

The protracted Holocene extinction of California's flightless sea duck (*Chendytes lawi*) and its implications for the Pleistocene overkill hypothesis

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Bones of the flightless sea duck (*Chendytes lawi*) from 14 archaeological sites along the California coast indicate that humans hunted the species for at least 8,000 years before it was driven to extinction. Direct ¹⁴C dates on *Chendytes* bones show that the duck was exploited on the southern California islands as early as ≈11,150–10,280 calendar years B.P., and on the mainland by at least 8,500 calendar years B.P. The youngest direct date of 2,720–2,350 calendar years B.P., combined with the absence of *Chendytes* bones from hundreds of late Holocene sites, suggests that the species was extinct by ≈2,400 years ago. Although the extinction of *Chendytes* clearly resulted from human overhunting, its demise raises questions about the Pleistocene overkill model, which suggests that megafauna were driven to extinction in a blitzkrieg fashion by Native Americans ≈13,000 years ago. That the extermination of *Chendytes* was so protracted and archaeologically visible suggests that, if the terminal Pleistocene megafauna extinctions were primarily the result of human exploitation, there should also be a long and readily detectable archaeological record of their demise. The brief window now attributed to the Clovis culture (≈13,300–12,900 B.P.) seems inconsistent with an overhunting event.

flightless birds | overhunting

The late Quaternary extinction of North America's large fauna has been a topic of intense scientific interest for decades, focused primarily on the Pleistocene overkill hypothesis, which suggests that 35 genera of megafauna were driven to extinction in a blitzkrieg fashion by Native Americans ≈13,000 years ago (1). This hypothesis has been challenged because of the paucity of supporting archaeological evidence for human hunting of most of the extinct taxa (2), while aspects of the extinctions have also been portrayed as inconsistent with climate change explanations (3). Added to this mix is a recent suggestion that an extraterrestrial impact ≈12,900 calendar years B.P. contributed to the megafauna extinctions (4). Here we challenge the overkill hypothesis based on the archaeological record of one of the few North American animals** demonstrably driven to extinction by Native Americans during the Holocene (6, 7)—the often overlooked flightless sea duck (*Chendytes lawi*).

Flightless birds are evolutionary oddities that developed almost exclusively in settings without major populations of terrestrial predators. On many Pacific islands, archaeological findings show that flightless birds were highly vulnerable to human hunting and were quickly decimated soon after humans arrived (8, 9). On the North American mainland many species of birds last disappear from the fossil record near the end of the Pleistocene, but their demise cannot be confidently attributed to human overhunting because their remains are absent from terminal Pleistocene archaeological sites (10). Indeed, a long-standing problem with the overhunting hypothesis is the fact that most genera that went extinct during the late Pleistocene have

never been found in archaeological contexts that document their exploitation by humans (2).

Such is not the case with the flightless sea duck. Since at least the 1950s, *Chendytes* bones have been recognized in California archaeological sites where their co-occurrence with other subsistence remains has led to a general consensus that the species was exploited as a food source and was driven to extinction by prehistoric people. Most of the sites that produced these bones were clearly of Holocene age, but their exact chronology and the corresponding date of *Chendytes*' disappearance were not established. The bird's persistence into the Holocene was generally attributed to a relatively recent development of watercraft by Native Californians (10). Once good boats became available, California Indians were able to reach the islands, islets, and offshore rocks the birds used as breeding colonies—then exploit them into extinction.

Archaeological data from the last decade provide new insights into the antiquity of watercraft use along the California coast that have important implications for the chronology and duration of *Chendytes*' exploitation. Here we combine recent findings on the antiquity of seaworthy watercraft in prehistoric California with archaeological data on the chronology of *Chendytes* hunting, including ¹⁴C dates obtained directly from *Chendytes* bones, to develop a most likely scenario for the species' extinction late in the Holocene. Key to this portrait is unequivocal evidence from the Channel Islands that Native Californians used watercraft at least 12,000 years ago (calendar years B.P.) and began exploiting flightless ducks soon thereafter. Together, the new dating for watercraft use and direct dates from *Chendytes* bones provide an absolute chronology for the extinction process. This new chronology relies on a highly visible record of human exploitation spanning at least 8,000 years before the species was completely exterminated.

Prehistoric California Watercraft

In the 1970s and 1980s, seaworthy boats were thought to be a relatively recent innovation in western North America. At European contact in A.D. 1542, three types of ocean-going vessels

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**The North American sea mink (*Mustela macrodon*) was exploited at least 5,100 years ago along the Gulf of Maine and was extinct at the time of European arrival, but the exact duration of species' exploitation has not been established (5).

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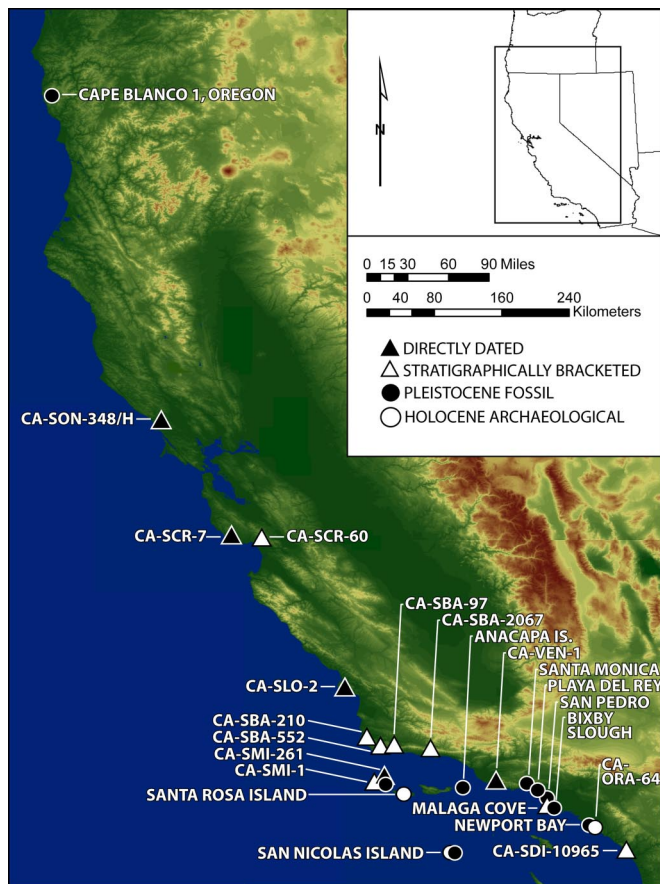


Fig. 1. Map showing location of archaeological and paleontological finds of *Chendytes lawi* along the California and Oregon coasts, highlighting locations of directly dated archaeological specimens. The figure was prepared by Brian F. Codding (Department of Anthropology, Stanford University, Stanford, CA).

were used by Native Californians: dugouts, tule balsas, and the sewn plank canoe (or *tomolo*, known only from the south coast and Channel Islands). The latter is a highly engineered craft that appears to have been developed more recently than the other vessels. Until the 1980s, the simpler craft [or possibly another composite vessel (11)] were thought to date no earlier than the early to middle Holocene, but it is now known that seaworthy boats were used to colonize the northern Channel Islands much earlier. Because these islands were never connected to the mainland even during the lowest global sea levels during the Last Glacial Maximum, the earliest archaeological evidence for human settlement also establishes a chronology for the use of watercraft. The earliest archaeological evidence for human presence on the islands is dated between 13,000 and 11,500 calendar years B.P. (12, 13). Similar findings from the western Pacific indicates that boats were used to settle islands at least $\approx 40,000$ years ago, and there is growing evidence that western North America may have been colonized at least partially by maritime peoples arriving via a coastal route sometime before 13,000 calendar years B.P. (14).

Paleontology and Archaeology

Chendytes lawi was identified as an extinct species in 1925 (15) based on finds of Pleistocene age from coastal southern California. Subsequent finds established its presence in prehuman contexts as far north as southern Oregon (16). The greatest concentration of *Chendytes* bones comes from the northern and southern Channel Islands (Fig. 1), including Anacapa, San

Nicolas, and particularly San Miguel, where ^{14}C dates on paleontological specimens establish a minimum antiquity of $\approx 40,000$ years for the taxon (17). Hundreds of *Chendytes* bones and egg shells found in Pleistocene deposits on San Miguel Island have been interpreted as evidence that some of these island fossil localities were nesting colonies, one of which Guthrie (17) dated to $\approx 12,000$ ^{14}C years ($\approx 13,500$ – $13,000$ calendar years B.P.).

The concentration of *Chendytes* fossils on the Channel Islands is consistent with their vulnerability to terrestrial predators and the absence of such predators from the islands^{††} (18). Pleistocene fossils have also been reported from at least four locations along southern California's mainland coast (Fig. 1), where offshore rocks and islets probably offered settings with comparable protection.

Results

Chendytes bones have been identified in archaeological assemblages from 14 coastal sites, including two on San Miguel Island and 12 in mainland localities. A directly dated specimen from the deepest cultural layer at Daisy Cave on San Miguel Island provides evidence for the earliest human exploitation of the species $>10,000$ years ago (11,150–10,280 calendar years B.P.) (Table 1). The oldest mainland date comes from Diablo Canyon on the central coast, where a *Chendytes* bone was dated to $\approx 8,500$ calendar years B.P., and *Chendytes* contributes 19% of the identified bird and mammal remains associated with the earliest occupation [supporting information (SI) Fig. 2]. A direct date of $\approx 7,500$ calendar years B.P. from Duncan's Point Cave on the north coast also indicates exploitation during the early Holocene, while a comparable age is suggested by stratigraphic associations to the south in San Diego County (SI Table 2). These dates suggest that, by at least 7,500 calendar years B.P., coastal peoples had a significant presence throughout the duck's California range and regularly exploited them by using watercraft to access nearshore rocks and islets. It seems likely that exploitation included the collection of eggs from offshore nesting sites, which may have contributed significantly to the eventual extinction of the species, although egg shells have not yet been identified in any archaeological site.

The youngest dates obtained for *Chendytes* bones from California archaeological sites fall between $\approx 3,500$ and 2,350 calendar years B.P. The youngest direct date (2,720–2,350 calendar years B.P.) comes from the Little Sycamore site in Ventura County, with another specimen from the Laguna Creek site in Santa Cruz County dated to 3,550–3,320 calendar years B.P. These direct dates are consistent with a *Chendytes* bone found in a stratified shell midden stratum buried in canyon fill along the Santa Barbara coast dated between 4,360 and 3,750 calendar years B.P.

Overall, archaeological data from coastal California show a record of human exploitation of *Chendytes lawi* for at least 8,000 years. Findings from the trans-Holocene occupation at Diablo Canyon show that *Chendytes* exploitation declined after the mid-Holocene (SI Fig. 2), presumably in response to human population growth and the decreasing availability of the birds. The absence of *Chendytes* bones from the later strata at Diablo Canyon, and hundreds of other excavated late Holocene sites in coastal California, is consistent with region-wide extinction by $\approx 2,400$ – $2,200$ calendar years B.P.

^{††}Today, the islands harbor only the diminutive Channel Islands fox (*Urocyon littoralis*)—which may have been introduced by Native Americans—and lack the coyote, bobcat, mountain lion, and bears common on the mainland. *Chendytes* may have been vulnerable to exploitation by bald eagles (17).

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