

Earliest Utilization of Chicken in Upper California: The Zooarchaeology of Avian Remains from the San Diego Royal Presidio

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The San Diego Presidio, established in AD 1769, was the first European settlement in Upper California. Very little is known about chicken husbandry in colonial America, which makes this study the first comprehensive analysis of chicken remains in North America. Chickens are scarcely mentioned in historical accounts describing early California, and information on their sex, age, or management is rare. The faunal assemblage from the San Diego Presidio yielded 20 avian and 14 mammalian species. Chicken remains were studied through a wide range of zooarchaeological methods, including taphonomy, biometry, medullary bone, epiphyseal fusion, butchering, and body-part representation. Taphonomic analysis indicates good preservation of the bone assemblage. The biometric study points to two breeds of chickens: a smaller (bantam) breed alongside a standard-size chicken. The percentage of juvenile chickens (23%), the rooster/hen ratio (1:8.5), and high proportion of medullary bone point to on-site chicken husbandry focusing on meat and egg production. The historical record suggests that California presidios were not self-sufficient and that they relied on food provisioned from Mexico and nearby missions. We argue that small-scale poultry production, likely managed by women and children, provided California presidios with a form of subsistence independence.

Keywords: historical archaeology, taphonomy, medullary bone, chicken husbandry, chicken breeds, colonial period, avifauna, bantam chicken

El Presidio de San Diego, establecido en 1769, fue el primer asentamiento Europeo en la Alta California. El record histórico sugiere que los presidios de California no eran autosuficiente y necesitaban subministro alimenticio de México y las misiones cercanas. Sin embargo, muy poco se conoce sobre la crianza de pollos en la América colonial. Este es el primer estudio comprensivo analizando restos de pollo en Norte América. Los pollos son raramente mencionados en acontecimientos históricos describiendo a la temprana California e información de su sexo, edad, o mantención es rara. La colección de fauna del Presidio de San Diego produjo especies de 20 aves y 14 mamíferos. Los restos de pollos fueron estudiados usando una amplia gama de métodos zooarqueológicos incluyendo tafonomía, biometría, hueso medular, fusión de epífisis, carnicería y representación de las partes del cuerpo. El análisis tafonómico, indico una buena preservación de la colección de huesos. El estudio biométrico apunta a dos razas de pollos, la pequeña raza (Bantam) junto a pollos de tamaño estándar. La proporción de pollos juveniles (23%), la proporción de gallo/gallina (1:8.5), y la alta proporción de hueso medular apunta a la crianza de pollos en sitio, enfocándose en la producción de carne y huevo. Argumentamos que la producción de pollos a escala pequeña, probablemente practicado por mujeres y niños, proporciono a los presidios de California con una forma de subsistencia independiente.

Palabras clave: arqueología histórica, tafonomía, hueso medular, cría de pollos, raza de pollos, período colonial, fauna avial, pollo bantam

The chicken (*Gallus gallus domesticus*) is the most widespread domestic food animal of our time. It is one of the most efficient farm animals for protein production—more so than dairy cattle (Redding 2015). Yet, chickens were not always used for meat and eggs. When introduced to the Americas, domesticated fowl were often used for feathers, for cockfighting, and as pets (Pitt et al. 2016; Sykes 2012). Their use for meat consumption

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is a fairly recent innovation in many regions of the world. In Japan, for example, there is little evidence that chickens were consumed regularly before the nineteenth century (Sykes 2012). In other parts of the world, such as Central Europe and the Pacific Islands, zooarchaeological and ethnographic data indicate that the primary motivation for introducing chickens to these regions was for meat but probably not for eggs (Benecke 1993; Langdon 1989).

Chickens were domesticated from wild jungle fowl (*Gallus gallus*) in Asia, and introduced to the New World by European settlers (Thomson et al. 2014). Neither domestic chickens nor wild jungle fowl have been recovered from prehistoric North American sites. According to Reitz and colleagues (1985:28), chickens arrived in what is now the southeastern United States with Spanish soldiers during the sixteenth century. According to Lawler (2014:193), they arrived in the northeastern United States (e.g., Jamestown) with British settlers in the early seventeenth century.

Historical accounts indicate that in the first two decades after their establishment (ca. AD 1769–1790), Upper California presidios and missions were regularly provisioned with goods and livestock from Mexico (Forbes 1839:11; Geiger 1963; Hackel 1997; Palóu 1926:356; Serra 1955:361). In an effort to ensure livestock (e.g., cattle, sheep) proliferation, the Spanish government largely forbade slaughter of these animals (Archibald 1978:177; Cheever 1983:40). When California missions became economically viable, agricultural surplus was provisioned to presidio military personnel against their wages (Archibald 1978:11; Forbes 1839:145; Serra 1955:365). While the Spanish crown promoted self-sufficiency among missions and presidios, California presidios do not appear to have reached the goal of agricultural sustainability (Aiken 1983:9; Bancroft 1888:240; Cheever 1983:47; Hittell 1897:507). In light of the economic uncertainty and irregular food supply, small-scale poultry husbandry practiced at the presidios would have provided soldiers and their families a form of economic independence. Although historical documentation does not indicate whether chickens and eggs played an integral part of the provisioning network,

zooarchaeological analysis of San Diego Presidio chicken remains sheds notable light on this question.

Our knowledge of chicken husbandry in colonial North America is fairly limited. Analyses of chicken remains from North American colonial sites commonly discuss only their relative frequency (Blind et al. 2004; Lucido 2013; Lyman 1977; Reitz et al. 1985:67; Schulz et al. 1987; Schweitzer 2010; Simons 1984; Szter 1996). Questions related to male/female ratios, age profiles, or whether chickens were managed for their eggs have not been addressed. In contrast to North America, chicken remains from Classical and post-Classical periods in Europe and the ancient Near East are well studied. The archaeological literature is accessible and allows comparative inferences about chicken husbandry through time and space (Boessneck and von den Driesch 1979; De Cupere et al. 2005; Gál 2006; Kysely 2010; Maltby 1997; Moreno-García and Detry 2010; Perry-Gal et al. 2015; Redding 2015; Slavin 2009; Van Neer et al. 2002).

As discussed below, historical data on chickens are also sparse. While large livestock animals—such as cattle, horses, mules, and sheep—are commonly enumerated in California mission inventories, and information about their age category and sex is often available (e.g., the number of mares, colts, calves, or lambs), this is not the case with chickens (Archibald 1978:159; Bancroft 1888:337; Forbes 1839:265–266; Palóu 1926:216–217; Richman 1911:31).

Chicken remains from the San Diego Presidio represent the earliest known utilization of domestic fowl on the western coast of what is now the United States. These remains serve as an excellent case study for addressing the following questions: What role did chickens play in the colonial Spanish subsistence economy, particularly at the time of their introduction to the Pacific coast of North America? Were the presidios provisioned with poultry, or did they raise and manage them on-site? Were chickens systematically raised for meat, eggs, or both? Using zooarchaeological methods and the limited historical accounts available, our study attempts to provide the first comprehensive assessment of chicken husbandry in Upper California.

Although the zooarchaeological sample available for this study is relatively small ($n = 790$), the number of identified species is strikingly high, with 20 avian and 14 mammalian taxa represented (Table 1; Supplemental Table 1). The number of identified chicken bones is also relatively high, compared to those identified from other presidio and mission sites (Benté et al. 1982; Pavao-Zuckerman 2011; Voss 2008:307–324; Walker 1985). For instance, while nearly 56,000 animal bones are reported from various zooarchaeological studies of the San Francisco Presidio, only 157 chicken bones were identified among them (Smith-Lintner 2007; Valente 2002a, 2002b; Wake 1996). In contrast, the San Diego Presidio yielded 303 chicken bones, making this sample especially useful for evaluating chicken husbandry in the late eighteenth to early nineteenth century (Table 2). Although it remains unclear why the number of chicken remains from other sites is relatively low, Table 2 demonstrates that chicken bones from the San Diego Presidio represent one of the largest samples to date and warrant comprehensive study.

Site Background

Established in AD 1769, the San Diego Royal Presidio was the earliest European settlement along the western coast of the future United States (Figure 1). Constructed on a hill, overlooking San Diego Bay and the San Diego River, it was the first of four military colonies (San Diego, Monterey [1770], San Francisco [1776], and Santa Barbara [1782]) established in the province of Upper (Alta) California (Voss 2008:54–65; Williams 2004a). The San Diego Presidio was a fortified military base for only two-thirds of its history (ca. AD 1780–1821). Along with Spanish military officers and Mexican soldiers, the garrison population included many civilians, representing an ethnically mixed community with a large number of Native American people. At its height, the outpost sheltered more than 500 inhabitants, and by AD 1790, it served as the chief administrative and judicial center for the surrounding region. The presidio of San Diego was abandoned in AD 1835 (Williams 1997, 2004b).

In the first decade of its history, the San Diego Presidio was unwallled. About 10 years after its establishment, it was rebuilt as a fortified adobe quadrangle with a chapel, areas assigned to soldiers' barracks, a commandant's house, a guardhouse, homes for civilians and troops with dependents, and a residential area for visiting padres (Figure 2; Williams 2004b).

Between 1927 and 1997, six different archaeological expeditions excavated the San Diego Presidio (Williams 1997). In the years 1965–1976, the chapel and the southern fortification wall were excavated by Paul Ezell (1976). Between 1976 and 1983, Diane Barbolla (1992) excavated the western fortification wall. A large midden outside the west wing of the fortification was also excavated. In the late 1980s, Brad Bartel (1991) excavated the northeast corner of the presidio, and in the late 1990s, the north wing's fortification wall and residential quarter were excavated by Jack Williams (1997, 2004b). The north wing served as a residential area with over 20 rooms and associated yards. The west wing consisted of two areas: a block of residential rooms within the western wall and a midden over 4 m deep that is outside the western wall. The midden very likely served as the foundation for a gun battery built between AD 1791 and 1810 (Barbolla 1992; Williams 1997, 2004b). Most of the faunal remains we examined were recovered from the north and west wings.

Only partial results of some of the excavations described above have been published. To date, no synthesis of excavation results has been carried out, nor has a comprehensive archaeological report on the San Diego Presidio been published. Only two zooarchaeological studies from the west and north wings of the San Diego Presidio are known to us. Over 2,600 large-mammal remains from the west wing were studied by Cheever (1983). According to this study, cattle constituted 72% of the identified elements, 6% were sheep, and 1.3% were deer. Over 4,000 animal bones were recovered from Bartel's (1991) excavation of the presidio's northeast corner. Of these, approximately 280 bone fragments (7%) were identified to species, with 25% representing cattle, 26% fish, 24% rodents, and 12% birds (Bartel 1991). Bird taxa were not specified.

Table 1. Avian NISP, MNI, and Modification Marks.

Common Name	Scientific Name	NISP	MNI	New Break	Gnaw	Cut	Burn
Chicken	<i>Gallus gallus domesticus</i>	303	8	41	5	17	5
Turkey	<i>Meleagris gallopavo</i>	1	1	0	0	0	0
Domestic Goose	<i>Anser anser</i>	9	1	2	0	1	0
California Quail	<i>Callipepla californica</i>	2	1	0	0	0	0
Cuckoo Family	Cuculidae	1	1	0	0	0	0
Eared Grebe	<i>Podiceps nigricollis</i>	1	1	0	0	0	0
Common Loon	<i>Gavia immer</i>	1	1	0	0	0	0
Lesser Scaup	<i>Aythya affinis</i>	2	1	0	0	0	0
Mallard Duck	<i>Anas platyrhynchos</i>	2	1	1	0	0	0
Gadwall	<i>Anas strepera</i>	1	1	0	0	0	0
American Wigeon	<i>Anas americana</i>	1	1	0	0	0	0
Redhead (Duck)	<i>Aythya americana</i>	3	1	0	0	0	0
Duck	<i>Anas</i> sp.	6	n/a	1	0	0	0
California Gull	<i>Larus californicus</i>	1	1	1	0	0	1
Crow	<i>Corvus brachyrhynchos</i>	2	1	0	0	0	0
Raven	<i>Corvus corax</i>	64	2	2	0	0	0
Barn Owl	<i>Tyto alba</i>	1	1	0	0	0	0
Red-Tailed Hawk	<i>Buteo jamaicensis</i>	2	1	0	0	0	0
Red-Shouldered Hawk	<i>Buteo lineatus</i>	1	1	0	0	0	0
Bald Eagle	<i>Haliaeetus leucocephalus</i>	1	1	0	0	0	0
Sandhill Crane	<i>Grus canadensis</i>	1	1	0	0	0	0
Small Bird	Aves	2	n/a	3	0	0	0
Medium Bird	Aves	54	n/a	1	0	1	0
Large Bird	Aves	4	n/a	1	0	0	0
Indeterminate Bird	Aves	3	n/a	0	0	0	0
Total		469	28	53	5	19	6

Table 2. Chicken Bones in California and Arizona Presidios and Missions.

Presidio/Mission	Date	Total Faunal Remains	Chicken Remains	Total Avian Species	Reference
San Diego	1769–1835	7,390	303	20	This study; Bartel 1991; Cheever 1983
San Francisco midden	1776–1835	41,702	88	8	Smith-Lintner 2007
San Francisco Unit RI (Block R)	1776–1835	7,182	17	3	Valente 2002a
San Francisco (Woodward-Clyde Exc.)	1776–1835	1,515	13	2	Wake 1996
San Francisco (Blocks H & Y)	1776–1835	5,301	34	2	Valente 2002b
Santa Barbara	1782–1835	160	4	1	Benté et al. 1982
Mission Santa Ines	1787–1812	119	6	1	Walker 1985
Mission Cocospera AZ	18th Century	6,406	18	3	Pavao-Zuckerman 2011
Mission San Agustin AZ	1795–1820	7,933	4	3	Pavao-Zuckerman 2011

Materials and Methods

Retrieval of the Bone Assemblage

In the late 1990s, the City of San Diego closed the presidio excavations, and the site was

backfilled. Apart from the chapel excavations (Ezell 1976), all presidio artifacts and ecofacts reside with the City of San Diego facility. Pending a comprehensive and costly inventory and cataloging of the presidio material culture, scholarly research remains on hold. Apart from faunal



Figure 1. San Diego Presidio location. (Color online)

studies concurrent with past excavations (Bartel 1991; Cheever 1983), no analysis or research on material, stored at the City of San Diego facility, has been conducted since the late 1990s.

A brief window opened in 2011, and the City of San Diego allowed the authors, among other scholars, access to the presidio storage facility for a limited time. During this time, we retrieved faunal material for analysis. The total number of presidio faunal specimens has yet to be determined. The authors' visual inspection of dozens of artifact storage boxes puts an estimate of specimens in the tens of thousands. The faunal sample bags were stored within mixed-content artifact boxes (e.g., bone, glass, ceramics). The authors searched through as many boxes as time allowed, locating and pulling sample bags containing avian remains. In addition to bird bones, many of these bags contained other classes of fauna. We studied these specimens too, and for this reason, we briefly describe the non-avian remains. In the search for chicken

remains among over 400 storage boxes, we sought to include specimens from the two primary excavations: the west wing (Barbolla 1992) and north wing (Williams 1997, 2004b). Specimens from the northeast corner of the presidio were also collected (Bartel 1991). As such, bird remains in our study come from all primary areas of the west wing (rooms within the compound and a deep midden outside the walls) and from 11 rooms within the north wing. Information on screening methods during excavations was only available from the west wing, where all soil was screened through 3 mm hardware mesh (Barbolla 1992). No information was provided on the use of screening methods in the excavation summaries of the north wing or northeast portion of the site (Bartel 1991; Williams 1997, 2004b).

In light of the goal of this study—to provide insights into chicken husbandry at the San Diego Presidio—it should be noted that, pending stratigraphic study, dates that might delineate chronological components or phases of the site

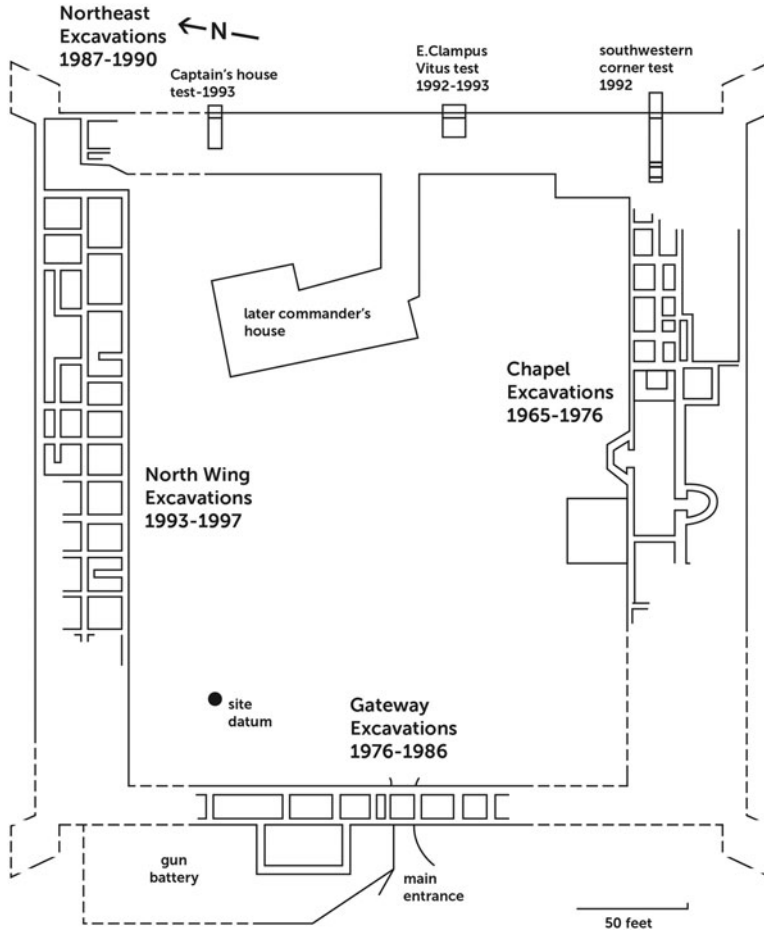


Figure 2. Primary excavation areas at San Diego (based on Williams 1997).

are unavailable. Therefore, our analysis may encompass the entire occupation period of the San Diego Presidio (AD 1769–1835).

Research Methods

The zooarchaeological study was carried out at the San Diego Zooarchaeology Laboratory using the osteological reference collection housed in the San Diego Natural History Museum. Anatomical skeletal atlases were also consulted (Cohen and Serjeantson 1996; Miles et al. 1985). Common and scientific names of animal species mentioned in the text follow Wilson and Reeder (2005) and Myers et alia (2018). Specimens were identified to species, skeletal element, and side (left or right) when possible. Limb bone fragments were identified as proximal

end, distal end, or shaft. Specimens unidentifiable to species or skeletal element were categorized by size. Small birds include those the size of most passerines, medium birds the size of ducks and chickens, and large birds the size of geese or larger.

The assemblage was quantified using two common zooarchaeological methods: NISP (number of identified specimens) and MNI (minimum number of individuals; Reitz and Wing 2008:202–204). Specimens were examined with a magnifying lens ($\times 40$) or digital microscope ($\times 60$) for evidence of bone modifications resulting from fire, butchering, weathering, and animal gnawing. New breaks (fractures) incurred during archaeological excavation, transport, or storage were also recorded. Cracked bones and

splinters were not counted as new breaks (Sasson 2010:62).

Differential representation of avian skeletal elements in archaeological sites may reflect cultural practices or natural (i.e., taphonomic) processes (Bovy 2012; Ericson 1987). We tested both notions within the historic archaeological context of the San Diego Presidio. The cultural hypothesis was assessed by examining body-part representation against the relative frequency of chicken leg and wing bones. The taphonomic hypothesis was tested by plotting the relative frequency of skeletal elements and their relative density (see discussion below). Dirrigl (2001) scanned and measured areal bone mineral density (BMDa) and volume bone mineral density (BMDv) of the wild turkey (*Meleagris gallopavo*). He scanned three areas (“scan site”) for each specimen: proximal, distal, and medial (shaft). For our analysis of density-mediated attrition, we included complete long bones as well as fragments of proximal ends, distal ends, and shafts. Following Dirrigl’s protocol, we assigned complete long bones to the medial category. For example, we counted a complete femur as one medial femur for the bone-density analysis (Supplemental Table 2). We used Dirrigl’s data on turkey-bone density because, to date, no data on chicken-bone density are available. Density-mediated attrition is tested by comparing the relative density of scan sites (e.g., proximal femur versus distal femur). We used data on turkey-bone density under the premise that the relative density of turkey bone at the sites scanned (e.g., distal femur) correlates with that at equivalent sites in the chicken. This supposition is based on Latimer’s studies, which showed that the relative weights of long bones of domestic chickens correlate with those of turkey hens (Latimer 1927; Latimer and Rosenbaum 1926).

Ageing and Sexing

The stages of limb bone fusion serves as one way to document a chicken’s age at death. In the chicken, true bony epiphyses (secondary ossification centers) occur only at the proximal end of the tarsometatarsus and at the proximal and distal ends of the tibiotarsus. However, cartilaginous growth plates are present at both ends

of every long bone from 16 days after hatching until growth is complete 30 weeks later (Church and Johnson 1964; Latimer 1927; Serjeantson 2009:39). For assessing relative age at death, we categorized long bones as either fused (mature) or unfused (immature; Supplemental Table 3). Additionally, the outer cortical bone of hatchlings and subadult fledglings retains a visibly porous outer texture (Fothergill et al. 2017; Gál 2006; Serjeantson 2009:38–40; Thomas et al. 2014). We categorized these specimens as immature also.

Well-developed, fully calcified bone spurs generally occur only on the distal shaft of the tarsometatarsus of roosters and castrated capons. We examined all tarsometatarsi for the presence or absence of bone spurs. It should be noted that spurs may occasionally fail to develop in males, and they may occur as an underdeveloped, oval knob in hens by one year of age. Additionally, in productive egg-layers, normal hormonal inhibition of spur growth may be reversed during the phase of the cycle following reproduction, resulting in spur growth (Sadler 1991; Serjeantson 2009:47–49; West 1982).

On average, hens are considerably smaller than roosters, although the sexes do overlap in size. We used osteometric data and statistical models to identify size variations between males and females, and possibly, different breeds. Following von den Driesch (1976), we measured the distal breadth (Bd, Did), proximal breadth (Bp, Dip), and greatest length (GL) of chicken skeletal elements. Only fully ossified, unburnt fragments were measured (Supplemental Table 4). To assess size variation in the osteological measurements, we applied two statistical methods. In the first phase, we used the “log-ratio” method to pool measurements from different skeletal elements (Fothergill et al. 2017; Haber and Dayan 2004; Payne and Bull 1988; Simpson et al. 1960:356–358). With this method, the logarithm of the ratio between the size of a zooarchaeological and a standard (modern) specimen is calculated. The standard skeleton used for this analysis was a domestic rooster from Arizona that died in 1977. Its measurements are presented in Supplemental Table 4. For example, if the Bp measurement of an archaeological femur is 15.5 mm and the

standard measurement of this element is 17.2, the log-ratio between 15.5 and 17.2 is calculated as $\log_{10}(15.5/17.2) = 0.0459$. Davis (1996) has shown that most measurements taken along the same axis—be it length, width, or depth—are quite highly correlated, but measurements taken along different axes tend to be less correlated. Following Davis, we compiled two log-ratio datasets for statistical modeling: one of the greatest length (length axis) and the other of the greatest breadth (breadth axis) of the proximal and distal portions of long bones.

In the second phase, we modeled the two datasets using “mixture analysis.” This technique can be used on samples that consist of a mixture of two or more different component populations (such as males and females), allowing individuals to be assigned to one or the other of the mixed components. In other words, in osteometric datasets, mixture analysis modeling detects and highlights the males, females, and in some cases, smaller breeds. It is based on the method of maximum likelihood and estimates the parameters for each group (mean, proportion, and standard deviation; De Cupere et al. 2005; Fernández and Monchot 2007; for further details, see Dong 1997; Monchot and Léchelle 2002). Statistical analysis was performed in PAST (Hammer et al. 2001).

Medullary bone is unique to female birds and crocodylians, and during eggshell formation, it serves as a source of stored calcium. This secondary bone is generated in varying densities within most skeletal elements and is readily visible in the open medullary cavities of a hen’s long bones. Medullary bone forms during the pre-laying period of approximately 7–14 days, and it is resorbed after the hen ceases laying (Cano-ville et al. 2019; Church and Johnson 1964; Rick 1975; Whitehead 2004). Zooarchaeological chicken limbs containing medullary bone reflect the presence of hens, most likely slaughtered at the end of their egg-laying cycle (Gál 2006; Kysely 2010; Rick 1975; Van Neer et al. 2002). We inspected all avian long bones in our study for medullary bone but analyzed only those from chickens. Proximal and distal ends of limbs that only retained a small fragment of the shaft were excluded from the analysis. In addition to examining substantive bone-shaft

fragments, we sectioned 40 complete long bones through the middle of the shaft area and inspected them for medullary bone after they were measured, weighed, and photographed.

Results

The faunal remains analyzed in this study originated from three areas of the San Diego Presidio, with 75% of the bone assemblage recovered from the west wing, 21% from the north wing, and 4% from the northeast corner inside of the presidio walls. Although the focus of this article is chicken husbandry, data on other species represented in the bone assemblage warrant mention.

In total, 790 animal bones were studied. Of these, 469 were avian, representing 20 species—17 wild and 3 domesticated. Domestic poultry account for over half of all bird specimens, most of which are chicken (Table 1). Since the bone assemblage for this study was collated with chicken bones as the primary focus, the scant representation of goose and turkey remains should not be interpreted as a measure of those species’ economic importance (or lack thereof).

The taphonomic data, summarized in Table 1 and Supplemental Table 1, suggest good preservation of the bone assemblage. Only 0.5% of specimens were weathered, 0.75% were gnawed, 1.5% were burnt, 3% were butchered, and 9% were newly broken, indicating that degradation by taphonomic agents was rather low. In contrast, among specimens from the historic site of the San Diego County Warner’s Trading Post, dated to AD 1849–1851, 75% of the bones were weathered, 21% were burnt, 10% were butchered, and 44% were newly broken (Sasson 2011). We also assessed the depositional integrity of the presidio bone assemblage based on density-mediated attrition of the chicken bones, plotting the frequency of 176 chicken limb elements against the corresponding mean BMDa and BMDv of wild turkey (Supplemental Table 2; Dirrigl 2001). If the relative frequency of high-density body parts is greater than that of low-density body parts, one could infer that taphonomic agents modified the bone assemblage and that density-mediated attrition is responsible for the loss or destruction of lower density skeletal elements (Lyman 1994:252).

Table 3. Mixture Analysis Results of Chicken Long Bones.

	Sex/ Breed	N	PP	Mean	SD
Breadth	M	7	0.050386	0.034027	0.003569
	F	83	0.94961	-0.05079	0.040664
Length	Bantam	3	0.15312	0.037883	0.002623
	F	32	0.77572	-0.02668	0.031233
	M	7	0.071161	-0.15581	0.011657

Notes: N = Number of Specimens; PP = Prior Probability; SD = Standard Deviation)

We found no significant correlation between the two variants ($r = 0.03$, $p = 0.87$ for BMDa; $r = 0.21$, $p = 0.30$ for BMDv), suggesting that density-mediated attrition did not play a major role in structuring the relative frequency of chicken skeletal elements. Additional evidence for postdepositional integrity of the assemblage is the large proportion of complete bones. Among all mammalian and avian specimens, 23% ($n = 185$) were whole (complete) bones. In the study of large-mammal remains from the San Diego Presidio, Cheever (1983) reported similar results: nearly 30% of the studied sample consisted of whole elements.

Adult/Juvenile Ratio

Data on the epiphyseal fusion of 106 chicken elements indicate that 23% of specimens were from birds culled at ages under four to six months. The assemblage of unfused bone includes six radii, with an MNI of three chickens killed prior to four months of age, and eight tarsometatarsi, with an MNI of five chickens killed before six months of age (Supplemental Table 3). Additionally, 12 specimens lacking fusion data exhibited a porous cortical surface. They also correspond in size to the smaller unfused specimens and appear to be from young birds likely culled well before their fourth month. Although juvenile chicken remains cannot be sexed, we believe that most if not all of the immature specimens belong to males. Very little data exists on the ratios of adult/juvenile chickens from North American sites. Simons's (1984) analysis of chicken remains from early twentieth-century Chinese-American communities at Ventura, California, and Lovelock, Nevada, point to equal proportions of adult and juvenile chickens.

The proportion of juvenile chickens in medieval and post-medieval European sites is more comparable to that of the San Diego Presidio, with over 20% of specimens from immature chickens (Moreno-García and Detry 2010; Serjeantson 2009:81).

Female/Male Ratio

We examined the chicken assemblage for spurs. Of 21 complete or partial tarsometatarsi, 15 specimens retained the distal end where large bone spurs typically develop in roosters and capons. None showed evidence of spurs, something not uncommon in zooarchaeological assemblages (Moreno-García and Detry 2010).

In our assessment of male/female ratio in the domestic fowl assemblage, we used two osteometric datasets: greatest breadth and length (Supplemental Table 4). Mixture analysis of the greatest breadth ($n = 90$) detected two groups of what appear to be female and male chickens at a ratio of 12:1 (Table 3; Figure 3). Mixture analysis of the greatest length ($n = 42$) detected three groups: males, females, and most likely a smaller breed of chicken (Table 3; Figure 4). The female/male ratio in this dataset is 5:1. All measurable specimens, including those containing medullary bone, were included in the mixture analysis modeling. None of the specimens identified as males in the mixture analysis contained medullary bone.

The smaller specimens, which were detected by the mixture analysis of the greatest length but not by that of the greatest breadth, suggest that the shorter specimens belong to a short-legged breed, probably the "creeper" bantam (Figure 5; Dunnington and Siegel 1991; Gordon et al. 2015). This correlates with evidence of smaller chicken breeds reported from European archaeological sites from the Roman period (Benecke 1993; Corona 2010; De Cupere et al. 2005) and from Spanish Florida (Reitz et al. 1985:71).

All avian remains, including 126 chicken specimens, were inspected for medullary bone. Of note are a barn owl (*Tyto alba*) tibiotarsus and redhead duck (*Aythya americana*) coracoid that also contained medullary bone. Among the 126 chicken specimens, 29 unfused or fragmented distal or proximal articular ends insufficient for determining the presence or absence of medullary bone were excluded from the analysis. Of the

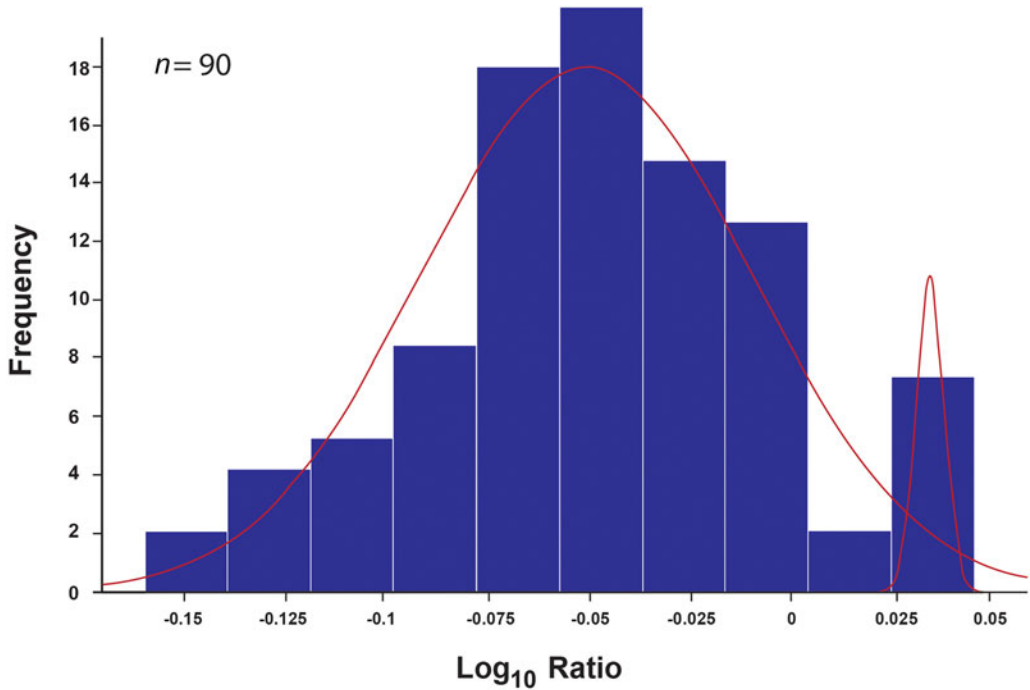


Figure 3. Distribution of the greatest breadth (Bp, Bd, Did, Dip) of long bones with corresponding results of mixture analysis ($n = 90$). The arches highlight the two groups detected. The larger group of smaller specimens (left) represents females, and the smaller group of larger specimens (right) represents males. The figure was produced with PAST 3.21 software.

97 remaining adult chicken specimens, 53% ($n = 51$) contained medullary bone (Supplemental Table 5). If we calculate the proportion of females identified from medullary bone identified through mixture analysis (see above), the percentage of egg-laying hens increases to 61% (51 out of 83; Table 3). It should be remembered that medullary bone occurs in chickens for a short time—during the egg-laying period—and it is fundamentally weaker than structural cortical bone (Whitehead 2004). Therefore, archaeological preservation of medullary bone should be relatively low. The high percentage of medullary bone in the present study provides strong evidence that chickens were utilized for egg production. It also suggests that a significant number of the older hens, whose productivity was decreasing, were culled (Van Neer et al. 2002).

Medullary bone in chickens has been reported from historic sites in the southeastern United States (Reitz et al. 1985:83; Rick 1975), but no quantitative data from western North American sites are available for comparison. Most data on

zoarchaeological medullary bone come from Europe and the Middle East. In Britain, Serjeantson (2009:283–284) noted an increase in the incidence of medullary bone from Roman times through the Middle Ages, from 20% to 66%. Moreno-García and Detry (2010) reported that 27% of the chicken-bone assemblage from a seventeenth-century monastery in Portugal contained medullary bone. The average proportions of fowl limbs with medullary bone from the Roman sites of Berenike on the Red Sea coast and Sagalassos in western Turkey were close to 66% and 54%, respectively (De Cupere et al. 2005; Van Neer et al. 2002). Biological and zooarchaeological studies indicate that skeletal elements with a rich blood supply also accumulate the greatest quantity of medullary bone (Canoville et al. 2019; Rick 1975; Van Neer et al. 2002; Whitehead 2004). Our data from the San Diego Presidio support this notion: three elements in particular—the tibiotarsus, femur, and ulna—contained high proportions of medullary bone at 80%, 75%, and 54%, respectively.

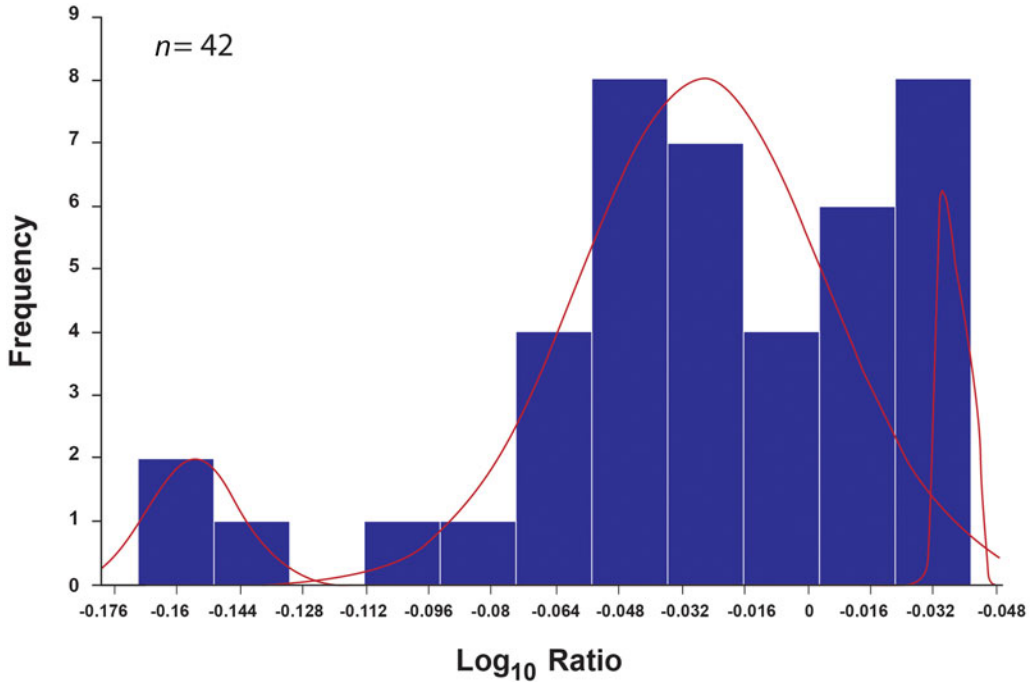


Figure 4. Distribution of the greatest length (GL) of long bones with corresponding results of mixture analysis ($n = 42$). The arches highlight three groups detected. The smaller group of longer bones (right) represents males, the larger group of shorter specimens (middle) represents females, and the small group of very short specimens (left) likely represents short-legged bantam. The figure was produced with PAST 3.21 software.



Figure 5. Chicken ulnae: (top) bantam chicken from north wing, Room10; (middle) normal-size chicken from north wing, Room 5; (bottom) modern chicken from the San Diego Natural History Museum collection. (Color online)

Body-Part Representation and Butchering

Differential disposal of butchering and consumption waste is evident among the San Diego Presidio chicken remains. Head bones and phalanges account for only 9% of chicken



Figure 6. Medullary bone (marked by arrow) in chicken tibiotarsus from the Gateway area, unit QR21, level 182–198 cm. (Color online)

elements, suggesting that they were not generally discarded with food waste (Supplemental Table 6; Figure 7). The phalanges include those of both the foot (NISP = 20) and the wing (NISP = 4). Seven foot phalanges (four first phalanges; three second phalanges), from the midden outside the western wall, were most likely articulated upon deposition, supporting the notion that head and toes were discarded prior to the preparation and consumption of the meat-bearing portions of the bird. Nearly even

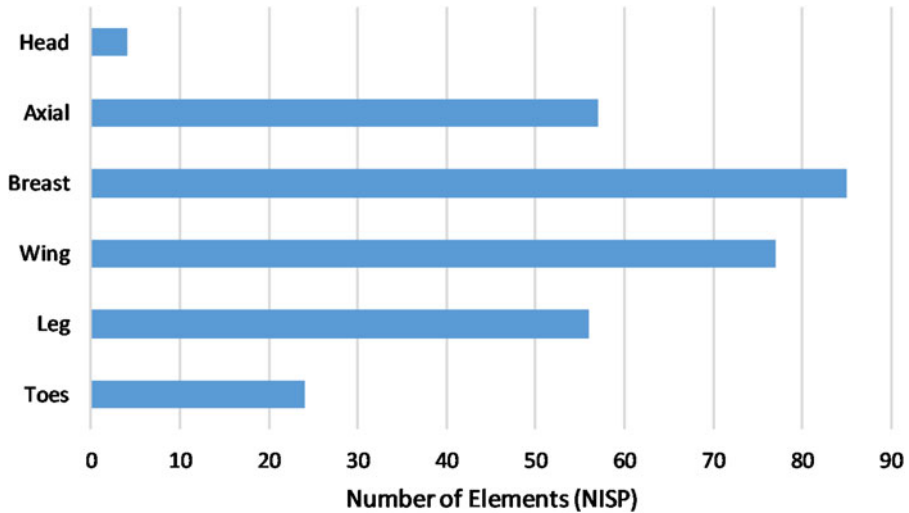


Figure 7. Chicken body-part representation.



Figure 8. Chicken axial skeleton and limb bones from the north wing, Building 2, Room 5. Elements sectioned for medullary bone inspection are marked by circles; cut marks are marked by arrows. (Color online)

representation of other body-part categories (axial, breast, leg, and wing) points to consumption of whole chickens, rather than merely legs and wings (Supplemental Table 6; Figures 7 and 8). As with other criteria for assessing chicken husbandry, discussed above, very little comparative data exists on chicken body-part representation from North American sites. A

study of chicken body-part representation from the early nineteenth-century Ontiveros Adobe in Santa Fe Springs, California, also notes the scarcity of head and foot bones, suggesting that these elements were disposed of separately from kitchen consumption refuse (Gust 1982).

All 17 recorded butchery scars (cleave and cut marks) were observed on specimens identified as



Figure 9. Cut marks (marked by arrows) on chicken coracoid from the north wing, Building 2, Room 5. Sectioning of the coracoid for medullary bone inspection is marked by an oval line. (Color online)

consumption waste. Close to 70% of the scars were on breast bones associated with disarticulation of the furcula, coracoid, and scapula—three elements bound at the shoulder by tenacious ligaments (Figure 9).

Other Fauna

The remains of wild birds in the bone assemblage from the San Diego Presidio include four species of raptors and eight of waterfowl (Table 1). The range of species reflects exploitation of a variety of local habitats including coastal bays, fresh- and saltwater estuaries, brush and grasslands, river bottoms, and environs ranging from coastal slopes to local mountain ranges (Unitt 2004).

Two species among the wild avifauna are worth comment. The American crow (*Corvus brachyrhynchos*) was unrecorded around San Diego from the 1870s until the 1980s, making its presence at the presidio in the late eighteenth to early nineteenth century surprising (Arter et al. 2018; Unitt 2004:381). The sandhill crane (*Grus canadensis*) no longer exists in San Diego County, but it was reported in the nineteenth century, flying over in significant numbers during spring and fall migrations. The presidio specimen represents the only physical evidence of cranes in this region (Arter et al. 2018; Unitt 2004:190–191).

Non-avian bone specimens ($n = 321$) include 16 species of wild and domesticated animals (Supplemental Table 1). Wild species include rabbit, hare, squirrel, and fish. Cattle, sheep, goat, pig, dog, and cat remains are also represented. Since our focus is on avian remains, the non-avian species are not further discussed here.

Discussion and Conclusions

California presidios were not economically self-sufficient. They were provisioned with livestock and a variety of goods from Mexico and, later, from nearby missions. Zooarchaeological analysis of chicken remains from the San Diego Presidio provides key insights into the important role of chickens both in the colonial Spanish subsistence economy and on husbandry practices within the presidios.

In traditional poultry husbandry, females are kept for reproduction and egg production, and males are culled (Blackie 2014; Van Neer et al. 2002). Consequently, if mission provisioning included regular transfer of chickens to the presidios, a high proportion of hens would be expected at the provisioning site (missions) and a high proportion of males at the provisioned site (presidios). Zooarchaeological data from the San Diego Presidio indicate the opposite; the representation of females in the death assemblage is significantly higher than males. Moreover, various criteria examined in this study—including the male/female ratio, adult/juvenile ratio, and relative proportion of egg-laying hens at the presidio—reflect on-site, small-scale chicken husbandry focused on meat and egg production. The osteometric data indicate an approximate average ratio of 8.5 hens to 1 rooster, suggesting that most males were culled at a young age, whereas most females were kept alive. The medullary bone data suggest that when hens' productivity declined, they were culled and eaten. Cut marks on two specimens with medullary bone support this interpretation. The age data indicate that nearly one-quarter of specimens were immature, which suggests that most of these juveniles were males. This could also explain the small percentage of adult males in the death assemblage.

Body-part representation suggests that, with the exception of the head and toes, nearly the entire chicken was consumed—consumption habits similar to those we see today. The fact that only 1.6% of the chicken bones were burnt provides additional evidence that chickens were roasted whole and that their bones were generally not exposed to fire. In addition, based on the medullary bone and the mixture analysis data,

61% of specimens were from egg-laying hens—a clear indication that chickens were raised at the San Diego Presidio for their eggs as well as for meat.

Studies of small-scale poultry production in developing countries show that all families at the village level are owners of poultry (Mack et al. 2007). Small-scale poultry production is maintained mainly by women with very low inputs (i.e., land, labor, and capital) while providing the population with dependable and readily harvested meat and eggs. This constitutes a vital source of protein for immediate home consumption as well as a valuable source of barter or income (Blackie 2014; Copland and Alders 2009; Guèye 2000; Sonaiya 2009). Poultry husbandry in developing countries is a practical and viable option for poverty alleviation. It allows for a quick return to productivity after environmental disasters, wars or, recently, pandemics, and it can be adapted to many different agroecological zones (Copland and Alders 2009; Guèye 2000; Mack et al. 2007; Sonaiya 2009).

Chickens obtain most of their diet from their immediate environment by scavenging for earthworms, insects, and household refuse. They play an important role in pest control and provide organic fertilizer (Abubakar et al. 2007; Copland and Alders 2009; Guèye 2000; Redding 2015; Webster 1899). Moreover, according to Redding (2015), in subsistence-based systems, chickens have a major advantage over almost every other domesticated animal in converting the food they ingest into protein. For example, production of chicken meat is two to three times more efficient than that of pig meat, and it is four to six times more efficient than meat production from cattle and sheep. Chickens also require less water (3,500 L) to produce 1 kg of meat than do pigs (6,000 L), cattle (43,000 L), or sheep (51,000 L). In addition, the chicken is a smaller “meat package” than most other domesticates, and a household can consume a chicken within 24 hours.

We believe that the extraordinary attributes of poultry production in developing countries are applicable to the small-scale chicken husbandry practiced by the inhabitants of the California presidios. Since the presidios were reliant on food supplied from Mexico and missions nearby, it

is very likely that the Spanish government was favorable toward the presidios raising chickens. Small-scale chicken husbandry could help alleviate food insecurity experienced by the presidio families while ultimately providing a form of economic independence. It is reasonable to assume that the presidio chickens were managed by women and children as a low-investment garden crop, providing high-value protein and a possible source of barter or income. We argue that poultry husbandry at the presidios also played an important role in household disaster-mitigation strategies (e.g., drought).

Interestingly enough, it seems that chickens were rather “invisible” when it came to enumerating livestock animals in the historical documentation of early California (Archibald 1978:178; for similar observation from Spanish Florida, see Reitz et al. [1985:71]). For example, a zooarchaeological study from deposits at the Mission Basilica San Diego de Alcalá, which was established contemporaneously with the San Diego Presidio, shows that chicken constituted 7% of the mission’s livestock remains (Sasson 2014). However, the inventories of livestock at the San Diego Mission in 1773 (Palóu 1926:216–217), 1777 (Engelhardt 1920:91–92), and 1783 (Kenneally 1965:93) enumerated cattle, sheep, goats, hogs, horses, and mules but neglected to mention chickens. Moreover, the “invisibility” of chicken is rather curious since our survey of historical documents describing early California suggests that chickens and eggs were common commodities in the presidios and missions (Bancroft 1888:628; Engelhardt 1912:602; Pourade 1961:217; Richman 1911:350; Webb 1952:189). Historical accounts note that ships anchored at San Diego, and travelers passing by the presidio or mission, were provisioned with chickens (Archibald 1978:106; Bancroft 1885:12, 1888:274; Pourade 1961:96; Serra 1955:1345). Redding (2015) suggests, with regard to pigs in the ancient Near East, that what the textual record reflects is what the central authority and bureaucrats valued as important. Hence, garden crops, such as chicken and pigs, managed by women, were generally not of interest to the central administration and were not central to the system-wide redistributive economy. This bureaucratic oversight does not,

however, preclude chickens from playing an important role in the presidio subsistence system.

Historical accounts about price regulations in Spanish California yield insight into the value of a chicken in AD 1781. Commodities supplied to soldiers in California presidios were charged against their wages, and the Spanish government had an interest in keeping food prices low. A price-fixing list indicates that the cost of a single hen (2.5 reales) was equivalent to the price of a suckling kid goat, five rabbits, or five pounds of cheese. A single hen was valued higher than a dozen quail or a pair of pigeons (Mosk 1938; see also Hackel 1997; Hittell 1897:534; Sánchez 1990). The fact that the price of hens was regulated may suggest that presidio families supplemented their income selling chickens.

Another historical account provides a rare opportunity to compare the results of our zooarchaeological study at the San Diego Presidio against statistical data in the historical record. Fermín de Francisco Lasuén arrived in Baja California in 1768 and ultimately founded eight missions in Alta California. In 1773, during his visit to Mission San Francisco Borja in Baja California Sur, Father Lasuén generated an inventory of the mission and noted, “Also, chicken run with two roosters and eighteen hens” (Kenneally 1965:28). This rare account from San Borja indicates husbandry focused on hens with a 1:9 rooster/hen ratio, which supports our conclusion that small-scale chicken husbandry was practiced at the presidios. The similarity between the data from San Borja and our osteometric analysis is striking. Our mixture analysis yielded an average rooster/hen ratio of 1:8.5 (1:12 based on the greatest breadth, and 1:5 based on the greatest length)—nearly equal to the ratio from the historical account.

Historical records also indicate that during the early years at the San Diego Presidio, soldiers were supplied powder and shot for hunting local wild birds to supplement their meager dietary rations (Mason 1978). This may explain the extraordinary number of wild avian species identified in our bone assemblage, including eight taxa of waterfowl (Table 1).

It is quite evident that once the Spanish colonists introduced domestic fowl to Alta California, chickens became an integral part of the

subsistence economy (Archibald 1978:160; Bancroft 1888:364). Mass production of chicken meat and eggs was feasible only with the introduction of commercial artificial incubation in the late 1800s (Christenson 1993; Lawler 2014:204; Simons 1980, 1984). Commercial poultry production required large capital inputs, technological investment, and much broader markets (Copland and Alders 2009). Backyard poultry husbandry on the other hand, proved to be an easy, viable, and reliable source of meat, eggs, and supplemental income for the smallholder, and it is not surprising that it continued to be practiced concurrent with commercial poultry production (Sasson 2017; Schulz et al. 1987; Schweitzer 2010; Simons 1984; Szuter 1996).

This article represents the first comprehensive study of chicken remains from a Spanish-era site in colonial North America. As discussed above, we posit that chickens were consequential to the food security of the early California settlers. Further zooarchaeological studies, however, are much needed to better document, interpret, and understand the nature and extent of the role chickens played in Spanish colonial economies.

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Data Availability Statement. The faunal remains discussed here are presently housed at the Zooarchaeology Laboratory, San Diego Natural History Museum. They are on loan from the City of San Diego.

Supplementary Materials. For supplementary material accompanying this article, visit <https://doi.org/10.1017/aaq.2020.27>.

Supplemental Table 1. Non-Avian NISP, Number of Bones per Size-Group, and Modification Marks.

Supplemental Table 2. Chicken Skeletal Elements NISP and Their Bone-Density Values (Density data from Dirrigl 2001).

Supplemental Table 3. Chicken Age at Death.

Supplemental Table 4. Measurements of Chicken Long Bones.

Supplemental Table 5. Chicken Medullary Bone Data (Medullary bone detected = M+; No medullary bone = M-; Questionable medullary bone = M?).

Supplemental Table 6. Relative Frequency of Skeletal Elements and Number of Elements with Butchery Marks.

References Cited

- Abubakar, Mustapha, Abdul-Ganiyu Ambali, and Tarik Tamjdo
2007 Rural Chicken Production: Constraints Limiting Rural Chicken Production in Some Areas of Nigeria and Cameroon. *Family Poultry* 17(1):57–62.
- Aiken, S. Robert
1983 The Spanish Missions of Alta California Rise, Decline, and Restoration. *Pioneer America* 15:3–19.
- Archibald, Robert
1978 *The Economic Aspects of the California Missions*. Academy of American Franciscan History, Washington, DC.
- Arter, Susan, Aharon Sasson, and Philip Unitt
2018 Avifaunal Change in Southern California from an Archaeological Perspective. In *Trends and Traditions: Avifaunal Change in Western North America*, edited by David Shuford, Robert Gill Jr., and Colleen Handel, pp. 442–452. Studies of Western Birds 3. Western Field Ornithologists, Camarillo, California.
- Bancroft, Hubert Howe
1885 *History of the Pacific States of North America: California*. A.L. Bancroft, San Francisco.
1888 *California Pastoral, 1769–1848*. History Company, San Francisco.
- Barbolla, Diane E.
1992 Alta California Troops: Acculturation and Material Wealth in a Presidio and Mission Context, 1769–1810. PhD dissertation, Department of Anthropology, University of California, Riverside.
- Bartel, Brad
1991 Archaeological Excavation and Education at the San Diego Royal Presidio, 1987–1990. *Journal of San Diego History* 37:1–30.
- Benecke, Norbert
1993 On the Utilization of the Domestic Fowl in Central Europe from the Iron Age up to the Middle Ages. *Archaeofauna* (2):21–31.
- Benté, Vance G., Judith D. Tordoff, and Mary Hilderman-Smith
1982 *Phase VIII: Archaeological Excavations of the Chapel Site CA-SBA-133*. Submitted to the Santa Barbara Trust for Historic Preservation, Santa Barbara, California.
- Blackie, Seth
2014 Village Chicken Production System in the Greater Accra Region Ghana. *Journal of Biology, Agriculture and Healthcare* 4(9):89–94.
- Blind, Eric B., Barbara L. Voss, Osborn. S. Kenton, and Leo R. Barker
2004 El Presidio De San Francisco: At the Edge of Empire. *Historical Archaeology* 38(3):135–149.
- Boessneck, Joachim, and Angela von den Driesch
1979 *Eketorp: Befestigung und Siedlung auf Öland/Schweden: Die Fauna*. Almqvist & Wiksell, Stockholm.
- Bovy, Kristine M.
2012 Why So Many Wings? A Re-examination of Avian Skeletal Part Representation in the South-Central Northwest Coast, USA. *Journal of Archaeological Science* 39:2049–2059.
- Canoville, Aurore, Mary H. Schweitzer, and Lindsay E. Zanno
2019 Systemic Distribution of Medullary Bone in the Avian Skeleton: Ground Truthing Criteria for the Identification of Reproductive Tissues in Extinct Avemetatarsalia. *BMC Evolutionary Biology* 19(1):71. DOI:10.1186/s12862-019-1402-7.
- Cheever, Dayle M.
1983 An Historical Faunal Analysis: Large Mammal Utilization at the San Diego Presidio. Master's thesis, Department of Anthropology, San Diego State University, San Diego, California.
- Christenson, Lynne
1993 Appendix A: Analysis of Faunal and Botanical Remains and Inferences on Hedges/Tumco Dietary Habits. In *Hedges/Tumco: Historic Mining Traditions of Southeastern California*, edited by Claudia B. Hemphill, pp. 1–18. Burney and Associates, Boulder, Colorado.
- Church, Lloyd E., and Lent C. Johnson
1964 Growth of Long Bones in the Chicken: Rates of Growth in Length and Diameter of the Humerus, Tibia, and Metatarsus. *American Journal of Anatomy* 114:521–538.
- Cohen, Alan, and Dale A. Serjeantson
1996 *Manual for the Identification of Bird Bones from Archaeological Sites*. Archetype Press, London.
- Copland, John W., and Robyn G. Alders
2009 The Comparative Advantages of Village or Smallholder Poultry in Rural Development. In *Village Chickens, Poverty Alleviation and the Sustainable Control of Newcastle Disease*, edited by Robyn G. Alders, Peter B. Spradbrow, and Mary P. Young, pp. 11–15. Australian Centre for International Agricultural Research, Canberra.
- Corona, Eduardo
2010 Small Domestic Fowl in a Roman Site from Spain (Veranes, Asturias). In *Birds in Archaeology: Proceedings of the 6th Meeting of the ICAZ Bird Working Group in Groningen*, edited by Wietske Prummel, Jørn T. Zeiler, and Dick C. Brinkhuizen, pp. 23–28. Barkhuis, Groningen, The Netherlands.
- Davis, Simon J. M.
1996 Measurements of a Group of Adult Female Shetland Sheep Skeletons from a Single Flock: A Baseline for Zooarchaeologists. *Journal of Archaeological Science* 23:593–612.
- De Cupere, Bea, Wim Van Neer, Hervé Monchot, Elina Rijmenants, Mircea Udrescu, and Marc Waelkens
2005 Ancient Breeds of Domestic Fowl (*Gallus Gallus F. Domesticus*) Distinguished on the Basis of Traditional Observations Combined with Mixture Analysis. *Journal of Archaeological Science* 32:1587–1597.
- Dirrigl, Frank J., Jr.
2001 Bone Mineral Density of Wild Turkey (*Meleagris Gallopavo*) Skeletal Elements and Its Effect on Differential Survivorship. *Journal of Archaeological Science* 28:817–832.
- Dong, Zhuan
1997 Mixture Analysis and Its Preliminary Application in Archaeology. *Journal of Archaeological Science* 24:141–161.
- Dunnington, E. Anne, and Paul B. Siegel
1991 Genetic Analyses of Bantam and Selected Low-Weight White Plymouth Rock Chickens and Their

- Crosses: 1. Growth, Immuno-responsiveness and Carcass Characteristics. *Genetics Selection Evolution* 23(2):141. DOI:10.1186/1297-9686-23-2-141.
- Engelhardt Zephyrin
1912 *The Missions and Missionaries of California*. James H. Barry Company, San Francisco, California.
- Engelhardt, Zephyrin
1920 *San Diego Mission*. James H. Barry, San Francisco.
- Ericson, Per G. P.
1987 Interpretations of Archaeological Bird Remains: A Taphonomic Approach. *Journal of Archaeological Science* 14:65–75.
- Ezell, Paul
1976 The Excavation Program at the San Diego Royal Presidio. *Journal of San Diego History* 22:1–20.
- Fernández, Hermógenes, and Hervé Monchot
2007 Sexual Dimorphism in Limb Bones of Ibex (*Capra ibex L.*): Mixture Analysis Applied to Modern and Fossil Data. *International Journal of Osteoarchaeology* 17:479–491.
- Forbes, Alexander
1839 *California: A History of Upper and Lower California from Their Discovery to the Present Time*. Smith, Elder and Company, London.
- Fothergill, Tyr B., Julia Best, Alison Foster, and Beatrice Demarchi
2017 Hens, Health and Husbandry: Integrated Approaches to Past Poultry-Keeping in England. *Open Quaternary* 3:5. DOI:10.5334/oq.34.
- Gál, Erika
2006 The Role of Archaeo-Ornithology in the Environmental and Animal History Studies. In *Archaeological and Cultural Heritage Preservation*, edited by Erzsébet Jerem, Zsolt Mester, and Benczes Réka, pp. 49–61. Archaeolingua, Budapest.
- Geiger, Maynard
1963 Fray Junípero Serra: Organizer and Administrator of the Upper California Missions, 1769–1784. *California Historical Society Quarterly* 42:195–220.
- Gordon, Rebecca, Richard Thomas, and Alison Foster
2015 The Health Impact of Selective Breeding in Poultry: A Probable Case of “Creepers” Chicken (*Gallus Gallus*) from 16th-Century Chester, England. *International Journal of Paleopathology* 9:1–7.
- Guèye, El Hadji Fallou
2000 Women and Family Poultry Production in Rural Africa. *Development in Practice* 10:98–102.
- Gust, Sherri M.
1982 Faunal Analysis and Butchering. In *The Ontiveros Adobe: Early Rancho Life in Alta California*, edited by Jay D. Frierman, pp. 101–144. Report on file at Greenwood and Associates, Pacific Palisades, California.
- Haber, Annat, and Tamar Dayan
2004 Analyzing the Process of Domestication: Hagoshrim as a Case Study. *Journal of Archaeological Science* 31:1587–1601.
- Hackel, Steven W.
1997 Land, Labor, and Production: The Colonial Economy of Spanish and Mexican California. *California History* 76:111–146.
- Hammer, Øyvind, David A. T. Harper, and Paul D. Ryan
2001 PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica* 4:1–9. Electronic document, https://palaeo-electronica.org/2001_1/past/past.pdf, accessed April 24, 2020.
- Hittell, Theodore Henry
1897 *History of California, Volume I*. N. J. Stone, San Francisco.
- Kenneally, Finbar (editor)
1965 *Writings of Fermin Francisco De Lasuen*. 2 vols. Academy of American Franciscan History, Washington, DC.
- Kysely, René
2010 Review of the Oldest Evidence of Domestic Fowl *Gallus Gallus f. Domestica* from the Czech Republic in Its European Context. *Acta Zoologica Cracoviensia - Series A: Vertebrata* 53:9–34.
- Langdon, Robert
1989 When the Blue-Egg Chickens Come Home to Roost: New Thoughts on the Prehistory of the Domestic Fowl in Asia, America and the Pacific Islands. *Journal of Pacific History* 24:164–192.
- Latimer, Homer B.
1927 Postnatal Growth of the Chicken Skeleton. *American Journal of Anatomy* 40:1–57.
- Latimer, Homer B., and John A. Rosenbaum
1926 A Quantitative Study of the Anatomy of the Turkey Hen. *Anatomical Record* 34:15–23.
- Lawler, Andrew
2014 *Why Did the Chicken Cross the World? The Epic Saga of the Bird That Powers Civilization*. Simon and Schuster, New York.
- Lucido, Jennifer A.
2013 Decoding the Bones: Spanish Colonial Butchering Practices at the Royal Presidio of Monterey. *Boletín* 29 (1):60–77.
- Lyman, Robert L.
1977 Analysis of Historic Faunal Remains. *Historical Archaeology* 11:67–73.
1994 *Vertebrate Taphonomy*. Cambridge University Press, New York.
- Mack, Simon, Dennis Hoffmann, and Joachim Otte
2007 The Contribution of Poultry to Rural Development. *World's Poultry Science Journal* 61:7–14.
- Maltby, Mark
1997 Domestic Fowl on Romano-British Sites: Inter-Site Comparisons of Abundance. *International Journal of Osteoarchaeology* 7:402–414.
- Mason, Bill
1978 The Garrisons of San Diego Presidio: 1770–1794. *Journal of San Diego History* 24:399–424.
- Miles, Gilbert B., Larry D. Martin, and Howard G. Savage
1985 *Avian Osteology*. Modern Printing Company, Laramie, Wyoming.
- Monchot, Hervé, and Jacques Léchelle
2002 Statistical Nonparametric Methods for the Study of Fossil Populations. *Paleobiology* 28:55–69.
- Moreno-García, Marta, and Cleia Detry
2010 The Dietary Role of Hens, Chickens and Eggs among a 17th-Century Monastic Order: The Clarisse of Santa Clara-a-Velha, Coimbra (Portugal). In *Birds in Archaeology: Proceedings of the 6th Meeting of the ICAZ Bird Working Group in Groningen*, edited by Wietske Prummel, Jørn T. Zeiler, and Dick C. Brinkhuizen, pp. 45–55. Barkhuis, Groningen, The Netherlands.
- Mosk, Sanford A.
1938 Price-Fixing in Spanish California. *California Historical Society Quarterly* 17:118–122.
- Myers, Philip, Roger Espinosa, Cynthia S. Parr, Tricia Jones, George M. S. Hammond, and Tanya A. Dewey
2018 The Animal Diversity Web. Electronic document,

- <http://www.animaldiversity.org>, accessed August 4, 2017.
- Palóu, Francisco
1926 *Historical Memoirs of New California*. 4 vols. University of California Press, Berkeley.
- Pavao-Zuckerman, Barnett
2011 Rendering Economics: Native American Labor and Secondary Animal Products in the Eighteenth-Century Pimería Alta. *American Antiquity* 76:3–23.
- Payne, Sebastian, and Gail Bull
1988 Components of Variation in Measurements of Pig Bones and Teeth, and the Use of Measurements to Distinguish Wild from Domestic Pig Remains. *Archaeozoologia* 2:27–65.
- Perry-Gal, Lee, Adi Erlich, Ayelet Gilboa, and Guy Bar-Oz
2015 Earliest Economic Exploitation of Chicken outside East Asia: Evidence from the Hellenistic Southern Levant. *Proceedings of the National Academy of Sciences of the United States of America* 112:9849–9854.
- Pitt, Jacqueline, Phillipa K. Gillingham, Mark Maltby, and John R. Stewart
2016 New Perspectives on the Ecology of Early Domestic Fowl: An Interdisciplinary Approach. *Journal of Archaeological Science* 74:1–10.
- Pourade, Richard F.
1961 *Time of the Bells: The History of San Diego*. Union-Tribune Publishing Company, San Diego.
- Redding, Richard W.
2015 The Pig and the Chicken in the Middle East: Modeling Human Subsistence Behavior in the Archaeological Record Using Historical and Animal Husbandry Data. *Journal of Archaeological Research* 23:325–368.
- Reitz, Elizabeth J., C. Margaret Scarry, and Donna J. Seifert
1985 *Reconstructing Historic Subsistence with an Example from Sixteenth-Century Spanish Florida*. Society for Historical Archaeology, Glassboro, New Jersey.
- Reitz, Elizabeth J., and Elizabeth S. Wing
2008 *Zooarchaeology*. Cambridge University Press, Cambridge.
- Richman, Irving Berdine
1911 *California under Spain and Mexico, 1535–1847*. Houghton Mifflin, Boston.
- Rick, Anne M.
1975 Bird Medullary Bone: A Seasonal Dating Technique for Faunal Analysts. *Canadian Archaeological Association Bulletin* 7:183–190.
- Sadler, Peta
1991 The Use of Tarsometatarsi in Sexing and Ageing Domestic Fowl (*Gallus Gallus L.*), and Recognising Five Toed Breeds in Archaeological Material. *Circaea* 8:41–48.
- Sánchez, Joseph P.
1990 *Spanish Bluecoats: The Catalan Volunteers in Northwestern New Spain, 1767–1810*. University of New Mexico Press, Albuquerque.
- Sasson, Aharon
2010 *Animal Husbandry in Ancient Israel, a Zooarchaeological Perspective on Livestock Exploitation, Herd Management and Economic Strategies*. Routledge, New York.
- 2011 Faunal Remains from the Carrillo Ranch House and Warner's Trading Post. In *Two Forks in the Road: Test Excavations of the Ranch House at Warner's Ranch (Warner – Carrillo Ranch House) and Site of Jonathan T. Warner's House and Store*, edited by Stephen R. Van Wormer and Susan D. Walter, pp. 30–58. Vol. III. Walter Enterprises, Chula Vista, California.
- 2014 *Faunal Remains from the Central Fountain Area at Mission San Diego De Alcalá (CA-SDI-35), San Diego, California*. Report on file at Mission Basilica San Diego de Alcalá. Copies available from San Diego Zooarchaeology Laboratory, San Diego.
- 2017 Zooarchaeology of Urban San Diego: The Vertebrate and Invertebrate Remains from F & 11th Avenue (CA-SDI-22034). In *Historical and Archaeological Investigations of SDI-22034, Block 55 (334) of the City of San Diego Horton's Addition Subdivision*, edited by Stephen Van Wormer, Susan D. Walter, and Mary Robbins Wade, pp. 1–33. San Diego, California. Report on File at HELIX Environmental Planning. Copies available from San Diego Zooarchaeology Laboratory, San Diego, California.
- Schulz, Peter D., Ronald Quinn, and Scott Fulmer
1987 Archaeological Investigations at the Rose-Robinson Site, Old Town San Diego *Pacific Coast Archaeological Society Quarterly* 23(2):1–51.
- Schweitzer, Teagan A.
2010 Philadelphia Foodways ca. 1750–1850: An Historical Archaeology of Cuisine. PhD dissertation, Department of Anthropology, University of Pennsylvania, Philadelphia.
- Serjeantson, Dale A.
2009 *Birds*. Cambridge Manuals in Archaeology. Cambridge University Press, New York.
- Serra, Junípero
1955 *Writings of Junípero Serra, Volume II*. Edited and translated by Antonine Tibesar. Academy of American Franciscan History, Washington, DC.
- Simons, Dwight D.
1980 Bird Remains. In *Historical Archaeology at the Golden Eagle Site*, edited by Mary Praetzellis, Adrian Praetzellis, and Marley R. Brown III, pp. 1–13. Sonoma State University, California.
- 1984 Avifaunal Remains at the Woodland Opera House Site. In *The Chinese Laundry on Second Street: Papers on Archaeology at the Woodland Opera House Site*, Vol. 24, edited by David L. Felton, pp. 167–180. California Department of Parks and Recreation, Sacramento.
- Simpson, George G., Anne Roe, and Richard C. Lewontin
1960 *Quantitative Zoology*. Harcourt Brace, New York.
- Slavin, Philip
2009 Chicken Husbandry in Late-Medieval Eastern England: C. 1250–1400. *Anthropozoologica* 44(2):35–56.
- Smith-Lintner, Cheryl A.
2007 *Becoming Californio: Archaeology of Communities, Animals, and Identity in Colonial California*. PhD dissertation, Department of Anthropology, University of California, Berkeley.
- Sonaiya, Emmanuel Babafunso
2009 Fifteen Years of Family Poultry Research and Development at Obafemi Awolowo University, Nigeria. In *Village Chickens, Poverty Alleviation, and the Sustainable Control of Newcastle Disease*, edited by Robyn Alders, Peter B. Spradbrow, and Marry P. Young, pp. 15–26. Australian Centre for International Agricultural Research, Canberra.
- Sykes, Naomi
2012 A Social Perspective on the Introduction of Exotic Animals: The Case of the Chicken. *World Archaeology* 44:158–169.

- Szuter, Christine R.
1996 Faunal Analysis of Home Butchering and Meat Consumption at the Hubbel Trading Post, Ganado, Arizona. In *Images of the Recent Past: Readings in Historical Archaeology*, edited by Charles E. Orser, pp. 333–354. AltaMira Press, Walnut Creek, California.
- Thomas, Richard, Pamela Sadler, and Joanne Cooper
2014 Developmental Osteology of Cross-Bred Red Junglefowl (*Gallus Gallus L. 1758*) and the Implications for Ageing Chickens from Archaeological Sites. *International Journal of Osteoarchaeology* 26:176–188.
- Thomson, Vicki A., Ophélie Lebrasseur, Jeremy J. Austin, Terry L. Hunt, David A. Burney, Tim Denham, Nicolas J. Rawlence, Jamie R. Wood, Jaime Gongora, Linus Girdland Flink, Anna Linderholm, Keith Dobney, Greger Larson, and Alan Cooper
2014 Using Ancient DNA to Study the Origins and Dispersal of Ancestral Polynesian Chickens across the Pacific. *Proceedings of the National Academy of Sciences of the United States of America* 111:4826–4831.
- Unitt, Philip
2004 *San Diego County Bird Atlas*. Proceedings 39. San Diego Natural History Museum, San Diego, California.
- Valente, Nancy
2002a Appendices E and F: The Vertebrate Assemblage from the Funston Avenue Project, Presidio of San Francisco, Psf Faarp 2000. In *Funston Avenue Archaeological Research Project, Presidio of San Francisco, 2000*, edited by Amy Ramsay and Barbara L. Voss, pp. 1–45. Archaeological Research Facility, University of California, Berkeley.
2002b The Vertebrate Assemblage from R-Block, Unit Ri the Funston Avenue Project, Presidio of San Francisco, Psf Faarp 2000. In *Funston Avenue Archaeological Research Project, Presidio of San Francisco, 2000*, edited by Amy Ramsay and Barbara L. Voss, pp. 1–56. Archaeological Research Facility, University of California, Berkeley.
- Van Neer, Wim, Katrien Noyen, Bea De Cupere, and Ingrid Beuls
2002 On the Use of Endosteal Layers and Medullary Bone from Domestic Fowl in Archaeozoological Studies. *Journal of Archaeological Science* 29:123–134.
- von den Driesch, Angela
1976 A Guide to the Measurements of Animal Bones from Archaeological Sites. *Bulletin of the Peabody Museum of Archaeology and Ethnology* 1:1–136.
- Voss, Barbara L.
2008 *The Archaeology of Ethnogenesis: Race and Sexuality in Colonial San Francisco*. University of California Press, Berkeley.
- Wake, Thomas A.
1996 Appendix A.1: Faunal Bone. In *Archaeological Discovery and Investigation of the Historic Presidio de San Francisco Archaeological Site*, edited by Barbara L. Voss and Vance Benté, pp. A.1-1-A.1-38, Oakland, California. Submitted to U.S. Army Corps of Engineers, Sacramento District. Copies available from Woodward Clyde Consultants.
- Walker, Phillip
1985 Analysis of Faunal Remains. In *Test Excavations in Ten Rooms of the Santa Ines Mission Quadrangle*, Vol. I: Archaeological Research, edited by Julia G. Costello and Janine Gasco pp. 70–79. Copies available from Social Process Research Institute, University of California, Santa Barbara.
- Webb, Edith Buckland
1952 *Indian Life at the Old Missions*. W.F. Lewis, Los Angeles.
- Webster, Richard W.
1899 *The Practical Management of Poultry with a View to Profit: A Guide to Successful Poultry Keeping on a Large or Small Scale*. Simpkin, Marshall, Hamilton, Kent, London.
- West, Barbara
1982 Spur Development: Recognizing Caponized Fowl in Archaeological Material. In *Ageing and Sexing Animal Bones from Archaeological Sites*, edited by Bob Wilson, Sebastian Payne, and Caroline Grigson, pp. 255–261. BAR International Series 109. British Archaeological Reports, Oxford.
- Whitehead, Colin C.
2004 Overview of Bone Biology in the Egg-Laying Hen. *Poultry Science* 83:193–199.
- Williams, Jack S.
1997 Adobe Ramparts: Archaeology and the Evolution of the Presidio of San Diego. *Pacific Coast Archaeological Society Quarterly* 33(4):30–56.
2004a The Evolution of the Presidio in Northern New Spain. *Historical Archaeology* 38(3):6–23.
2004b San Diego Presidio: A Vanished Military Community of Upper California. *Historical Archaeology* 38(3):121–134.
- Wilson, Don E., and DeeAnn M. Reeder (editors)
2005 *Mammal Species of the World: A Taxonomic and Geographic Reference*. 3rd ed. Johns Hopkins University Press, Baltimore, Maryland.

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