>
<td>Tundra Swan, Sandhill Crane, California Condor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Those specimens that strongly resembled a particular genus or species but could not positively be identified as such are noted as “cf.”, or compares favorably with the taxonomic assignment in question. Identifications were made using the comparative collections of the Anthropology and Biology departments housed at California State University, Sacramento. The collection(s) of over 300 avifauna reference specimens contains multiple specimens of almost every taxon needed for the study. Several reference materials were also consulted to aid in the identification process in addition to the examination of multiple specimens per taxon. Specifically, I used diagnostic criteria found in Bovy (2005), Broughton (2004a), Cohen and Serjeantson (1996), Gilbert et al. (1996), Howard (1929), Jangala (2004), Livezey (1996a), Livingston (1988), Oates et al. (2003), and Olsen (1979). Specific identification criteria used to distinguish particular genera and species outside of these references are noted below. Anatomical terminology follows Howard (1929) and Serjeantson (2009).

Age at death was recorded for all elements analyzed; age categories recorded include adult, sub-adult, or juvenile. Juvenile specimens are very porous, small in size, and lack cortical bone. Sub-adult specimens are full-size, fused, and only slightly porous. Adult bones exhibited complete ossification. When present, modifications were recorded for each specimen. Types of cultural and non-cultural modifications recorded include: processing marks, degree of thermal alteration, animal gnaw marks, fracturing, and weathering (following Behrensmeyer 1978). These data are available in the accompanying Microsoft Excel analysis databases (see Appendix B).
**Taxonomic Summary**

**CLASS AVES—BIRDS**

**Material**

CA-SAC-15/H: 138 specimens of mostly unidentifiable elements.

CA-SAC-29: 394 specimens of mostly unidentifiable elements.

**Remarks**

These specimens are elements or portions of elements that lack distinguishable morphological features and could not be identified beyond Class level and were too fragmentary to assign size.

Aves—very small

**Material**

CA-SAC-15/H: 3 carpometacarpi, 2 humeri, 1 ulna, 1 tibiotarsus, 1 tarsometatarsus, 1 second digit (first phalanx), and 1 indeterminate long bone shaft: 10 specimens.

CA-SAC-29: 1 cranium, 1 pelvis, 1 sternum, 1 scapula, 1 coracoid, 2 humeri, 8 ulnae, 1 second digit (first phalanx), 1 femur, 2 tibiotarsi, 3 tarsometatarsi, and 2 indeterminate long bone shafts: 24 specimens.

**Remarks**

These specimens are elements or portions of elements that lack distinguishable morphological features and could not be identified beyond Class level. These specimens represent avifauna that weigh less than 150 grams, and are very likely passerine birds.

Aves—small
Material

CA-SAC-15/H: 277 specimens representing all Aves elements.
CA-SAC-29: 391 specimens representing all Aves elements.

Remarks

These specimens are elements or portions of elements that lack distinguishable morphological features and could not be identified beyond Class level. These specimens represent avifauna that weigh between 150 to 600 grams, and are similar in size to a small duck (e.g., *Bucephala albeola*) or rail (e.g., *Fulica americana*).

Aves—medium

Material:

CA-SAC-15/H: 508 specimens representing all Aves elements.
CA-SAC-29: 747 specimens representing all Aves elements.

Remarks

These specimens are elements or portions of elements that lack distinguishable morphological features and could not be identified beyond Class level. These specimens represent avifauna that weigh between 600 to 1,000 grams, and are similar in size to medium to large duck, *Larus* spp. (gulls), and *Corvus corax* (common raven).

Aves—large

Material

CA-SAC-15/H: 183 specimens representing all Aves elements.
CA-SAC-29: 500 specimens representing all Aves elements.

Remarks

These specimens are elements or portions of elements that lack distinguishable morphological features and could not be identified beyond Class level. These specimens represent avifauna that weigh between 1,000 to 5,000 grams, and are similar in size to medium to large geese or a large heron (e.g., *Ardea herodias*).

Aves—very large

Material

CA-SAC-15/H: 3 cervical vertebrae, 1 third digit (first phalanx): 4 specimens.

CA-SAC-29: 2 mandibles, 1 pelvis, 1 cervical vertebra, 1 scapula, 3 humeri, 3 ulnae, 3 carpometacarpi, 1 cuneiform, 2 second digits (first phalanges), 1 third wing digit, 1 pollex, 2 fibulae, 1 tibiotarsus, 1 phalanx, 1 hallux: 24 specimens

Remarks

These specimens are elements or portions of elements that lack distinguishable morphological features and could not be identified beyond Class level. These specimens represent avifauna that weigh greater than 5,000 grams. Due to their size, morphology, and species presence in the Sacramento Valley region, these specimens are likely either *Cygnus columbianus* (tundra swan) or *Grus canadensis* (sandhill crane).

Order Anseriformes—Swans, Geese, Ducks

Family Anatidae—Geese, Ducks
Material

CA-SAC-29: 1 cranium, 1 tympani syringeal, 2 synsacra, 1 pelvis, 2 sterna, 1 furculum, 1 ulna, 2 tarsometatarsi: 11 specimens.

Remarks

These specimens are from a species of small goose or large duck. Due to fragmentation, more detailed taxonomic identification was not possible. The tympani syringeal may be from a small species of *Branta*, based on criteria provided by Livezey (1996a:443); however, due to limited reference material and similar morphology among Anatid trachea, no attempt was made to identify this element beyond family.

Subfamily Anserinae—Swans and Geese

Tribe Anserini—Geese

Material

CA-SAC-15/H: 10 mandibles, 2 synsacra, 2 pelves, 11 sterna, 9 furcula, 21 coracoids, 11 scapulae, 21 humeri, 11 ulnae, 8 radii, 15 carpometacarpi, 17 second digits (16 first phalanges, 1 second phalanx), 12 pollices, 3 femora, 13 tibiotarsi, 1 phalanx: 167 specimens (57 small, 76 medium, 34 indeterminate-sized).

CA-SAC-29: 3 crania, 12 mandibles, 2 pelves, 25 synsacra, 17 sterna, 51 coracoids, 37 scapulae, 21 furcula, 44 humeri, 19 ulnae, 26 radii, 33 carpometacarpi, 41 second digits (39 first phalanges, 2 second phalanges), 1 third digit, 40 pollices, 3 femora, 19
Remarks

There are five species of geese that are common to the Sacramento Valley: *Anser albifrons* (Greater white-fronted goose), *Chen caerulescens* (snow goose), *C. rossii* (Ross’s goose), *Branta hutchinsii* (cackling goose), and *B. canadensis* (Canada goose).

Geese are predominately present in the region during the winter months (mid-September to mid-April).

Geese are surface feeders and ground foragers and consume a variety of grains, seeds, grasses, succulents, forbes, sedges and other aquatic vegetation, in freshwater marshes and flooded grasslands. In water, they feed by “tipping up” and submerging their head and neck to graze on aquatic plants and seeds near the surface. On land, they feed by grazing on grasses. They molt and brood near open water in stands of vegetation and rarely overnight on dry shores. Geese are strong flyers and flush vertically from land or water when startled and are able to gain altitude quickly. They are also capable of diving if provoked. Geese are strong walkers and can run readily in terrestrial habitats. Most adult species weigh between 2,000 to 4,000 grams and average life span ranges from 15 to 25 years. They typically lay one brood per year with a clutch-size ranging from two to five chicks (Bellrose 1980; Ely and Dzubin 1994; Mowbray et al. 2000, 2002; Ryder and Alisauskas 1994).

Identifications beyond tribe were not attempted for the majority of Anserinae elements, save the cranium, furcula, and sterna, due to a dearth of diagnostic osteological
characters. All elements were thus sorted by size and sizes of identified specimens are noted within the material description (see Table A-1 for size categories). Specimens small in size are similar to *C. rossii* and *B. hutchinsii* and medium-sized specimens are likely *C. caerulescens* or *A. albifrons*. Those Anserinae elements that were significantly larger in size were assigned to cf. *Branta canadensis*, a similar approach taken by others (Broughton 2004a; Livezey 1996a; Livingston 1988; Woolfenden 1961). Although no Ross’s or snow goose specimens were identified in the assemblages, it is likely that many of the small and medium-sized unidentified specimens are these taxa. These species are both very abundant in the valley during the winter months, and Ross’s goose historically wintered exclusively in the Sacramento Valley (Madge and Burn 1988:144). Population estimates of snow geese wintering in the Sacramento Valley are upwards of 330,000 in 1980 (Bellrose 1980:119,132).

cf. Anserini—Geese

Material

CA-SAC-15/H: 1 cranium, 2 pelves, 1 sternum, 1 ulna, 1 radius, 1 tarsometatarsus, 4 phalanges: 11 specimens (5 medium, 8 indeterminate-sized).

CA-SAC-29: 1 cranium, 1 synsacrum, 3 sterna, 1 scapula, 2 humeri: 8 specimens (3 small, 1 medium, 4 indeterminate-sized).

Remarks

These elements resemble goose bones but were too fragmentary to identify.

*Anser albifrons*—Greater White-fronted Goose
Material

CA-SAC-15/H: 1 mandible, 1 sternum, 1 furcula: 3 specimens.

CA-SAC-29: 1 maxilla, 9 mandibles, 1 furcula: 11 specimens.

Remarks

There are two subspecies of *Anser albifrons* that are common and abundant winter and migrant visitors to the Sacramento Valley, *A. albifrons gambelli* (Pacific Greater white-fronted goose) and *A. albifrons frontalis* (Tule Greater white-fronted goose). *A. albifrons frontalis* are smaller in size than the other subspecies and winter with large flocks of *A. albifrons gambelli* in central California. Tule geese are more cautious behaviorally than the Pacific subspecies and clutch size ranges from one to five chicks (Ely and Dzubin 1994). Tule geese have a larger bill and feet and longer neck than the Pacific subspecies, making them well-adapted to foraging in deep marshes for roots and shoots of emergent vegetation such as, bulrush (*Scirpus* spp.) and cattails (*Typha* spp.). Due to the loss of historic wetlands, modern populations have adapted to foraging in agricultural fields and also feed on seeds of rice, water grass, and barley (Deuel and Takekawa 2008:76). Modern population estimates are very low at 5,000 to 10,000 individuals and wintering ranges are small; they only winter in three discrete locations in central California—in the Suisan marsh, the Sacramento National Wildlife Refuge in Winters, and Butte Creek Basin near Marysville. Historical accounts suggest this species had a larger population and range in the past (Bellrose 1980:110-111; Deuel and Takekawa 2008:75-76).
No attempt was made to distinguish these subspecies skeletally. The manubrial spine of the sternum, which is a peg-like shape, was used to identify the sternum specimen following criteria outlined by Woolfenden (1961:38-39). The occurrence and position of pneumatic foramina were used to distinguish the furcula specimens following Gotfresden (2002:185-186). The mandible of *Anser* is more slender than that of *Chen* and more robust than *Branta* and exhibits a pronounced ventral curvature (Broughton 2004a:18; Livezey 1996a:440,448).

*Branta cf. bernicla or cf. hutchinsii*—Brant or Cackling Goose

**Material:**
CA-SAC-15/H: 2 furcula: 2 specimens
CA-SAC-29: 1 sternum: 1 specimen.

**Remarks**

The manubrial spine of the sternum was used to identify the sternum specimen following criteria outlined by Woolfenden (1961:38-39, 61). The manubrial spine is spatulate and dorso-ventrally elongate, a characteristic of *Branta* sp. Given the small size of the specimen, this most likely represents *B. bernicla or hutchinsii*. The occurrence and position of pneumatic foramina were used to distinguish the furcula specimens following Gotfresden (2002:185-186) are assigned to *B. bernicla or B. hutchinsii* based on their small size. Since Brant geese winter on coastal bays and estuaries and are thus only an occasional or accidental winter visitor inland, these specimens are most likely *B. hutchinsii*. 
Until relatively recently, the *B. hutchinsii* was considered to be the same species or a subspecies of *B. canadensis* (American Ornithologists’ Union 2004). The cackling goose is considerably smaller than Canada goose, weighing an average 2.2 kilograms. Historically, nearly 98 percent of the 135,000 Pacific flyway cackling geese were reported to winter in the Central Valley of California (Bellrose 1980:154). The Pacific flyway population now spends its winters primarily in the Willamette Valley, Oregon (Jarvis and Bromley 1998). Cackling geese winter in freshwater marshes, lakes, and rivers and primarily graze and forage on a variety of native grasses and forbs, in large, dense flocks (Mowbray et al. 2002).

*Branta canadensis*—Canada Goose

**Material**

CA-SAC-15/H: 1 coracoid, 1 furcula: 2 specimens.

CA-SAC-29: 1 mandible, 5 sterna, 3 furcula: 9 specimens.

**Remarks**

*B. canadensis* is one of the most proliferate geese in the country, with current population estimates of three to four million. They are also one of the most well-studied waterfowl species. There are 11 subspecies of *B. canadensis*. The subspecies that migrates to the Central Valley of California is *B. canadensis moffitti*. This subspecies breeds in Alaska and migrates south to the interior of Washington, northeast Oregon, and the Central Valley of California. Population estimates of this group are around 250,000 birds in 1980, and are only common in the valley during the winter months (Bellrose 1980:153). Canada geese are primarily ground foragers and prefer to consume grasses,
seeds, rushes, and cattails, but also feed by dabbling in shallow waters of marshes, lakes, and rivers. Their ability to adapt to modern agricultural development and feed on grains and cereal foods has significantly increased their population (Bellrose 1980:164).

The posterior mandible is distinguished from similarly-sized species of *A. albifrons* and *C. caerulescens* using criteria in Broughton (2004a:18-19). The manubrial spine of the sternum was used to identify the sternum specimen following criteria outlined by Woolfenden (1961:38-39, 61). The occurrence and position of pneumatic foramina in the furcula were used to distinguish the furcula specimens following Gotfresden (2002:185-186).

*cf. Branta canadensis*—Canada Goose

**Material:**

CA-SAC-29: 1 mandible, 5 sterna, 1 synsacrum, 3 furcula, 3 coracoids, 5 scapulae, 8 humeri, 6 ulnae, 2 radii, 5 carpometacarpi, 5 second digits (first phalanges), 1 third digit, 2 tibiotarsi, 3 tarsometatarsi: 41 specimens.

**Remarks**

These specimens are significantly larger in size than other goose specimens in the assemblages and are likely Canada goose.

Subfamily Anatinae—Ducks

**Material**
CA-SAC-15/H: 5 crania, 9 mandibles, 3 synsacra, 6 pelves, 2 sterna, 16 furcula, 42 coracoids, 30 scapulae, 13 humeri, 40 ulnae, 28 radii, 29 carpometacarpi, 21 second digits (first phalanx), 10 pollices, 2 femora, 28 tibiotarsi, 7 tarsometatarsi, 11 phalanges: 302 specimens (132 large, 60 medium, 53 small, 57 indeterminate-sized).

CA-SAC-29: 9 crania, 45 mandibles, 13 synsacra, 2 pelves, 23 sterna, 66 furcula, 116 coracoids, 104 scapulae, 36 humeri, 102 ulnae, 91 radii, 91 second digits (first phalanges), 79 carpometacarpi, 27 pollices, 9 femora, 23 tarsometatarsi, 82 tibiotarsi, 26 phalanges: 944 specimens (210 small, 170 medium, 340 large, 224 indeterminate-sized).

Remarks

There are 19 species of resident and migratory ducks found in the Sacramento Valley. These are broadly grouped as dabblers or divers, based on their diet and feeding strategies. Dabbling ducks include the tribe Anatini, and diving ducks include the tribes, Aythyini, Mergini, and Oxyurini. Dabblers feed in shallow waters of marshes, ponds, lakes, rivers, and streams by obtaining food by grazing on aquatic plants and seeds at or near the surface. Divers feed in deeper waters of bays, estuaries, lakes, sloughs, ponds, and marshes, where they feed on a variety of resources, including aquatic plants, seeds, invertebrates, algae, and small fish. Relative to geese, ducks have a higher fecundity rate with a one-year period to maturity and large clutch-size, ranging from 6 to 14 eggs on average. The average lifespan of a duck is between five and 15 years in the wild, and they typically weigh between 300 grams to 1,500 grams (Austin and Miller 1995; Austin et al. 1998; Bellrose 1980; Drilling et al. 2002; Mallory and Metz 1999).
Post-cranial duck elements are notoriously difficult, or impossible, to identify beyond the subfamily level (Grayson 1973; Howard 1929; Woolfenden 1961). There are qualitative structural differences between the various tribes (and to an extent genera) of ducks permitting most elements to be identified to a considerable degree of confidence at this level. I used a set of comprehensive osteological criteria derived from several sources to distinguish duck taxa. These sources include: Bovy (2005), Broughton (2004a), Howard (1929), Jangala (2004), Livezey (1991, 1995, 1996a, 1996b), Livingston (1988), Oates et al. (2003), and Woolfenden (1961).

Due to the difficulty of accurate identification, no attempt was made to identify specimens at the species-level except for Oxyura jamaicensis (ruddy duck) and Bucephala albeola (bufflehead), due to their distinctive morphology and size (Livingston 1988:303; Woolfenden 1961). I also identified specimens as Anas platyrhynchos (mallard) based on their substantially larger size relative to other Anas spp. (Jangala 2004:196). Specimens identified to Mergus merganser (common merganser) were differentiated from other Mergini species with a moderate degree of confidence based on their relative large size and diagnostic criteria detailed by Broughton (2004a:23) and Woolfenden (1961).

The carpals, wing digits, and foot phalanges were not identified beyond the subfamily level, but were assigned to a size class. The sizes of the identified specimens are noted within the material description (see Table A-1 for size categories). Small ducks that are present in the Sacramento Valley, include: Anas cynapotera (cinnamon teal), A. crecca (green-winged teal), B. albeola, and O. jamaicensis. Medium species present in
the region, include: *Anas strepera* (gadwall), *A. americana* (American wigeon), *A. acuta* (northern pintail), *A. clypeata* (Northern shoveler), *Aythya affinis* (lesser scaup), *A. collaris* (ring-necked duck), *Aix sponsa* (wood duck), *Bucephala islandica* (Barrow’s goldeneye), *B. clangula* (common goldeneye), *M. serrator* (red-breasted merganser), and *Lophodytes cucullatus* (hooded merganser). Large ducks present in the region, include: *Anas platyrhynchos*, *Aythya valisineria* (canvasback), *A. americana* (redhead), and *M. merganser*.

All taxa are winter migrants except mallard, cinnamon teal (*A. cyanoptera*), gadwall, northern shoveler (*A. clypeata*), ruddy duck (*Oxyura jamaicensis*), wood duck (*Aix sponsa*), and common merganser, which are either year-round residents or breed in the valley during the summer season (Jangala 2004:18). The most common and abundant species to the region include, mallard, northern pintail, northern shoveler, and American wigeon (Bellrose 1980).

cf. Anatinae—Ducks

**Material**

CA-SAC-15/H: 1 furcula, 1 coracoid, 2 humeri, 2 ulnae, 1 tibiotarsus, 1 fibula: 8 specimens (5 large, 3 indeterminate-sized).

CA-SAC-29: 1 humerus, 1 ulna, 1 tibiotarsus, 1 tarsometatarsus: 4 specimens (3 small, 1 large-sized).

**Remarks**
These specimens closely resemble ducks but were too fragmentary to confidently identify as such.

Tribe Anatini—Dabbling Ducks

Material
CA-SAC-15/H: 1 pelvis, 2 synsacra, 4 furcula, 4 coracoids, 5 humeri, 8 carpometacarpi: 24 specimens.
CA-SAC-29: 5 mandibles, 1 sternum, 1 synsacrum, 1 furculum, 3 coracoids, 1 humerus, 11 carpometacarpi: 23 specimens.

Remarks
Dabbling ducks include the genera Anas and Aix, representing a total of eight species common to the region. Four species of Anas are year-round residents, and the other three species are winter migrants. Aix sponsa (wood duck) is the only species in the genera Aix, and is also a year-round resident to the region. Wood ducks prefer open water with heavy vegetation cover and are mostly found in riverine and riparian habitats, as they nest in trees near water (Hepp and Bellrose 1995). Other dabblers are commonly found in various habitats throughout the Sacramento Valley feeding in shallow waters of marshes, ponds, lakes, rivers, and streams.

These specimens could not be confidently differentiated from Aix sponsa.

Anas sp.

Material
CA-SAC-15/H: 1 sternum, 1 pelvis, 1 synsacrum, 4 coracoids, 1 scapula, 3 humeri, 2 carpometacarpi, 1 tibiotarsus: 14 specimens (4 medium, 10 large-sized).

CA-SAC-29: 1 mandible, 3 synsacra, 21 sterna, 2 furcula, 37 coracoids, 37 humeri, 33 carpometacarpi, 2 femora, 13 tarsometatarsi, 15 tibiotarsi: 164 specimens (86 large, 36 medium, and 42 small-sized).

**Remarks**

Most species within the genus *Anas* are year-round residents to the Sacramento Valley. Mallards are permanent residents and are the most abundant breeding duck to the region (Bellrose 1980:232). The cinnamon teal and northern shoveler are also an abundant breeding species and winter in the Sacramento Valley as well.

*Anas* elements were differentiated from those of the other anatinae genera based on morphological and metric criteria detailed in Broughton (2004a:19-20), Jangala (2004:150-154), Livezey (1991), Livingston (1988), Oates et al. (2003), and Woolfenden (1961). The small-sized specimens identified as *Anas* are teals, either *A. cynapota* or *A. crecca*. The medium-sized specimens include all other species common to the Valley, except mallard.

*Anas platyrhynchos*—Mallard

**Material**

CA-SAC-15/H: 2 coracoids, 1 humerus, 3 carpometacarpi: 6 specimens.

CA-SAC-29: 1 cranium, 4 mandibles, 1 synsacrum, 4 sterna, 4 furcula, 5 coracoids, 8 humeri, 6 carpometacarpi, 3 tarsometatarsi, 3 tibiotarsi: 39 specimens.
Remarks

Mallard elements are significantly larger than other *Anas* elements and were identified based on size difference alone.

Tribe Aythyini—Diving Ducks

*Aythya* sp.

Material

CA-SAC-15/H: 2 sterna, 1 synsacrum, 2 coracoids, 2 scapulae, 2 humeri, 2 carpometacarpi, 3 tarsometatarsi: 14 specimens (1 small, 5 medium-sized)

CA-SAC-29: 6 mandibles, 3 sterna, 6 synsacra, 1 furculum, 18 coracoids, 18 humeri, 11 carpometacarpi, 9 tarsometatarsi, 8 tibiotarsi: 80 specimens (12 small, 68 medium-sized).

Remarks

There are five species of *Aythya* present in the Sacramento Valley during the winter months: *Aythya valisineria*, *A. americana*, *A. collaris*, and *A. affinis*. All *Aythya* are winter migrants and arrive in the valley from their wintering grounds in southern Canada and Alaska between September and October and stay through March. Diving ducks wintering in the valley prefer freshwater lakes and marshes and feed on aquatic vegetation, insects, and other invertebrates (Bellrose 1980; Mowbray et al. 2002).

(2003), and Woolfenden (1961). The small-sized specimens identified as *Aythya* include canvasback and redhead; medium *Aythya* include ring-necked and lesser scaup.

Subfamily Merginae—Seaducks

Tribe Mergini—Mergansers

Material

CA-SAC-15/H: 4 mandibles, 2 pelves, 2 synsacra, 2 coracoids, 2 carpometacarpi, 2 femora, 1 tibiotarsus, 1 tarsometatarsus: 16 specimens.

CA-SAC-29: 2 sterna, 3 synsacra, 2 furcula, 10 coracoids, 5 scapulae, 7 humeri, 7 carpometacarpi, 1 femur, 3 tarsometatarsi: 40 specimens.

Remarks

The species of mergansers present in the region, include: *Mergus merganser*, *M. serrator*, *Lophodytes cucullatus*, *Bucephala albeola*, *B. clangula*, and *B. islandica*, the majority of which are uncommon or rare visitors to the valley. *M. merganser* is a winter migrant to the Sacramento Valley and has a small breeding population as well. This species prefers deep lakes and rivers. *Lophodytes cucullatus* is present in the valley from November to December. *M. serrator*, *B. clangula*, *B. islandica*, and *B. albeola* are sighted ocassionally in the Sacramento Valley, but they winter primarily on the coast or further north in California, and typically prefer saltwater bays and lagoons. Mergansers’ diet consists almost exclusively on fish, except for the hooded merganser which feeds on small fish, crustaceans, particularly crayfish, and aquatic insects (Bellrose 1980; Dugger et al. 2009; Eadie et al. 1995; Small 1994).
Mergini elements were differentiated from those of the other anatinae genera based on morphological and metric criteria detailed in Broughton (2004a), Jangala (2004:154-170), Livezey (1995), Livingston (1988), Oates et al. (2003), and Woolfenden (1961).

*Bucephala albeola*—Bufflehead

**Material**

CA-SAC-15/H: 1 scapula: 1 specimen.

CA-SAC-29: 2 sterna: 2 specimens.

**Remarks**

The bufflehead is the smallest duck of North America, weighing an average 450 grams. They mainly occur near the coast in winter in estuaries, shallow coves, and harbors, avoiding open coastlines. They are rarely found inland in the Sacramento Valley from October to December and prefer ponds, lakes, and slow moving rivers. In freshwater, buffleheads forage in open shallow water with dense vegetation and eat insect larvae, zooplankton, snails, and claims (Bellrose 1980; Gauthier 1993).

The specimens identified as *Bucephala albeola* are easily distinguished from other *Bucephala* species based on their small size and other small ducks, such as *Oxyura jamaicensis*, based on morphological differences (Broughton 2004a:22; Oates et al. 2003; Woolfenden 1961:44).

*Mergus merganser*—Common Merganser

**Material**
CA-SAC-15/H: 1 pelvis, 1 coracoid, 3 humeri: 5 specimens.

CA-SAC-29: 1 sternum, 2 coracoids, 1 carpometacarpus: 4 specimens.

Remarks

These specimens were identified as common merganser based on criteria outlined in Broughton (2004a:23) and Woolfenden (1961) and based on their large size.

cf. Mergus merganser

Material

CA-SAC-29: 1 coracoid: 1 specimen.

Remarks

This proximal coracoid fragment is likely common merganser based on its large size, but was too fragmented to identify.

Subfamily Oxyurinae

Tribe Oxyurini

Oxyura jamaicensis—Ruddy Duck

Material

CA-SAC-15/H: 3 coracoids, 3 scapulae, 1 humerus, 1 carpometacarpus: 8 specimens.

CA-SAC-29: 3 synsacra, 4 sterna, 3 coracoids, 1 scapula, 4 humeri, 1 tarsometatarsus, 1 tibiotarsus: 17 specimens.

Remarks
The ruddy duck is a common winter visitor to Sacramento Valley with a year-round population as well. Ruddy ducks prefer freshwater lakes, ponds and marshes with dense stands of vegetation (Bellrose 1980). Ruddy duck skeletal elements are easily distinguishable from other ducks (Oates et al. 2003; Wolfenden 1961).

**Order Podicipediformes—Grebes**

**Family Podicipedidae—Grebes**

**Material**

CA-SAC-15/H: 1 mandible, 1 sternum, 1 coracoid, 1 humerus, 4 ulnae, 2 radii, 1 second digit (first phalanx), 1 femur, 3 tibiotarsi: 15 specimens.

CA-SAC-29: 1 sternum, 3 coracoids, 1 scapula, 4 humeri, 2 second digits (first phalanges), 1 femur, 1 tibiotarsus: 13 specimens.

**Remarks**

There are three species of grebe common to the Sacramento Valley: *Aechmophorus occidentalis* (western grebe), *A. clarkia* (Clark’s grebe), and *Podilymbus podiceps* (pied-billed grebe). Clark’s and pied-billed grebes are resident species and Western grebes are present during the summer breeding months. Grebes prefer fresh water lakes and marsh habitats. Grebes dive in shallow waters to feed on fish, and aquatic invertebrates and insects. Two other species, horned grebe (*Podiceps auritus*) and eared grebe (*Podiceps nigricollis*) are rare winter migrants and prefer coastal and bay habitats (LaPorte et al. 2013; Muller and Storer 1999).
Unlike ducks, grebes are reluctant to take flight when flushed. Instead, these birds prefer to escape danger by diving underwater or skimming along the surface while flapping their wings to become airborne. Grebes, in particular, are very strong divers and swimmers but are slow on land due to the extreme posterior placement of their feet (McAllister 1963). Grebes are rarely observed far distances inland from water and rarely fly except during night migratory flights. Grebes roost in loose flocks in open water. Grebes typically average one to two broods per year with a clutch-size ranging from two to six chicks in grebes (LaPorte et al. 2013; McAllister 1963; Muller and Storer 1999).

*Podilymbus podiceps*—Pied-billed Grebe

**Material**

CA-SAC-15/H: 1 sternum, 1 scapula, 11 coracoids, 5 humeri, 3 carpometacarpi, 1 femur, 6 tibiotarsus, 2 tarsometatarsus: 30 specimens.

CA-SAC-29: 1 humerus, 2 carpometacarpi, 3 tibiotarsus: 6 specimens.

**Remarks**

The pied-billed grebe has the largest distribution of all grebes and is common and abundant year-round in the Sacramento Valley. This small grebe is opportunistic and will forage on crustaceans, frogs, fishes, and insects. Pied-billed grebes are commonly found in slow-moving waters of freshwater marsh, lakes, and rivers and nests in emergent vegetation (Muller and Storer 1999).

*Podilymbus podiceps* was distinguished from other Podicipedidae by the morphological criteria outlined in Bocheński (1994).

**Material**

CA-SAC-15/H: 1 mandible, 1 sternum: 2 specimens.

*Aechmophorus* sp.—Western and Clark’s Grebe

**Material**

CA-SAC-15/H: 1 sternum, 1 radius, 2 carpometacarpus, 1 second digit (first phalanx), 2 femora, 1 tibiotarsus, 1 tarsometatarsus: 9 specimens.

CA-SAC-29: 1 cranium, 2 humeri, 1 femur, 1 tarsometatarsus: 5 specimens.

**Remarks**

*A. occidentalis* (Western Grebe) and *A. clarkii* (Clark’s Grebe) are very similar physically and until relatively recently they were considered to be conspecific (American Ornithologists’ Union 1998). Thus, no attempt was made to identify these specimens at the species level.

These specimens are distinguished from other grebes based on their large size and distinct morphology (Bocheński 1994:287-325; Broughton 2004a:14).

**Order Suliformes—Frigatebirds, Boobies, Cormorants, Darters, and Allies**

**Family Phalacrocoracidae—Cormorants, Shags**

*Phalacrocorax auritus*—Double-crested Cormorant
CA-SAC-15/H: 2 sterna, 1 scapula, 1 humerus, 2 femora, 1 tarsometatarsus: 7 specimens.
CA-SAC-29: 1 synsacrum, 5 coracoids, 2 scapulae, 5 humeri, 4 ulnae, 2 radii, 2 second digits (first phalanges), 1 carpometacarpus, 1 tarsometatarsus, 1 tibiotarsus, 1 phalanx: 25 specimens.

Remarks

There are three species of cormorant common to California: *Phalacrocorax auritus* (double-crested cormorant), *P. pelagicus* (pelagic cormorant) and *P. penicillatus* (Brandt’s cormorant). The double-crested cormorant is commonly found inland and in the Sacramento Valley, as it prefers fresh water lakes, rivers, and marsh habitats in addition to seacoasts. The pelagic cormorant prefers sea cliffs and offshore islands for nesting and is almost never found away from the ocean. Similarly, Brandt’s cormorant nests on cliffs along the Pacific Ocean, but often enters larger bays and harbors in central California. Although no reference specimens were available for the other species of cormorants, diagnostic criteria for differentiating species detailed in Howard (1929:337-339) and Broughton (2004a:15-17) were used.

**Order Pelecaniformes—Pelicans, Herons, Ibises, and Allies**

Material

CA-SAC-29: 1 ulna, 3 second digits (first phalanges): 4 specimens.

Remarks
Materials represent two large, one medium, and one small-sized specimen of Pelecaniformes. These could include any number of pelicans, herons, ibises and allies present in the valley.

Family Ardeidae—Bittens, Herons, and Allies

Material
CA-SAC-15/H: 1 scapula, 2 tarsometatarsi; 3 specimens.
CA-SAC-29: 1 mandible, 2 coracoids, 2 scapulae, 1 ulna, 1 carpometacarpus, 2 digits (first phalanges), 1 femur, 2 tarsometatarsi, 6 phalanges: 18 specimens.

Remarks
These specimens are medium to small herons or egrets and may include several common species to the Sacramento Valley: *Botaurus lentiginosus* (American bittern), *Egretta thula* (snowy egret), *Bubulcus ibis* (cattle egret), or *Butorides virens* (green heron).

*Ardea sp.*

Material
CA-SAC-29: 1 scapula, 1 coracoid, 1 humerus, 2 ulnae, 1 second digit (first phalanx), 1 tibiotarsus, 4 tarsometatarsi, 9 phalanges: 20 specimens.

Remarks
These are all large heron specimens that either represent *A. herodias* (great blue heron) or *A. alba* (great egret).
*Ardea herodias*—Great Blue Heron

**Material**

CA-SAC-29: 3 mandibles, 2 coracoids, 2 femora, 2 tibiotarsi, 1 tarsometatarsus: 10 specimens.

**Remarks**

The largest heron in North American, great blue heron, is a fairly common resident in California and breeding colonies are known in the Sacramento Valley. They live in both freshwater and saltwater habitats and are commonly found in freshwater marshes and riparian enviorns in the valley. They feed primarily on fish, but may also take amphibians, reptiles, insects, small birds, and even small mammals. Although they forage alone, breeding birds nest in large colonies (Vennesland and Butler 2011).

Identifications were made using criteria outlined in Boev (1988).

**cf. Ardea herodias**

**Material**

CA-SAC-15/H: 1 carpometacarpus: 1 specimen.

**Remarks**

The carpometacarpus from Sac-15/H is likely from a great blue heron based on the width and straightness of the shaft. However, no other diagnostic features were visible.

**Order Accipitriformes—Hawks, Kites, Eagles, and Allies**
Material

CA-SAC-29: 1 synsacrum, 1 furcula, 1 humerus, 3 phalanges (distal): 6 specimens.

Remarks

These specimens are all medium-sized hawks and may include a number of hawks and allies common to the region, such as *Buteo swainsoni* (Swainson’s hawk) or *Accipiter cooperii* (Cooper’s hawk). Accipers were typically hunted for feathers in ethnographic accounts and were not a significant dietary source.

*Cathartes aura*—Turkey Vulture

Material

CA-SAC-29: 2 femurs, 2 phalanges (distal): 4 specimens.

Remarks

The distal phalanges were differentiated from other talons based on reference specimens and limited criteria provided by Gilbert and colleagues (1996:236). These specimens are smaller than *Gymnogyps californianus* (California condor).

Family Accipitrineae—Kites, Hawks, Eagles, and Allies

Material

CA-SAC-15/H: 2 phalanges (distal): 2 specimens.

CA-SAC-29: 1 phalanx (distal): 1 specimen.

*Haliaeetus leucocephalus* or *Aquila chrysaetos*—Bald or Golden Eagle
Material
CA-SAC-15/H: 1 ulna, 1 carpometacarpus: 2 specimens.

Remarks
No eagle reference specimens were available and identifications were made using morphological and measurement data provided in Gilbert and colleagues (1996) and Morejohn and Galloway (1983). The maximum width of the proximal carpometacarpus fragment recovered from Sac-15/H measures 24.5 mm, this falls in the range of golden (24 to 29 mm) or bald eagle (22 to 27 mm) (Gilbert et al. 1996: 144).

Ulnae of eagles were used as bone whistles in the region prehistorically (Morejohn and Galloway 1983). The complete ulna is likely a bald eagle based on its size. It measures 229 mm long and 23 mm wide. Gilbert and colleagues (1996:118) recorded length measurements of six bald eagle ulnae which ranged from 220-247 mm and from 21 to 24 mm wide. Measurements of four golden eagle ulnae ranged from 200-220 mm in length and 21 to 25 mm in width. Morphological criteria outlined by Morejohn and Galloway (1983:90-91) were also used in an attempt to distinguish *Haliaeetus* from *Aquila*. The external cotyla of the proximal end appears to be somewhat sharply angled underneath, a characteristic of bald eagle, as opposed to “smoothly supported,” as in golden eagles, but this is not very obvious. Similarly, the second criterion used to distinguish the two species is not clear. As in *Haliaeetus* the area of the bicipital attachment of this ulna specimen has one large tendinal scar, but appears to also have one or two less defined scars, which is more characteristic of *Aquila*. For these
reasons, I was not able to securely identify this ulna specimen as either bald or golden eagle.

_Buteo_ sp.—Hawk

**Material**

CA-SAC-29: 1 carpometacarpus, 2 phalanges (distal): 3 specimens.

**Remarks**

The carpometacarpus is a medium to large size hawk, similar to _B. swainsoni_ (Swainson’s hawk). The phalanges are all large, and likely represent _B. jamaicensis_ (red-tailed hawk).

**Order Gruiformes—Cranes and Rails**

**Material**

CA-SAC-29: 2 coracoids, 1 second digit (first phalanx), 1 phalanx: 4 specimens.

**Remarks**

These specimens are from medium and large sized cranes and rails.

**Family Rallidae—Rails, Gallinules, and Coots**

**Material**

CA-SAC-15/H: 1 phalanx: 1 specimen.

**Remarks**
This specimen is a small to medium rail, but is not *Fulica americana*. Other rails found in freshwater marsh habitats in the valley include: *Rallus limicola* (Virginia rail), *Porzana carolina* (sora), and *Gallinula galeata* (common gallinule).

*Fulica americana*—American Coot

**Material**

CA-SAC-15/H: 5 sternae, 1 pelvis, 1 mandible, 18 coracoids, 5 scapulae, 4 humeri, 9 ulnae, 8 radii, 7 carpometacarpi, 7 second digits (first phalanges), 2 femora, 14 tibiotarsi, 4 tarsometatarsi: 85 specimens.

CA-SAC-29: 2 synsacra, 10 sternae, 35 coracoids, 20 scapulae, 47 humeri, 37 ulnae, 14 radii, 14 second digits (first phalanges), 71 carpometacarpi, 6 femora, 38 tarsometatarsi, 28 tibiotarsi, 20 phalanges: 342 specimens.

**Remarks**

*Fulica americana* are commonly identified in archaeofaunal assemblages of central California and appear to have been a favored avian resource (Craw 2002; Schulz et al. n.d.; Simons 1994).

American coots are a resident species to the Sacramento Valley, and prefer shallow, fresh water lakes and marsh habitats to feed on aquatic plants, such as sedges, pond-weeds, and algae, but may also forager on terrestrial grasses and grains. Coots are reluctant to take flight when flushed. Instead, these birds prefer to escape danger by diving underwater or skimming along the surface while flapping their wings to become airborne. Coots are also fast on land and are adept at walking and running rapidly on land
or across water. On wintering grounds in the Sacramento Valley, coots are observed in
large communal roosts in dense stands of cattail and other emergent plants. Coots average
one to two broods per year with a clutch-size ranging from eight to 12 chicks (Brisbin
and Mowbray 2002).

cf. *Fulica americana*—cf. American Coot

**Material**

CA-SAC-15/H: 1 humerus, 1 ulna, 1 tibiotarsus: 3 specimens.

Family Gruidae—Cranes

*Grus cf. Canadensis*—Sandhill Crane

**Material**

CA-SAC-15/H: 1 coracoid: 1 specimen.

CA-SAC-29: 1 mandible, 2 coracoids, 1 humerus, 1 carpometacarpus, 1 ulna, 1 radius, 1
second digit (first phalanx), 1 femur, 1 tibiotarsus, 1 tarsometatarsus: 11 specimens.

**Remarks**

No sandhill crane specimens were available for reference; identifications were
based on criteria provided in Howard (1929: 354-356). The larger species of sandhill
crane (*Grus canadensis tabida*) does not occur in California today, but specimens were
identified at nearby Emeryville shellmound in the San Francisco Bay (Howard 1929).
Prehistorically, sandhill crane bones, particularly the ulna and tarsometatarsus, were used
to make bone tools (whistles) in the region (Morejohn and Galloway 1983:91; Wulf
1990).
Order Charadriiformes—Plovers, Sandpipers, and Allies

Material

CA-SAC-15/H: 1 coracoid, 1 carpometacarpus, 1 tarsometatarsus: 3 specimens.

CA-SAC-29: 6 coracoids, 1 scapula, 4 humeri, 1 carpometacarpus, 3 ulnae, 1 tibiotarsus: 16 specimens.

Remarks

Identification of elements from the over 100 species of shorebirds, including plovers, gulls, and stilts, of the order Charadriiformes were not attempted due to lack of reference specimens and similarity between families of this order. A variety of resident and migrant shorebirds are present in the area and include, *Himantopus mexicanus* (black-necked stilt), *Charadrius vociferous* (killdeer), *Recurvirostra americana* (American avocet), *Actitis macularius* (spotted sandpiper), *Tringa melanoleuca* (greater yellowlegs), long-billed curlew, *Calidris alpine* (dunlin), and *Larus californicus* (California gull), to name a few (Sacramento Audubon Society 2011).

Order Strigiformes—Owls

Family Strigidae—Typical Owls

Material

CA-SAC-29: 1 radius, 1 pollex, 3 tarsometatarsi, 1 phalanx (distal): 6 specimens.

Remarks
There are a variety of species of owls that are common and widespread in the region and are found in a variety of habitats including, grasslands, freshwater marshes, and woodlands (Sacramento Audubon Society 2011). Two specimens are from a larger owl, such as *Bubo virginianus*, the rest are from a medium-sized owl, such as *Tyto alba*.

**Order Piciformes—Woodpeckers**

Family Picidae—Woodpeckers and Allies

**Material**

CA-SAC-29: 1 sternum, 2 coracoids, 1 humerus, 1 ulna: 5 specimens.

**Remarks**

These specimens are smaller than *Colaptes* sp. and may represent *Picoides nuttallii* (Nuttall’s woodpecker) or *P. pubescens* (downy woodpecker).

*Colaptes sp.*—Flicker

**Material**

CA-SAC-15/H: 1 coracoid: 1 specimen.

CA-SAC-29: 1 maxilla: 1 specimen.

**Remarks**

The northern flicker is a fairly large-sized member of the family of woodpeckers, Picidae, and is a year-round resident of central California. They occur predominately in open habitats near woodlands, as they nest in holes of trees. Flickers forage on the ground for mostly insects, but also forage for seeds, nuts, and berries (Wiebe and Moore 2008).
Ethnographies of central California document the use of flicker primary and tail feathers, which are bright red in color, in Native American ceremonial clothing, particularly as decorative elements on headbands (Barrett and Gifford 1933).

**Order Falconiformes—Caracaras and Falcons**

*Falco sparverius*—American Kestrel

**Material**
CA-SAC-15/H: 1 coracoid, 1 scapula: 2 specimens.

**Remarks**

The American Kestrel is a common resident throughout California, and occurs in most open habitats of grassland, shrub, and woodlands. Kestrels forage on small mammals, insects, reptiles, and amphibians. American kestrels are known to build their nests in cavities of California sycamore (Dawson 1923; Polite and Alborn 1990). The two specimens recovered from Sac-15/H are from the same provenience and are likely from the same individual.

**Order Passeriformes—Perching Birds**

**Material**
CA-SAC-15/H: 1 sternum, 5 humeri, 9 ulnae, 1 carpometacarpus, 2 second digits (first phalanx), 2 femora, 5 tibiotarsi, 5 tarsometatarsi: 30 specimens.

CA-SAC-29: 4 crania, 1 sternum, 1 coracoid, 12 humeri, 8 ulnae, 2 carpometacarpi, 3 femora, 4 tibiotarsi: 35 specimens.
Remarks

There are over 100 species in the order Passeriformes that are common to the Sacramento Valley. These specimens were all small to very small Passeriformes and no attempt was made to identify these specimens beyond Order-level.

Family Corvidae—Jays, Magpies, and Crows

Material

CA-SAC-15/H: 1 ulna: 1 specimen
CA-SAC-29: 1 coracoid, 2 humeri, 3 ulnae, 4 carpometacarpi, 2 second digits (first phalanges), 2 femora, 2 tibiotarsi, 1 tarsometatarsus, 2 phalanges (distal): 19 specimens.

Remarks

Four species of the family Corvidae are common year-round to the Sacramento Valley, these include, *Aphelocoma californica* (Western scrubjay), *Pica nuttalli* (yellow-billed magpie), *Corvus corax* (Common Raven), and *C. brachyrhynchos* (American crow). The Western scrubjay prefers lower mountain woodlands. The yellow-billed magpie prefers oaks and open oak grasslands. American crows and ravens are very opportunistic and are found in a variety of habitats (Sacramento Audubon Society 2011).

These specimens are likely magpie or scrubjay due to their smaller size.

*Corvus brachyrhynchos*—American Crow

Material

CA-SAC-15/H: 1 synsacrum, 1 humerus, 1 ulna, 2 coracoids, 1 femur: 6 specimens.
CA-SAC-29: 1 coracoid, 1 ulna, 1 carpometacarpus, 1 tibiotarsus, 1 tarsometatarsus: 5 specimens.

Remarks

These specimens are larger than other jays and magpies, but are smaller than *C. corax*.

*Corvus corax*—Common Raven

Material

CA-SAC-15/H: 1 carpometacarpus: 1 specimen

Remarks

*C. corax* elements are significantly larger than all other corvids and can be differentiated by size alone (Tomek and Bocheński 2009:07).
Table A-2. Life History Summary of Avian Taxa Examined (data from Poole 2002).

<table>
<thead>
<tr>
<th>Latin Name</th>
<th>Common Name</th>
<th>Seasonality</th>
<th>Habitat</th>
<th>Food</th>
<th>Nesting</th>
<th>Clutch-size</th>
<th>Behavior</th>
<th>Avg. Weight (g)</th>
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<tbody>
<tr>
<td><em>Podilymbus podiceps</em></td>
<td>Pied-billed Grebe</td>
<td>Year-round</td>
<td>Freshwater Marsh</td>
<td>Fish, Invertebrates</td>
<td>Floating</td>
<td>3-10</td>
<td>Surface dive</td>
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<td><em>Podiceps auritus</em></td>
<td>Horned Grebe</td>
<td>Winter</td>
<td>Marine/Bay</td>
<td>Fish, Invertebrates</td>
<td>Floating</td>
<td>3-8</td>
<td>Surface dive</td>
<td>435</td>
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<td>Eared Grebe</td>
<td>Winter</td>
<td>Marine/Bay</td>
<td>Invertebrates</td>
<td>Floating</td>
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<td>Surface dive</td>
<td>460</td>
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<td><em>Aechmophorus occidentalis</em></td>
<td>Western Grebe</td>
<td>Summer</td>
<td>Freshwater Marsh/Lacustrine</td>
<td>Fish</td>
<td>Floating</td>
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<td>Surface dive</td>
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<td>Clark's Grebe</td>
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<td>Surface dive</td>
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<td>Plants</td>
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<td><em>Chen caerulescens</em></td>
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<td>Ground forager</td>
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<td>Dabbler</td>
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<td>Lesser Scaup</td>
<td>October to March</td>
<td>Freshwater Marsh/Lacustrine</td>
<td>Plants, Invertebrates</td>
<td>Ground</td>
<td>6-14</td>
<td>Surface dive</td>
<td>770</td>
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<td>Bucephala albeola</td>
<td>Bufflehead</td>
<td>November to March</td>
<td>Marine/Bay</td>
<td>Invertebrates</td>
<td>Cavity</td>
<td>6-11</td>
<td>Surface dive</td>
<td>450</td>
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<td>Latin Name</td>
<td>Common Name</td>
<td>Seasonality</td>
<td>Habitat</td>
<td>Food</td>
<td>Nesting</td>
<td>Clutch-size</td>
<td>Behavior</td>
<td>Adult Avg. Weight (g)</td>
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<td>B. clangula</td>
<td>Common Goldeneye</td>
<td>November to February</td>
<td>Marine/Bay</td>
<td>Invertebrates</td>
<td>Cavity</td>
<td>5-16</td>
<td>Surface dive</td>
<td>950</td>
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<td>B. islandica</td>
<td>Barrow's Goldeneye</td>
<td>October to March</td>
<td>Marine/Coast</td>
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<td>Cavity</td>
<td>6-12</td>
<td>Surface dive</td>
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<td>Lophodytes</td>
<td>Hooded Merganser</td>
<td>November to December</td>
<td>Freshwater Marsh/Lacustrine</td>
<td>Fish, Insects, Invertebrates</td>
<td>Cavity</td>
<td>5-13</td>
<td>Surface dive</td>
<td>660</td>
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<td>Mergus</td>
<td>Common Merganser</td>
<td>September to January</td>
<td>Freshwater Marsh/Lacustrine</td>
<td>Fish</td>
<td>Cavity</td>
<td>6-17</td>
<td>Surface dive</td>
<td>1530</td>
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<td>Oxyura jamaicensis</td>
<td>Ruddy Duck</td>
<td>Year-round</td>
<td>Freshwater Marsh</td>
<td>Plants</td>
<td>Ground</td>
<td>3-13</td>
<td>Surface dive</td>
<td>575</td>
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<td>Fulica americana</td>
<td>Coot</td>
<td>Year-round</td>
<td>Freshwater Marsh</td>
<td>Aquatic plants</td>
<td>Floating</td>
<td>8-12</td>
<td>Surface dive</td>
<td>650</td>
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APPENDIX B: SAC-15/H AND SAC-29 FAUNAL ANALYSIS DATA

See accompanying CD-ROM.
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