

The Holocene

<http://hol.sagepub.com>

**Dogs, humans and island ecosystems: the distribution, antiquity and ecology of domestic dogs
(*Canis familiaris*) on California's Channel Islands, USA**

Torben C. Rick, Phillip L. Walker, Lauren M. Willis, Anna C. Noah, Jon M. Erlandson, René L. Vellanoweth, Todd J.

Braje and Douglas J. Kennett

The Holocene 2008; 18; 1077

DOI: 10.1177/0959683608095579

The online version of this article can be found at:
<http://hol.sagepub.com/cgi/content/abstract/18/7/1077>

Published by:



<http://www.sagepublications.com>

Additional services and information for *The Holocene* can be found at:

Email Alerts: <http://hol.sagepub.com/cgi/alerts>

Subscriptions: <http://hol.sagepub.com/subscriptions>

Reprints: <http://www.sagepub.com/journalsReprints.nav>

Permissions: <http://www.sagepub.co.uk/journalsPermissions.nav>

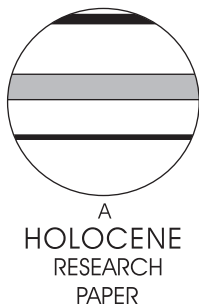
Citations <http://hol.sagepub.com/cgi/content/refs/18/7/1077>

Dogs, humans and island ecosystems: the distribution, antiquity and ecology of domestic dogs (*Canis familiaris*) on California's Channel Islands, USA

Torben C. Rick,^{1*} Phillip L. Walker,³ Lauren M. Willis,² Anna C. Noah,⁴ Jon M. Erlandson,^{5,6} René L. Vellanoweth,⁷ Todd J. Braje⁶ and Douglas J. Kennett⁶

(¹Department of Anthropology, National Museum of Natural History, Smithsonian Institution, Washington DC 20013-7012, USA; ²Department of Anthropology, Southern Methodist University, Dallas TX 75275-0336, USA; ³Department of Anthropology, University of California, Santa Barbara CA 93106-3210, USA; ⁴Cotsen Institute of Archaeology, University of California, Los Angeles CA 90095-1510, USA; ⁵Museum of Natural and Cultural History, University of Oregon, Eugene OR 97403-1224, USA; ⁶Department of Anthropology, University of Oregon, Eugene OR 97403-1218, USA; ⁷Department of Anthropology, Humboldt State University, Arcata CA 95521-8299, USA)

Received 23 October 2007; revised manuscript accepted 8 April 2008



Abstract: Archaeologists have made significant contributions to our understanding of ancient island environments, including the timing and implications of the introduction of non-native animals (pigs, chickens, rats, etc.) by humans. Here, we focus on the historical ecology and biogeography of domestic dogs (*Canis familiaris*) on California's Channel Islands during the Holocene. Dogs are the only animal known unequivocally to have been introduced by Native Americans to the islands, but relatively little is known about their distribution, antiquity or influence on native island fauna and flora. We identified a minimum of 96 dogs from 42 archaeological sites on six of the eight islands. Dogs were present for at least 6000 years and appear to have increased in abundance through time. Our analysis suggests that dogs, along with humans and island foxes (*Urocyon littoralis*), would have had an impact on native animals and ecosystems, especially breeding birds and marine mammals. Dogs and island foxes likely competed with one another for food, however, and the impacts of dogs on island ecosystems may have been reduced by the presence of island foxes and the symbiotic relationship between dogs and humans. Dogs have been removed from all but one of the islands today, eliminating one of the few terrestrial carnivores present for most of the Holocene.

Key words: Dogs, palaeoecology, human environmental impacts, zooarchaeology, *Canis familiaris*, Channel Islands, Holocene.

Introduction

The domestication of animals and plants was a major milestone in human history, when numerous species around the world were selectively bred to increase their value (food, labour, protection, etc.) for people (see Bellwood, 2004; Barker, 2006; Zeder, 2006;

Kennett and Winterhalder, 2006). Developments in the domestication of plants and animals significantly contributed to the acceleration of human population growth and the growing effects of people on Earth's natural ecosystems. A major source of such impacts is related to the translocation (intentional or unintentional) of both wild and domestic animals to new regions of the world. Such biotic introductions often result(ed) in significant alterations in natural landscapes and ecological communities, including numerous extinctions (Kirch and Hunt, 1997; Grayson,

*Author for correspondence (e-mail: trick@smu.edu)

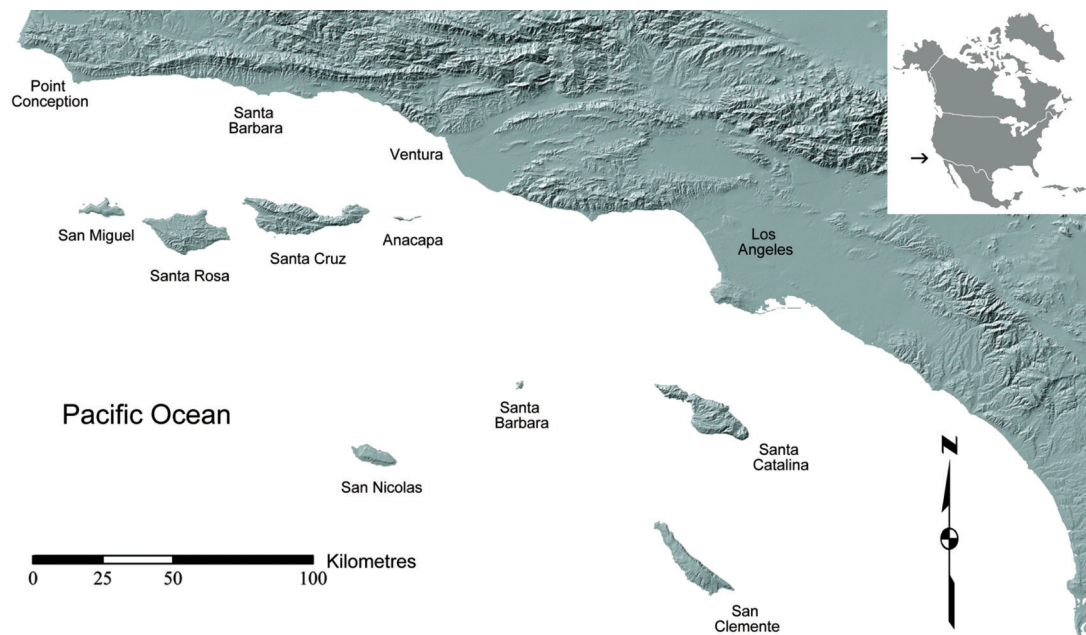


Figure 1 The Channel Islands and southern California Coast

2001; Kirch, 2005), a process that continues to pose costly and global ecological challenges for human societies worldwide.

Some of the best documented cases of ancient animal introductions and their environmental impacts come from islands, specifically analyses of island zooarchaeological and palaeontological collections. On Pacific Islands in Polynesia, for example, the transport of chickens, dogs, pigs and rats had a devastating effect on native floral and faunal communities (Steadman, 1995, 2006; Kirch, 2000, 2005). Rats, often transported unintentionally as stowaways on long ocean voyages and possibly sometimes intentionally introduced, had particularly devastating impacts on local bird populations and played a role in avian extinctions. In Southeast Asia and western Melanesia, hunter-gatherers and later agriculturalists also appear to have carried animals to islands (eg, the Bismarcks, Solomons, Moluccas, Sulawesi and Lesser Sundas) for at least 20 000 years, contributing to very early, but still poorly understood transformations of their endemic landscapes (White, 2004). Introduced domestic and wild animals have also been documented on islands in the Caribbean (dogs, guinea pigs, agouti and hutia), Mediterranean (red deer, wild goats, etc.), North Atlantic (dogs, sheep, pigs, cattle, horses) and beyond, demonstrating similar practices around the world (Grayson, 2001; Newsom and Wing, 2004: 204–208). While domestic dogs may have had less profound ecological consequences than rats and some other animals, they were a predator that often had an impact on naïve insular fauna. In New Zealand, for example, a single feral dog killed over half of a brown kiwi (*Apteryx australis*) colony of 900 birds in about six weeks (Taborsky, 1988), and on the Galapagos Islands feral dogs have been observed to prey heavily on marine iguanas (Kruuk and Snell, 1981). The middle- to late-Holocene introduction of the dingo (*Canis lupus dingo*) to Australia also appears to coincide with significant ecological changes, including the extinction of three vertebrates (see Corbett, 1995; Johnson and Wroe, 2003; Savolainen *et al.*, 2004).

In this paper, we provide evidence for the transport of domestic dogs (*Canis familiaris*) by hunter-gatherers to California's Channel Islands during the Holocene (Figure 1). Dogs are one of the few domestic animals to be found in most areas of the world among hunter-gatherers and agriculturalists. In the Americas, they have a long presence probably spanning at least 10 000–8500

years (Morey and Wiant, 1992; Lupo and Janetski, 1994; Fiedel, 2005; Snyder and Leonard, 2006). Recent mtDNA analysis of modern and ancient dogs around the world points to their domestication about 15 000 years ago in East Asia, with New World dogs currently thought to be derived from Old World populations rather than independently domesticated from American grey wolves (Leonard *et al.*, 2002; Savolainen *et al.*, 2002; Wayne *et al.*, 2006). The available data suggest that dogs were present throughout much of the Americas (Schwartz, 1997) by the early Holocene, including a few potential early Holocene dogs in coastal California (Erlandson, 1994:194, 220, 222).

Owing to excellent archaeological integrity and an archaeological record spanning some 13 000 calendar years, California's Channel Islands provide an important laboratory for investigating animal translocation to islands by foragers, the historical biogeography of domestic dogs, and the effects that dogs may have had on island ecosystems. Archaeologists have known for some time that Native Americans brought dogs to the islands (Schumacher, 1877: 48; Bowers, 1890; Wagner, 1929; Nidever, 1937), but the distribution, antiquity and potential effects of dogs on island ecology have received limited attention. A few researchers have discussed the role of dogs in Channel Island ritual (eg, Collins, 1991a; Raab *et al.*, 1994; Hardy, 2000; Hale and Salls, 2000), but there has been no attempt to assess when dogs were introduced or how widespread they became on these islands. To help fill this void, we synthesize published and unpublished occurrences of Channel Island dogs, including specimens from southern California museums.

Cultural and environmental context

The eight Channel Islands are located between 20 and 98 km off the southern California Coast, and range in size from about 2.6 to 249 km² (Table 1). The islands are divided into northern (Anacapa, Santa Cruz, Santa Rosa and San Miguel) and southern (San Clemente, Santa Catalina, San Nicolas and Santa Barbara) groups, which were never connected to the mainland during the Quaternary. The northern islands are an east–west trending chain along the Santa Barbara Channel, but the southern islands are considerably more dispersed and isolated. All of the islands have a

Table 1 General attributes of the Channel Islands and number of sites known to contain dogs^a

Island	Area (km ²)	Max elevation(m)	Distance from mainland (km)	No. of land mammals	Native plant taxa	No of sites with dogs	Dog MNI ^b
Anacapa	2.9	283	20	2	190	–	–
Santa Cruz	249	753	30	12	480	11	21
Santa Rosa	217	484	44	4	387	3	10
San Miguel	37	253	42	3	198	7	10
Santa Barbara	2.6	149	61	2	88	–	–
Santa Catalina	194	648	32	9	421	1	1
San Nicolas	58	277	98	2	139	13	29
San Clemente	145	599	79	6	272	7	25

^a Physical characteristics based on Schoenherr *et al.* (1999:7).

^b MNI, minimum number of individuals.

Mediterranean climate, with mild summers and generally cool, wet winters, but climatic conditions fluctuated throughout the Holocene (Kennett and Kennett, 2000; Kennett *et al.*, 2007a).

The Channel Islands have a limited terrestrial flora and fauna, lacking many plants and animals found on the mainland (Schoenherr *et al.*, 1999: 7–17). The marine environment surrounding the islands, in contrast, is rich in marine mammals, seabirds, fish and shellfish. Except for the diminutive (roughly house-cat sized) island fox (*Urocyon littoralis*) and spotted skunk (*Spilogale gracilis*), and a few rodents (eg, deer mouse (*Peromyscus maniculatus*)), the islands lack terrestrial mammals. Subspecies of the island fox occur on each of the islands except Anacapa and Santa Barbara. Skunks are currently only found on Santa Cruz and Santa Rosa. Pygmy mammoths roamed the northern islands during the Pleistocene, but it is unclear if they persisted into the human era (see Erlandson *et al.*, 2004; Agenbroad *et al.*, 2005). Vegetation communities on the islands are also distinct, including a number of endemic and relict species, but are generally impoverished compared with mainland communities. The limited terrestrial fauna on the Channel Islands suggests that domestic dogs, along with the people who introduced them, would have had significant effects on potentially naïve native animals, especially breeding marine mammals and seabirds. Collins (1991a, b), Vellanoweth (1998), Kennett (2005: 49) and Rick *et al.* (2008a) have also suggested that island foxes may have been introduced by humans to some or all of the islands, raising further questions about the role of introduced animals in island ecology during the Holocene.

While terrestrial resources are generally limited, Channel Island marine environments are exceptionally productive, with the upwelling of nutrient-rich waters supporting large populations of pinnipeds, cetaceans, seabirds, shellfish and fishes. These rich marine communities also include scores of breeding seabirds, seals and sea lions. Located on a boundary between colder currents to the north and warmer currents to the south, the waters surrounding the Channel Islands contain a mix of cold- and warm-water marine fauna.

These productive and diverse marine environments fostered human occupation spanning the last 13 000 years (Erlandson *et al.*, 1996; Johnson *et al.*, 2002). Thousands of archaeological sites, ranging from large shell middens and villages to small lithic scatters, have been documented on the eight islands (Kennett, 2005; Rick *et al.*, 2005). At the time of European contact, the northern Channel Islands were inhabited by Chumashan-speaking peoples, while the southern islands were inhabited by Uto-Aztecan-speaking peoples (Kennett *et al.*, 2007a, b). Although linguistically and culturally distinct, both groups had a similar maritime technology and kept domestic dogs. While the Channel Islands contain a lengthy record of human occupation, analyses of

dog skeletal remains from the Channel Islands suggest that they are not a relict population of animals brought out by the earliest inhabitants. Instead many of these dogs appear to fall within the ‘small short-faced pueblo dog’ size category (cf. Colton, 1970; Olsen and Olsen, 1970), which is considerably smaller than the earliest known North American dogs such as those found at the Koster site (Morey and Wiant, 1992). The size of these island dogs suggests that there was at least sporadic exchange of dogs between the islands and mainland as part of the highly developed island mainland exchange systems. The exchange of dogs also likely worked against the development of a distinctive breed of island dog such as those in other island contexts (eg, Busuttil, 1969).

Methods

For this study, we systematically reviewed the published and unpublished literature for accounts of dogs from the California Channel Islands. The available literature on Channel Island dogs is widely scattered, with few researchers consistently noting the amount or types of recovered dog remains. Nonetheless, we have assembled a comprehensive data set. We also included unpublished data from archaeological specimens housed at the Santa Barbara Museum of Natural History and the Fowler Museum at the University of California, Los Angeles. These and other specimens are part of our ongoing analysis of ancient southern Californian dog populations.

Table 2 presents the available domestic dog data, including site or location, minimum number of individuals (MNI) and the elements recovered or degree of skeletal completeness. We were as specific as possible, but in many cases some or all of these data were not available. We caution that researchers were not always clear on how they determined if specimens were from dogs rather than other species of *Canis* (eg, *C. latrans* (coyotes)) or hybrids, but we suspect that these species would be very rare on the Channel Islands. There are likely dog remains from early antiquarian projects on the islands during the late eighteenth and early nineteenth centuries housed at the Smithsonian and other institutions that lack detailed provenance and are not included in this study.

To our knowledge, there are relatively few direct ¹⁴C dates on archaeological dog remains from the Channel Islands (see Vellanoweth *et al.*, 2008). Consequently, in Table 2 most of the dates for the various dog remains are from ¹⁴C associations. In some cases we listed general time frames (eg, late Holocene) based on the presence of multiple ¹⁴C dates from a single site. These dates are generally for a site or site component rather than directly for a dog burial or dog remains. These dates provide a reasonable estimate of the age of the dog remains, but future direct dating of dog specimens could significantly enhance their chronology. Our estimates of

Table 2 Domestic dog remains from Channel Islands archaeological sites

Site or locality	Age	MNI	Comments	References
<i>San Clemente Island</i>				
SCLI-43 ^a	~2000 cal. yr BP	7	Dog burials, as well as scattered additional bones	Porcasi, 1995: 9; Hardy, 2000; Walker, unpublished data, 2008
SCLI-119	Historic	1	Large dog in a bundle wrap with fibers, sea otter robes, and mission cloth	Woodward, 1941; McKusick and Warren, 1959; Salls, 1990: 38
SCLI-120	~1050 cal. yr BP	1	3 metacarpals and 1 axis vertebra	Noah, 1987: 71; age estimated from Porcasi and Fujita, 2000: 549
SCLI-126	Historic	8	Dog burials, as well as scattered additional bones	Raab <i>et al.</i> , 1994; Walker, unpublished data, 2008
SCLI-1487	Historic	1 ^b	Numerous canine/island fox bones in disturbed context, but no NISP or MNI	Hale and Salls, 2000: 83
SCLI-1492	post 1000 cal. yr BP–Historic	1	Remains of 1 dog	Noah, 1987: 62
SCLI-1524	1170–320 cal. yr BP	6	Six dog burials and some contain ritual goods	Raab <i>et al.</i> , 1994
<i>Santa Catalina Island</i>				
SCAI-17	Middle–Late Holocene	1 ^b	No NISP or MNI available	Porcasi, 2002: 584
<i>San Nicolas Island</i>				
SNI-4	Late Holocene?	1	Left and right premaxilla and maxilla	Santa Barbara Museum of Natural History specimen
SNI-8	Late Holocene?	1	Fairly complete skeleton	Santa Barbara Museum of Natural History specimen
SNI-10	Late Holocene?	2	Two crania	Santa Barbara Museum of Natural History specimen
SNI-11	6950–520 cal. yr BP	5	39 bones present: 1 burned element; 2 MNI and 2 NISP are from early stratum	Bleitz, 1993: 527
SNI-12	Late Holocene?	1	Cranium minus rostrum	Santa Barbara Museum of Natural History specimen
SNI-13	Late Holocene?	3	Three crania	Santa Barbara Museum of Natural History specimen
SNI-18	420–80 cal. yr BP	1	Dog burial	Reimman and Townsend, 1960; Kerr <i>et al.</i> , 2002: 33
SNI-21	2120–1630 cal. yr BP	3	Complete articulated skeleton and parts of two other dogs	Santa Barbara Museum of Natural History specimen; dates from Vellanoweth <i>et al.</i> , 2002
SNI-25	670 cal. yr BP–Historic	4	Three complete burials and 1 partially scattered dog	Dates from Vellanoweth <i>et al.</i> , 2002
SNI-25	Historic	1	Dog burial	Kerr <i>et al.</i> , 2002: 33
SNI-25	670 cal. yr BP–Historic	3	Three specimens from same locality, with several mandibles, one from a puppy	Santa Barbara Museum of Natural History specimen, Dates from Vellanoweth <i>et al.</i> , 2002
SNI-26	Late Holocene?	1	Complete cranium	Santa Barbara Museum of Natural History specimen
SNI-73	930–790 cal. yr BP	1 ^b	No NISP or MNI available	Santa Barbara Museum of Natural History specimen
SNI-160	1710–930 cal. yr BP	1 ^b	No NISP or MNI available	Martz, 2005: 73; dates from Vellanoweth <i>et al.</i> , 2002
SNI-214	Historic	1	Dog burial	Martz, 2005: 75; dates from Vellanoweth <i>et al.</i> , 2002 Kerr <i>et al.</i> , 2002: 33
<i>Santa Cruz Island</i>				
SCRI-?	n/a	1	Complete dog from biological collection with very heavily worn teeth	–
SCRI-109	Middle Holocene	1	Bone pins from dog tibia and ulna	Glassow <i>et al.</i> , 2008
SCRI-191	1550–650 cal. yr BP	1	Mandible and metacarpal	Colten, 1993: 90, 2001: 210, personal communication, 2007
SCRI-192	Historic	2	NISP = 5 from House 4 (2 <i>Canis</i> sp. as well); NISP = 7 from House 8 (5 <i>Canis</i> sp. as well)	Noah, 2005: 165, 171
SCRI-192	Historic	1	Phalanx	Colten, 1993: 90, 2001: 210
SCRI-192	650–168 cal. yr BP	1	Metacarpal, metatarsal, carpals, radius, and phalanx, NISP = 13	Colten, 1993: 90, 2001: 210, personal communication, 2007
SCRI-236	Historic	2	NISP = 5 from House 5; NISP = 2 from House 9	Noah, 2005: 194
SCRI-236	Late Holocene	1	Dog burial found by Olson at B-83	Hoover, 1971: 120
SCRI-240	Historic	2	Spaulding Excavation: NISP = 15; Arnold excavation: NISP = 22 and NISP = 1 <i>Canis</i> sp. from House 1, NISP = 14 from feast deposit	Noah, 2005: 240, Walker and Sneathkamp, 1984; Walker, unpublished data, 2008
SCRI-328/330	Historic	2	NISP = 3 from two different houses	Noah, 2005: 206; this paper
SCRI-330	650–168 cal. yr BP	1	Femur and sacrum	Colten, 1993: 90, 2001: 210, personal communication, 2007

Table 2 (Continued)

Site or Locality	Age	MNI	Comments	References
SCRI-Locality 125	Late Holocene	2	Two complete crania, Coches Prietos	Santa Barbara Museum of Natural History specimen
SCRI-Forney's	Late Holocene	2	Two complete crania	Santa Barbara Museum of Natural History specimen
SCRI-434	Late Holocene	1	Almost complete crania probably aboriginal dog	Santa Barbara Museum of Natural History specimen
SCRI-474	Late Holocene	1	Fully articulated dog skeleton buried on its side and recovered by Olson	Hoover, 1971: 137
<i>Santa Rosa Island</i>				
SRI-2	500–150 cal. yr BP	1	Partially complete dog burial eroding out of sea cliff	–
SRI-2	2000–150 cal. yr BP	6	Seven specimens excavated by Orr, including juvenile and adult remains	Santa Barbara Museum of Natural History specimen
SRI-41	Middle–Late Holocene	2	Two separate specimens with cranial and post-cranial elements	Santa Barbara Museum of Natural History specimen
SRI-60	Late Holocene–Historic	1	Miscellaneous dog bones recovered by David Banks Rogers in early 20th century	Santa Barbara Museum of Natural History specimen, J. Johnson, personal communication, 2008
<i>San Miguel Island</i>				
SMI-1	7140–3250 cal. yr BP	1 ^b	Canid remains identified in 12 units	Walker, unpublished data, 2008
SMI-87	c3500–2500 cal. yr BP	1	Fragmentary cranium	Rick, 2007
SMI-261	Early Holocene?	1	Left mandible; morphology indicative of short-faced breed	Walker <i>et al.</i> , 1978: 11, 78
SMI-390 and SMI-392?	n/a	1	Right mandible found on surface near these two sites	Santa Barbara Museum of Natural History specimen
SMI-481	Late Holocene?	1	Nearly complete, heavily weathered cranium	Walker and Sneathkamp, 1984: 140, D-12
SMI-481?	Late Holocene?	2	Two crania and mandibles, Otter Harbor	Santa Barbara Museum of Natural History specimen
SMI-485	570–480 cal. yr BP	1	NISP=4 probably from a single individual	Walker and Sneathkamp, 1984: 140, D-14
SMI-525	650–168 BP	1	Mandible	From Kennett excavations
SMI-525	~620–520 cal. yr BP	1	Mandible that lacks first premolar	Walker and Sneathkamp, 1984: 140–41

^a Garlinghouse, 2000:106 reported a NISP of 18 and MNI of 9 for SCLJ-43, -126, and -1524 but it is unclear what site or time period these come from.

^b MNI (Minimum number of individuals) unknown but at least one individual is present.

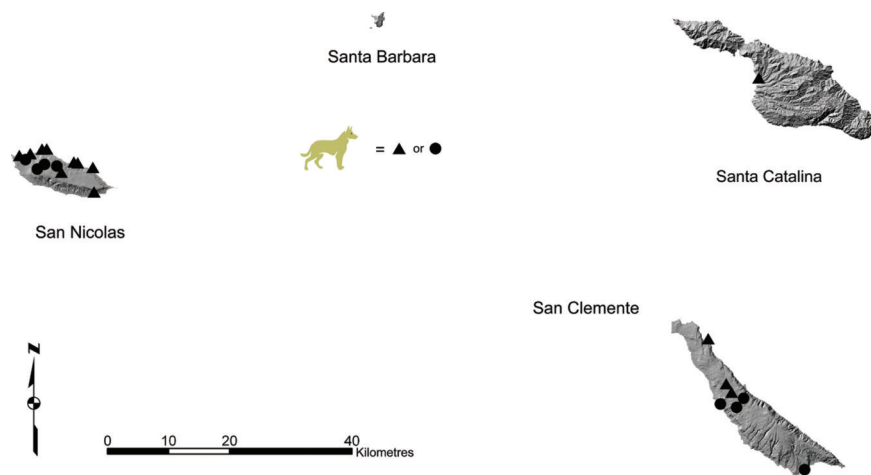


Figure 2 Distribution of dog remains on the southern Channel Islands. Triangles indicate dog remains and circles indicate definitive dog burials

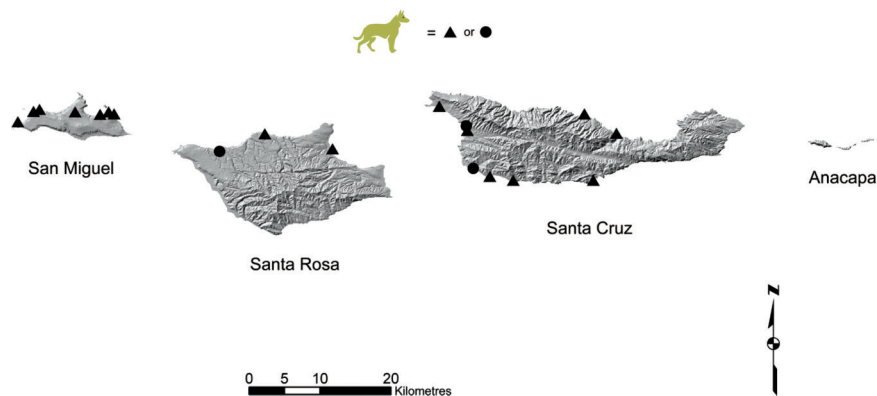


Figure 3 Distribution of dogs on the northern Channel Islands. Triangles indicate dog remains and circles indicate definitive dog burials

the age of each of these dog specimens suggest that, as elsewhere in North America, dogs have a long history on the Channel Islands, probably spanning most of the Holocene, and their presence appears to increase significantly through time.

Results

At least 42 Channel Island archaeological sites or localities are known to contain dog remains, with a number of other known dog parts assigned to an island but to no known location. This includes at least 96 individual dogs, a conservative value given the absence of MNI data from many reports. A number of sites (eg, SRI-2, SCRI-240, SCLI-1524 and SNI-25) also produced multiple dog remains or sometimes multiple dog burials. Dogs were found on six of the eight Channel Islands, with only the smallest islands (Anacapa and Santa Barbara, each about 2.5–3 km² in total area) lacking documented dog remains (Figures 2 and 3). These two islands have also seen the least amount of archaeological research. The larger islands had relatively sizeable human settlements during the middle and late Holocene, and most of these have a number of sites with dog bones. Santa Catalina, the largest and closest to the mainland of the southern islands, has only one site with documented dog remains, but it has seen little archaeological work. Lupu and Janetski (1994: 201) noted that for the entire eastern Great Basin (the state of Utah) only 29 dogs have been identified from deposits spanning the Holocene, suggesting that the density of dogs on the Channel Islands was relatively high.

The largest number of sites or localities with dog remains occurs on San Nicolas Island ($n = 13$), followed by Santa Cruz ($n = 11$), San Clemente ($n = 7$), San Miguel ($n = 7$), Santa Rosa ($n = 3$) and Santa Catalina ($n = 1$). San Nicolas, at roughly 98 km from the mainland, has the most sites with dogs, including several sites with dog burials. Similarly, San Clemente Island, located about 79 km offshore, has seven sites with dog remains, including late-Holocene sites such as SCLI-1524 that produced six dog burials alone (Hale and Salls, 2000).

The oldest dog remains from the Channel Islands appear to be a left mandible fragment from Daisy Cave on San Miguel Island, the depth of which may correlate with the site's early-Holocene (*c.* 8600–10 000 cal. yr BP) deposits (Walker *et al.*, 1978; Erlandson, 1994: 194). An early-Holocene date would make these remains among the oldest dog bones in the Americas (see Morey, 2006), but the specimen has not been directly dated and it could be from one of the younger site components. The possible early-Holocene age of the Daisy Cave specimen may be supported by dog remains identified in a few early mainland sites (Erlandson, 1994), but stratigraphic mixing is an issue in many of these sites and mainland specimens have not been directly dated. Four sites contain dog remains that are either middle or early late Holocene in age. Two dog bone tools identified by Glassow *et al.* (2008) from Punta Arena on Santa Cruz Island date to the middle Holocene, but it is unclear if these were made from a dog that lived on the island or from tools traded or transported from the mainland. Two dogs identified from SNI-11 were from Stratum 3, dated between about 6950 and 4500 years ago, providing a reasonably

secure middle-Holocene age for these materials. Dog remains from SRI-41 on Santa Rosa Island and SCA-17 on Santa Catalina Island may also be middle or early late Holocene in age. The majority of sites ($n = 38$) date to the late Holocene, indicating that dog populations, similar to human populations, increased through time on the islands. More late-Holocene sites have been excavated than middle- and early-Holocene sites, however, which may contribute to the dearth of earlier dog evidence.

Dog remains are found in a wide range of archaeological contexts, including shell middens and formal burials. The latter are better documented on the southern islands, where several sites on San Clemente (eg, Eel Point, Lemon Tank and Big Dog Cave) and San Nicolas islands (SNI-25) have produced formal dog burials, some with grave goods. On San Clemente, researchers have suggested that these dog burials, including apparently dismembered dogs, may be part of ancient religious ceremonies (Raab *et al.*, 1994; Hardy, 2000; Hale and Salls, 2000). On the northern islands formal dog burials are less common, but dogs have been found fully articulated in midden deposits, where they were either discarded, intentionally buried or died naturally in place. Although some of the San Clemente dogs may have been ritually modified and perhaps decapitated (Hardy, 2000), signs of butchery or other indications of human consumption are rare. At SNI-11 a burned dog bone was identified (Bleitz, 1993), and a few San Clemente sites also contained burned dog bones (Garlinghouse, 2000). However, this burning may be a product of inadvertent burning of bones buried near to hearths or the use of fire to dispose of the remains of dogs that were not consumed. Overall, these data suggest that dogs that generally not consumed, except perhaps during times of scarcity. The two dog-bone pins identified by Glassow *et al.* (2008) from middle-Holocene deposits on Santa Cruz Island suggest that dog bones were occasionally used to make utilitarian objects. Gnaw marks that are probably from dogs, and possibly foxes, have been noted on human remains from Eel Point (SCLI-43) on San Clemente Island (Titus and Walker, 2000: 85) and on non-human faunal remains from three Santa Cruz Island sites (SCRI-192, -236 and -240; Noah, 2005: 120) and at SRI-2 on Santa Rosa Island. These data demonstrate that canids were also scavengers and agents of taphonomic disturbance.

Discussion

Dogs were a significant component of Holocene Channel Island ecosystems and were widespread during the late Holocene. Humans and dogs had a symbiotic relationship, with dogs probably functioning as hunting companions, sentinel animals, pets, offal scavengers, food sources and potentially as status symbols as they did elsewhere in the world. During periods of high interpersonal violence, dogs may have also served an important function by warning people of intruders (Walker and Sneathkamp, 1984: 142; Walker, 1989). Ethnographic data for the Chumash (Blackburn, 1975: 242), Hopi (Titiev, 1972), Navajo (Downs, 1972), Chippewa (Sharp, 1976) and Mundurucú (Murphy, 1985) suggest that dogs also consume human excrement, which is important for disposing of waste. Dogs likely did the same on the Channel Islands.

Like their wolf ancestors, dogs are pack animals that generally have good hunting skills. A few ethnographic accounts of Chumash and Gabrielino peoples on the mainland, however, suggest that some Chumash groups may not have employed dogs for hunting, but occasionally used them for food (Kroeber, 1941; Harrington, 1942: 6–7). Given the dearth of terrestrial animals on the Channel Islands, dogs probably were of limited use in hunting. They would hinder hunting sea mammals hauled out along the coast, for example, because they would likely scare them into the

water before they could be taken. With their presence on the islands for at least 6000 years, we argue that dogs, together with foxes and humans, negatively affected breeding bird and sea mammal populations on the mainland portions of the islands, likely driving these animals to offshore islets or other isolated areas. If feral dog populations were present, as they were historically (see below), these impacts would have been more pronounced. Guthrie (1993) has identified the fossil remains of *Chendytes lawi*, a ground-nesting, flightless scoter, on San Miguel Island dated to *c.* 12 000 RYBP (~14 000 cal. yr BP). Extensive *Chendytes* breeding colonies would not have been possible with the regular presence of dogs, foxes and humans. It is conceivable that dogs contributed to the extinction of the flightless goose near the end of the middle Holocene or beginning of the late Holocene (see Guthrie, 1993; Jones *et al.*, 2008; Rick *et al.*, 2008b).

One of the most significant ecological impacts of Channel Island dogs was probably related to their propensity to disturb aggregations of breeding animals. A recent study on disturbance to western snowy plovers (*Charadrius alexandrinus nivosus*), a threatened shore bird, and other birds near the Devereux Slough on the Santa Barbara mainland demonstrated that unleashed dogs had some of the highest impacts on plovers, probably influencing reproduction, survivorship and distribution (Lafferty, 2001a, b). Since snowy plovers are also found on the Channel Islands, including a protected area near Skunk Point on Santa Rosa Island, Native American dogs may have had much the same impact on these and other birds in the more distant past. This is especially true since no disturbances to snowy plovers were observed at the protected area of Santa Rosa today (Lafferty, 2001a), but in the past Skunk Point was close to numerous large centres of Native American habitation, including the historic Chumash village of *Qshiwqshiw* that would have almost certainly had dogs.

Dogs would also have competed directly with island foxes for food and other resources. Although a great deal of attention has been given to the biology and ecology of island foxes (eg, Collins, 1991a, 1991b; Roemer *et al.*, 2001, 2002; Coonan *et al.*, 2002, 2005), few studies have examined the possible interactions between dogs and foxes in the distant past. Collins (1991a) discussed the burial of both dogs and foxes in island sites, demonstrating that people often gave the same ritual treatment to these animals. Collins (1991b) and Vellanoweth (1998) argued that Native Americans introduced island foxes to the southern Channel Islands but, based on a single 'Pleistocene' specimen from Santa Rosa Island recovered in the 1950s by Phil Orr, it has been suggested that foxes arrived naturally on the northern islands prior to human arrival (see Collins, 1991b). However, recent direct ^{14}C dating of this and several other fox specimens, previously thought to be as much as 38 000 years old, suggests that they are all middle or late Holocene in age, raising significant questions about the natural dispersal of foxes to the northern islands (Shelley, 2001; Rick *et al.*, 2008a). As Collins (1991a) noted, island fox behaviour meshes well with humans, and their presence in formal burials clearly demonstrates their importance in Island Chumash society.

Dogs and foxes appear to have lived along side one another since at least the middle Holocene, but it is still unclear how they would have influenced each others' lives. They would have competed for food and the small size of island foxes would have made them potential prey for feral dogs (eg, Ralls and White, 1995). Dog pups could also have been prey for island foxes, but we suspect direct predation may have been limited, especially if people actively discouraged it. In this context, both island foxes and dogs may have provided an additional benefit to people by eating discarded food and human waste, preying on rodents and other pests around habitation sites and providing protection from intruders. The introduction of dogs to the Channel Islands and occasional prehistoric transport of mainland dogs to the islands could also

have had deleterious consequences by transmitting potential lethal pathogens such as canine distemper, canine adenovirus, canine parvovirus and toxoplasma to endemic island foxes (Clifford *et al.*, 2006).

Despite these potential negative consequences for foxes, we know from archaeological evidence that both canids coexisted for several thousand years, making it clear that potential niche overlap between the two species resulted in some form of equilibrium rather than competitive exclusion. The key adaptive difference that made this possible is likely the symbiotic relationship between humans and their domestic dog companions. Interestingly, the earliest secure date for island foxes is about 7000 cal. yr BP, a date comparable with the earliest secure dates available for dogs. Future research on the antiquity and distribution of dogs and island foxes should prove important for delineating the relationship between these two animals and their ecological impacts.

Historically, dogs were present on all the islands and were introduced during successive ranching occupations since the nineteenth century (Schoenherr *et al.*, 1999). The fate of Native American dogs on the islands during the Historic period is poorly documented. Many dogs were probably left behind when Native peoples left the islands for mainland missions, and a few accounts suggest that 'wild dogs' were present historically (Schumacher, 1877). Juana Maria, the lone woman of San Nicolas Island, who survived alone on the island for many years in the mid nineteenth century, had several dogs (Nidever, 1937). Juana Maria even suggested that her child was eaten by wild dogs (Hardy, 2000: 95). Schoenherr *et al.* (1999: 41) noted that feral dogs descended from Native American dogs were removed from San Nicolas Island by shepherders because they were impacting sheep populations. Native American dogs may have survived on the other islands as well, but the fate or abundance of these dogs is poorly known. In recent years, dogs were removed and banned from some of the islands by the National Park Service and US Navy, with dogs present only on Santa Catalina today. Canine diseases and parasites were implicated as one component of the dramatic reduction of island fox populations during the last decade, although predation by golden eagles appears to be the major cause of the fox decline (Coonan *et al.*, 2002, 2005; Roemer *et al.*, 2002). The introduction of dogs in the distant past by Native Americans raises questions about the nature of such dog/fox interactions. Canine diseases may have passed back and forth between the two populations in the past, but both foxes and dogs appear to have co-existed for much of the Holocene and we argue played a role in island ecology, biogeography and Native American culture.

Conclusion

The evidence we have presented in this paper for the translocation of dogs to the Channel Islands adds to our growing understanding of the influence of Native Americans and other pre-Industrial peoples on ecology and biogeography (Redman, 1999; Grayson, 2001; Kirch, 2005). These impacts are particularly significant on islands, which contain unique fauna and ecosystems that are generally more vulnerable to human activities than continental landmasses. Although we are just beginning to understand the role of people in shaping ancient Channel Island marine and terrestrial ecosystems (Erlandson *et al.*, 2004, 2005; Kennett, 2005; Braje, 2007; Rick, 2007; Braje *et al.*, 2007; Rick *et al.*, 2008a, b), the introduction of domestic dogs to the islands is part of a much larger 'domestication' of the Channel Islands landscape. The Channel Islands contain unique ecosystems distinct from the nearby mainland, with a number of island endemic and relict species (Schoenherr *et al.*, 1999). It is clear, however, that these environments were also influenced by the direct and indirect

actions (eg, hunting, setting of wildfires, dune stabilization and de-stabilization, and animal translocations) of Native peoples for at least 13 000 calendar years.

Understanding and documenting the activities of ancient people, and the animals they introduced, we can improve models of ancient island ecosystems and significantly enhance the management and restoration of these habitats by providing important baseline data on how island ecosystems may have been structured and functioned in the past. Dogs were a predator/scavenger introduced to the Channel Islands by humans that, along with island foxes and humans, influenced the biogeography and breeding behaviour of birds, marine mammals and other animals that, largely free from predation today, breed in large numbers on several of the islands, including over 100 000 seals and sea lions on San Miguel Island alone (DeLong and Melin, 2002). The greatest ecological influence of dogs would have been in the areas closest to human communities. Since Native villages and their dogs were present across much of the islands, especially around the coastlines and near good water sources, these impacts may have been fairly widespread.

There is still much to be learned about the antiquity and effects of the prehistoric introduction of domestic dogs on the ecology of California's Channel Islands. At the very least, dogs may have scared marine mammals and birds off island beaches and other landforms, driving them to breed, roost and haul-out elsewhere. On San Miguel Island, all foxes were pulled into captivity for breeding starting in the late 1990s, which resulted in the rapid spread of ground-breeding northern harriers (*Circus cyaneus*), western gulls (*Larus occidentalis*) and Brandt's cormorants (*Phalacrocorax penicillatus*) in vulnerable and conspicuous locations around the island (Drost *et al.*, 2008). This significant expansion of bird breeding habitat provides a possible glimpse of what seabird populations may have looked like prior to the late-Pleistocene/Holocene arrival of foxes, dogs and humans. Given the lengthy presence of people and dogs on the islands, the modern situation appears to be radically different from much of the Holocene.

Acknowledgements

We thank Ann Huston, Kelly Minas, Don Morris, Mark Senning and Ian Williams of Channel Islands National Park for supporting our research and enhancing our understanding of island ecology and natural history. Steve Schwartz supported our research on San Nicolas and San Miguel islands and our work on the northern Channel Islands has been supported by Channel Islands National Park, the National Science Foundation, Western National Parks Association, the University of Oregon and Southern Methodist University. Roger Colten provided data on some of the dog remains from Santa Cruz Island. We are also indebted to Paul Collins and Dan Guthrie for discussions that deepened our understanding of island ecology and palaeoecology. We thank Virginia Butler and William Keegan for thoughtful comments on an earlier version of this manuscript. Finally, we thank anonymous reviewers and the editors and staff of *The Holocene* for help in the review and production of this manuscript.

References

- Agnew, L.D., Johnson, J.R., Morris, D. and Stafford, T.W., Jr 2005: Mammoths and humans as Late Pleistocene contemporaries on Santa Rosa Island. In Garcelon, D. and Schwemm, C., editors, *Proceedings of the sixth California Islands symposium*. National Park Service Technical Publication CHIS-05-01, Institute for Wildlife Studies, 3–7.

- Barker, G.** 2006: *The agricultural revolution in prehistory: why did foragers become farmers?* Oxford University Press.
- Bellwood, P.** 2004: *First farmers: the origins of agricultural societies.* Blackwell.
- Blackburn, T.C.,** editor 1975: *December's child: a book of Chumash oral narratives.* University of California Press.
- Bleitz, D.E.** 1993: The prehistoric exploitation of marine mammals and birds at San Nicolas Island, California. In Hochberg, F.G., editor, *Third California Islands symposium: recent advances in research on the California Islands.* Santa Barbara Museum of Natural History, 519–36.
- Bowers, S.** 1890: *San Nicolas Island.* California State Mining Bureau, Ninth Annual Report of the State Mineralogist 9, 57–61.
- Braje, T.J.** 2007: Archaeology, human impacts, and historical ecology on San Miguel Island, California. PhD dissertation, University of Oregon.
- Braje, T.J., Kennett, D.J., Erlandson, J.M. and Culleton, B.J.** 2007: Human impacts on nearshore shellfish taxa: a 7000 year record from Santa Rosa Island, California. *American Antiquity* 74, 735–56.
- Busuttill, J.** 1969: The Maltese dog. *Greece & Rome* 16, 205–208.
- Clifford, D.L., Mazet, J.A.K., Dubovi, E.J., Garcelon, D.K., Coonan, T.J., Conrad, P.A. and Munson, L.** 2006: Pathogen exposure in endangered island fox (*Urocyon littoralis*) populations: implications for conservation management. *Biological Conservation* 131, 230–43.
- Collins, P.W.** 1991a: Interaction between island foxes (*Urocyon littoralis*) and Native Americans on islands off the coast of southern California: II. Ethnographic, archaeological, and historical evidence. *Journal of Ethnobiology* 11, 205–29.
- 1991b: Interaction between island foxes (*Urocyon littoralis*) and Indians on islands off the coast of southern California: I. Morphological and archaeological evidence of human assisted dispersal. *Journal of Ethnobiology* 11, 51–81.
- Colten, R.H.** 1993: Prehistoric subsistence, specialization, and economy in a southern California Chiefdom. Ph.D. dissertation, University of California.
- 2001: Ecological and economic analysis of faunal remains from Santa Cruz Island. In Arnold, J.E., editor, *The origins of a Pacific Coast chiefdom: the Chumash of the Channel Islands.* University of Utah Press, 199–219.
- Colton, H.S.** 1970: The aboriginal southwestern Indian dog. *American Antiquity* 35, 153–59.
- Coonan, T.J., Schwemm, C.A., Roemer, G.W. and Austin, G.** 2002: Population decline of island foxes (*Urocyon littoralis littoralis*) on San Miguel Island. In Browne, D., Mitchell, K. and Chaney, H., editors, *Proceedings of the fifth California Islands symposium.* Santa Barbara Museum of Natural History, 289–97.
- Coonan, T.J., Rutz, K., Garcelon, D.K., Latta, B.C., Gray, M.M. and Ashehoug, E.T.** 2005: Progress in island fox recovery efforts on the northern Channel Islands. In Garcelon, D. and Schwemm, C., editors *Proceedings of the sixth California Islands symposium.* National Park Service Technical Publication CHIS-05-01, Institute for Wildlife Studies, 263–73.
- Corbett, L.** 1995: *The dingo in Australia and Asia.* University of New South Wales Press.
- DeLong, R.L. and Melin, S.R.** 2002: Thirty years of pinniped research at San Miguel Island. In Browne, D., Mitchell, K. and Chaney, H., editors, *The fifth California Islands symposium.* Santa Barbara Museum of Natural History, 401–406.
- Downs, J.F.** 1972: *The Navajo.* Holt, Rinehart, and Winston.
- Drost, C.A., Schwemm, C., Coonan, T. and Richards, D.** 2008: Ecosystemwide response to extirpation of island foxes on San Miguel Island. Paper presented at the Seventh California Islands Symposium, Oxnard, CA.
- Erlandson, J.M.** 1994: *Early hunter-gatherers of the California Coast.* Plenum.
- Erlandson, J.M., Kennett, D.J., Ingram, B.L., Guthrie, D.A., Morris, D.P., Tveskov, M.A., West, G.J. and Walker, P.L.** 1996: An archaeological and paleontological chronology for Daisy Cave (CA-SMI-261), San Miguel Island, California. *Radiocarbon* 38, 355–73.
- Erlandson, J.M., Rick, T.C. and Vellanoweth, R.L.** 2004: Human impacts on ancient environments: a case study from California's northern Channel Islands. In Fitzpatrick, S.M., editor, *Voyages of discovery: the archaeology of islands.* Praeger, 51–83.
- Erlandson, J.M., Rick, T.C. and Peterson, C.** 2005: A geoarchaeological chronology for Holocene dune building on San Miguel Island, California. *The Holocene* 15, 1227–35.
- Fiedel, S.J.** 2005: Man's best friend – mammoths worst enemy? A speculative essay on the role of dogs in Paleoindian colonization and megafaunal extinction. *World Archaeology* 37, 11–25.
- Garlinghouse, T.** 2000: Human responses to insularity: the intensification of a marine oriented economy on San Clemente Island. Ph.D. Dissertation, University of California, Davis.
- Glassow, M.A., Paige, P. and Perry, J.** 2008: *The Punta Arena site and early and middle Holocene cultural development on Santa Cruz Island, California.* Santa Barbara Museum of Natural History Contributions in Anthropology, in press.
- Grayson, D.K.** 2001: The archaeological record of human impacts on animal populations. *Journal of World Prehistory* 15, 1–68.
- Guthrie, D.A.** 1993: New information on the prehistoric fauna of San Miguel Island, California. In Hochberg, F.G., editor, *Third California Islands symposium: recent advances in research on the California Islands.* Santa Barbara Museum of Natural History, 405–16.
- Hale, A. and Salls, R.A.** 2000: The canine ceremony: dog and fox burials on San Clemente Island. *Pacific Coast Archaeological Society Quarterly* 36, 80–94.
- Hardy, A.T.** 2000: Religious aspects of the material remains from San Clemente Island. *Pacific Coast Archaeological Society Quarterly* 36, 78–96.
- Harrington, J.P.** 1942: Culture element distributions, XIX: central California Coast. *University of California Anthropological Records* 7, 1–46.
- Hoover, R.L.** 1971: Some aspects of Santa Barbara Channel prehistory. Ph.D. dissertation, University of California, Berkeley.
- Johnson, C.N. and Wroe, S.** 2003: Causes of extinction of vertebrates during the Holocene of mainland Australia: arrival of the dingo or human impact? *The Holocene* 13, 941–48.
- Johnson, J.R., Stafford, T.W., Jr, Ajie H.O. and Morris, D.P.** 2002: Arlington Springs revisited. In Browne, D., Mitchell, K. and Chaney, H., editors, *Proceedings of the fifth California Islands symposium.* Santa Barbara Museum of Natural History, 541–45.
- Jones, T.L., Porcasi, J.F., Erlandson, J.M., Dallas, H., Jr, Wake, T.A. and Schwaderer, R.** 2008: Overhunting takes time: protracted Holocene extinction of California's flightless sea duck (*Chendytes lawi*). *Proceedings of the National Academy of Sciences* 105, 4105–108.
- Kennett, D.J.** 2005: *The Island Chumash: behavioral ecology of a maritime society.* University of California Press.
- Kennett, D.J. and Kennett, J.P.** 2000: Competitive and cooperative responses to climatic instability in southern California, *American Antiquity* 65, 379–95.
- Kennett, D.J. and Winterhalder, B.,** editors 2006: *Behavioral ecology and the transition to agriculture.* University of California Press.
- Kennett, D.J., Kennett, J.P., Erlandson, J.M. and Cannariato, K.G.** 2007a: Human responses to middle Holocene climate change on California's Channel Islands, *Quaternary Science Reviews* 26, 351–67.
- Kennett, D.J., Culleton, B.J., Kennett, J.P., Erlandson, J.M. and Cannariato, K.G.** 2007b: Middle Holocene climate change and population dispersal in western North America. In Anderson, D., Sandweiss, D. and Maasch, K.A., editors, *Climate and culture change.* Elsevier, 531–57.
- Kerr, S.L., Walker, P.L., Hawley, G.M. and Yoshida, B.Y.** 2002: Physical anthropology. In Ezzo, J., editor, *The Ancient Mariners: a bioarchaeological analysis of the burial collections.* Technical Report 01-64. Statistical Research Inc., 25–55.
- Kirch, P.V.** 2000: *On the road of the winds: an archaeological history of the Pacific Islands before European contact.* University of California Press.
- 2005: Archaeology and global change: the Holocene record. *Annual Review of Environment and Resources* 30, 409–40.
- Kirch, P.V. and Hunt, T.L.,** editors 1997: *Historical ecology in the Pacific Islands: prehistoric environmental and landscape change.* Yale University Press.

- Kroeber, A.L.** 1941: Culture element distributions, XV: salt, dogs, tobacco. *University of California Anthropological Records* 6, 1–20.
- Kruuk, H.** and **Snell, H.** 1981: Prey selection by feral dogs from a population of marine iguanas (*Amblyrhynchus cristatus*). *The Journal of Applied Ecology* 18, 197–204.
- Lafferty, K.D.** 2001a: Disturbance to wintering western snowy plovers. *Biological Conservation* 101, 315–25.
- 2001b: Birds at a southern California beach: seasonality, habitat use and disturbance by human activity. *Biodiversity and Conservation* 10, 1949–62.
- Leonard, J.A., Wayne, R.K., Wheeler, J., Valadez, R., Guillén, S.** and **Vilà, C.** 2002: Ancient DNA evidence for Old World origin of New World dogs. *Science* 298, 1613–16.
- Lupo, K.D.** and **Janetski, J.C.** 1994: Evidence of domesticated dog and some related canids in the eastern Great Basin. *Journal of California and Great Basin Anthropology* 16, 199–220.
- Martz, P.C.** 2005: Prehistoric subsistence and settlement on San Nicolas Island. In Garcelon, D. and Schwemm, C., editors, *Proceedings of the sixth California Islands symposium*. National Park Service Technical Publication CHIS-05-01, Institute for Wildlife Studies, 65–82.
- McKusick, M.B.** and **Warren, C.N.** 1959 Introduction to San Clemente island archaeology. *University of California Archaeological Survey Annual Report* 1, 107–83.
- Morey, D.F.** 2006: Burying key evidence: the social bond between dogs and people. *Journal of Archaeological Science* 33, 158–75.
- Morey, D.F.** and **Wiant, M.D.** 1992: Early Holocene domestic dog burials from the North American Midwest. *Current Anthropology* 33, 224–29.
- Murphy, Y.** 1985: *Women of the forest*. Columbia University Press.
- Newsom, L.A.** and **Wing, E.** 2004: *On land and sea: Native American uses of biological resources in the West Indies*. University of Alabama Press.
- Nidever, G.** 1937: *The life and adventures of George Nidever 1802–1883*. William Henry Ellison, editor. University of California Press.
- Noah, A.C.** 1987: A meeting of paradigms: a late-century analysis of mid-century excavations on San Clemente Island. Master's thesis, Department of Anthropology, San Diego State University.
- 2005: Household economies: the role of animals in a Historic period chiefdom on the California Coast. Ph.D. dissertation, University of California, Los Angeles.
- Olsen, S.J.** and **Olsen, W.** 1970: The Chinese wolf, ancestor of New World dogs. *Science* 197, 533–35.
- Porcasi, J.F.** 1995: Trans-Holocene marine mammal hunting on San Clemente Island, California: additional data to assess a prehistoric 'tragedy of the commons' and declining mammalian foraging efficiency. MA thesis, California State University, Northridge.
- 2002: Updating prehistoric maritime subsistence at Little Harbor, Santa Catalina Island, California. In Browne, D., Mitchell, K. and Chaney, H., editors, *Proceedings of the fifth California Islands symposium*. Santa Barbara Museum of Natural History, 580–89.
- Porcasi, J.F.** and **Fujita, H.** 2000: The dolphin hunters: a specialized prehistoric maritime adaptation in the southern California Channel Islands and Baja California. *American Antiquity* 65, 543–66.
- Raab, L.M., Bradford, K.G.** and **Yatsko, A.** 1994: Advances in southern Channel Islands archaeology: 1983 to 1993. *Journal of California and Great Basin Anthropology* 16, 243–70.
- Ralls, K.,** and **White, P.J.** 1995: Predation on San Joaquin kit foxes by larger canids. *Journal of Mammalogy* 76, 723–29.
- Redman, C.L.** 1999: *Human impact on ancient environments*. University of Arizona Press.
- Reinman, F.M.** and **Townsend, S.** 1960: Six burial sites on San Nicolas Island. *University of California Archaeological Survey Annual Report* 2, 1–134.
- Rick, T.C.** 2007: *The archaeology and historical ecology of Late Holocene San Miguel Island*. Cotsen Institute of Archaeology, University of California, Los Angeles.
- Rick, T.C., Erlandson, J.M., Vellanoweth, R.L.** and **Braje, T.J.** 2005: From Pleistocene mariners to complex hunter-gatherers: the archaeology of the California Channel Islands. *Journal of World Prehistory* 19, 169–228.
- Rick, T.C., Erlandson, J.M., Vellanoweth, R.L., Braje, T.J., Collins, P.W., Guthrie, D.A.** and **Stafford, T.W., Jr** 2008a: The origins and antiquity of the island fox (*Urocyon littoralis*): AMS ¹⁴C evidence from California's Channel Islands. *Quaternary Research*, in review.
- Rick, T.C., Erlandson, J.M., Braje, T.J., Estes, J.A., Graham, M.H.** and **Vellanoweth, R.L.** 2008b: Historical ecology and human impacts on coastal ecosystems of the Santa Barbara Channel, California. In Rick, T.C. and Erlandson, J.M., editors, *Human impacts on ancient marine ecosystems: a global perspective*. University of California Press, 77–101.
- Roemer, G.W., Smith, D.A., Garcelon, D.K.** and **Wayne, R.K.** 2001: The behavioural ecology of the island fox (*Urocyon littoralis*). *Journal of Zoology* 255, 1–14.
- Roemer, G.W., Donlon, C.J.** and **Courchamp, F.** 2002: Golden eagles, feral pigs, and insular carnivores: how exotic species turn native predators into prey. *Proceedings of the National Academy of Sciences* 99, 791–96.
- Salls, R.A.** 1990: Return to Big Dog Cave: the last evidence of a prehistoric fishery on the Southern California Bight. *Pacific Coast Archaeological Society Quarterly* 26, 38–60.
- Savolainen, P., Zhang, Y., Luo, J., Lundeberg, J.** and **Leitner, T.** 2002: Genetic evidence for East Asian origin of domestic dogs. *Science* 298, 1610–13.
- Savolainen, P., Leitner, T., Wilton, A.N., Matisoo-Smith, E.** and **Lundeberg, J.** 2004: A detailed picture of the origin of the Australia dingo, obtained from the study of mitochondrial DNA. *Proceedings of the National Academy of Sciences* 101, 12 387–90.
- Schoenherr, A.A., Feldmeth, C.R.** and **Emerson, M.J.** 1999: *Natural history of the Islands of California*. University of California Press.
- Schumacher, P.** 1877: Researches in the kjoekenmoddings and graves of a former population of the Santa Barbara Islands and the adjacent mainland. *U.S. Geological and Geographical Survey of the Territories Bulletin* 3, 37–56.
- Schwartz, M.** 1997: *A history of dogs in the early Americas*. Yale University Press.
- Sharp, H.S.** 1976: Man: wolf: woman: dog. *Arctic Anthropology* 13, 25–34.
- Shelley, S.D.** 2001: *Archaeological evidence of the island fox (Urocyon littoralis) on California's Channel Islands*. Technical Report 98-12, Statistical Research Inc.
- Snyder, L.M.** and **Leonard, J.A.** 2006: Dog. In Ubelaker, D.H., editor, *Handbook of North American Indians. Environment, origins, and population, Vol. 3*. Smithsonian Institution Press, 452–62.
- Steadman, D.W.** 1995: Prehistoric extinction of Pacific Island birds: biodiversity meets zooarchaeology. *Science* 267, 1123–30.
- 2006: *Extinction and biogeography of tropical Pacific birds*. University of Chicago Press.
- Taborsky, M.** 1988: Kiwis and dog predation: observations in Waitangi State Forest. *Notornis* 35, 197–202.
- Titiev, M.** 1972: *The Hopi Indians of Old Orabi: change and continuity*. University of Michigan Press.
- Titus, M.D.** and **Walker, P.L.** 2000: Skeletal remains from San Clemente Island. *Pacific Coast Archaeological Society Quarterly* 36, 79–87.
- Vellanoweth, R.L.** 1998: Earliest island fox remains on the southern Channel Islands: evidence from San Nicolas Island, California. *Journal of California and Great Basin Anthropology* 20, 100–108.
- Vellanoweth, R.L., Martz, P.** and **Schwartz, S.** 2002: The Late Holocene archaeology of San Nicolas Island. In Erlandson, J. and Jones, T., editors, *Catalysts to complexity: Late Holocene societies of the California Coast*. Cotsen Institute of Archaeology, University of California, Los Angeles, 82–100.
- Vellanoweth, R.L., Bartelle, B.G., Ainis, A.F., Cannon, A.C.** and **Schwartz, S.J.** 2008: A double dog burial from San Nicolas Island, California, USA: osteology, context, and significance. *Journal of Archaeological Science* in press.
- Wagner, H.R.** 1929: *Spanish voyages to the Northwest Coast of North America in the sixteenth century*. California Historical Society.
- Walker, P.L.** 1989: Cranial injuries as evidence of violence in prehistoric southern California. *American Journal of Physical Anthropology* 80, 313–23.

Walker, P.L. and Snethkamp, P.E. 1984: *Archaeological investigations on San Miguel Island – 1982: prehistoric adaptations to the marine environment*. Report on file at the Central Coast Information Center, University of California, Santa Barbara.

Walker P., Craig, S., Guthrie, D. and Moore, R. 1978: *An ethnozoological analysis of faunal remains from four Santa Barbara Channel Island archaeological sites*. Report on file at the Central Coast Information Center, University of California, Santa Barbara.

Wayne, R.K., Leonard, J.A. and Vila, C. 2006: Genetic analysis of dog domestication. In Zeder, M.A., Bradley, D.G., Emshwiller, E. and

Smith, B.D., editors, *Documenting domestication: new genetic and archaeological paradigms*. University of California Press, 279–93.

White, P.J. 2004: Where the wild things are: prehistoric animal translocation in the Circum New Guinea Archipelago. In Fitzpatrick, S.M., editor, *Voyages of discovery: the archaeology of islands*. Praeger, 147–64.

Woodward, A. 1941: Communication to ‘notes and news’. *American Antiquity* 6, 284–85.

Zeder, M.A. 2006: Central questions in the domestication of plants and animals. *Evolutionary Anthropology* 15, 105–17.