 

# HOLOCENE MARINE RESERVOIR TIME SERIES ΔR VALUES FROM CEDROS ISLAND, BAJA CALIFORNIA

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**ABSTRACT.** ΔR values have been calculated based on offsets in radiocarbon values exhibited in a series of stratigraphically paired charcoal and marine shell values, ranging from about 300 to 10,000 BP, excavated from archaeological sites on Cedros Island, Baja California, Mexico. Based on this data, there appears to be the equivalent of about an 800-yr range in inferred ΔR values (–400 to 400 yr) exhibited in Holocene-age marine shells from this portion of the central Baja California coast.

## INTRODUCTION

Ocean surface waters taken as a global average are depleted in radiocarbon content relative to atmospheric values by about 5.0% or 400 yr (MacFadgen and Manning 1990; Stuiver and Braziunas 1993). Regional variations have been documented for many coastal areas expressed in terms of the deviation from the worldwide average (ΔR). However, most regional ΔR values, including those for the Pacific coastal areas, have been inferred from $^{14}C$ measurements on carbonates from known-age, pre-bomb marine shell samples (e.g. Berger et al. 1966; Taylor and Berger 1967; Robinson and Thompson 1981; Ingram and Southon 1997). Fortunately, studies have demonstrated that there are no statistically significant variations in ΔR values calculated from different species of marine mollusk, even if they inhabit different habitats and utilize different food sources within a given regional near-shore or intertidal zone (Ascough et al. 2005). However, estimates of ΔR based on $^{14}C$ measurement on *in vivo* marine shells collected in the 19th and pre-bomb 20th century do not monitor temporal changes in the value of ΔR in the same locality (Taylor 1987:49–52).

In a relatively small number of cases, ΔR values have been obtained on a time series, permitting an estimate of the temporal variability in these values for a given region. When detailed studies are undertaken for a given region (e.g. Southon et al. 1990; Ingram 1998; Soares and Dias 2006), significant temporal fluctuations in inferred ΔR values are often documented. We here report ΔR values obtained from stratigraphically associated charcoal and marine shells, yielding $^{14}C$ values in the range of ~300 to 10,000 BP, collected during archaeological investigations on Cedros Island, Baja California, Mexico. We compare these values with 2 ΔR time series previously reported for the eastern central North Pacific based on sites located in coastal southern California and offshore islands in the Santa Barbara Channel.

## EASTERN NORTH PACIFIC COASTAL UPWELLING

A characteristic feature of the eastern North Pacific is the relatively cold surface water off the California and Baja California coasts (Roden 1972). Its presence is largely a consequence of the upwelling of deeper water caused by wind energy moving southward parallel to the coastline. Affected by the rotation of the earth, these winds move water at right angles to the wind direction (Coriolis effect), driving ocean surface waters offshore. As a consequence, deeper, colder water rises

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to replace the surface water (Smith 1968). This upwelling process causes water depleted in $^{14}C$ by longer residence times in the deeper ocean to be brought to the surface, and the $^{14}C$ content of marine organisms deriving all or most of their carbon from the water column are offset from that of contemporary organics deriving their $^{14}C$ from the atmosphere.

The magnitude of temporal variations in the ΔR values for coastal northern Mexico had not been previously examined. Based on studies in an adjacent region (coastal southern California), variations during portions of the Holocene were expected to be at least 700 yr. Since the Mexican coastal upwelling regimes reflect a wide range of regional and localized coastal geographic and oceanographic factors, the magnitude of the temporal variations in ΔR values were expected to be at least at the level reported for the southern California coast.

## CENTRAL BAJA CALIFORNIA PACIFIC HOLOCENE ΔR VALUES: CEDROS ISLAND

Prior to this study, for the entire length of the Baja California Pacific coast, there were only 3 published ΔR values and these data are included in the CALIB (5.0.2) Marine Reservoir Correction Database (Reimer and Reimer 2001). All of the values were based on measurements on modern, pre-bomb marine shells. One of these (ΔR = 155 ± 51 yr) was obtained on a marine shell sample collected in 1939 from Cedros Island. The 2 other ΔR values, based on modern marine shell samples from the southern portion of the peninsula, are 201 ± 53 and 329 ± 45 yr (Berger et al. 1966).

Cedros Island (Spanish: *Isla Cedros* ["Island of Cedars"], aboriginal: *Amalgua* or *Huamalgua*, ["Island of Fogs"]) encompasses an area of 347 $km^2$ and lies approximately 24 km from the nearest point on the central Baja California, Mexico coastline (Figure 2). Recent archaeological investigations on the island have resulted in establishing that it was the locus of some of the earliest documented terminal Pleistocene human occupations of coastal North America (Des Lauriers 2006).

The dominant oceanographic feature surrounding the island is the California Current, which is characterized by a southward surface current, a northward tending undercurrent, and surface countercurrents. In addition, the presence of the North Equatorial Counter Current (NECC) and recently documented intricate eddy motions of ocean water masses in the region contribute to the complexity of the coastal upwelling regime. In recent historic times, major Pacific hurricanes have occurred in the vicinity of the island on an average of 3 per decade (Miller et al. 1999).

The vicinity of Cedros Island is the most southerly portion of the coast influenced by the California Current year round. South of this area, species of the tropically associated Panamic faunistic province begin to appear, and mangroves are encountered in estuaries and bays along the coast of Baja California south of Bahía Asunción. While some species associated with the California faunistic province can be found as far south as Bahía Magdalena, the transition begins sharply at Punta Eugenia. South of Cedros Island, tropical marine species become more common and kelp forests do not persist much south of Punta Eugenia.

Solid circles in Figure 1 represent the ΔR values calculated on the basis of $^{14}C$ values obtained on 8 stratigraphically associated charcoal and marine shell paired samples ($n$ = 16) recovered as part of archaeological investigations undertaken on Cedros Island (Des Lauriers 2006). The obvious fundamental assumption in employing stratigraphically associated sample materials for such studies is that the archaeological excavations are undertaken in a manner in which the observations of contemporary placement in the site are valid. We wish to emphasize that the archaeological research design included an explicit element that addressed the desire to obtain paired charcoal and shell samples during excavations, and considerable diligence was exercised to ensure direct physical association of such samples and appropriate collection and curation standards.

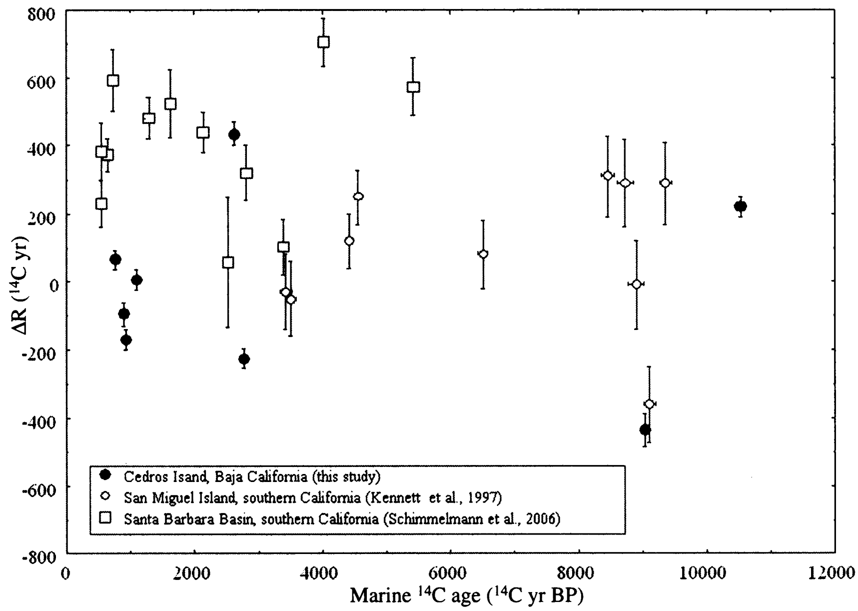


Figure 1 Marine $^{14}$C ages associated with ΔR values for Cedros Island, Baja California, Mexico (this study) and the southern California coast, USA (Kennett et al. 1997; Schimmelmann et al. 2006).

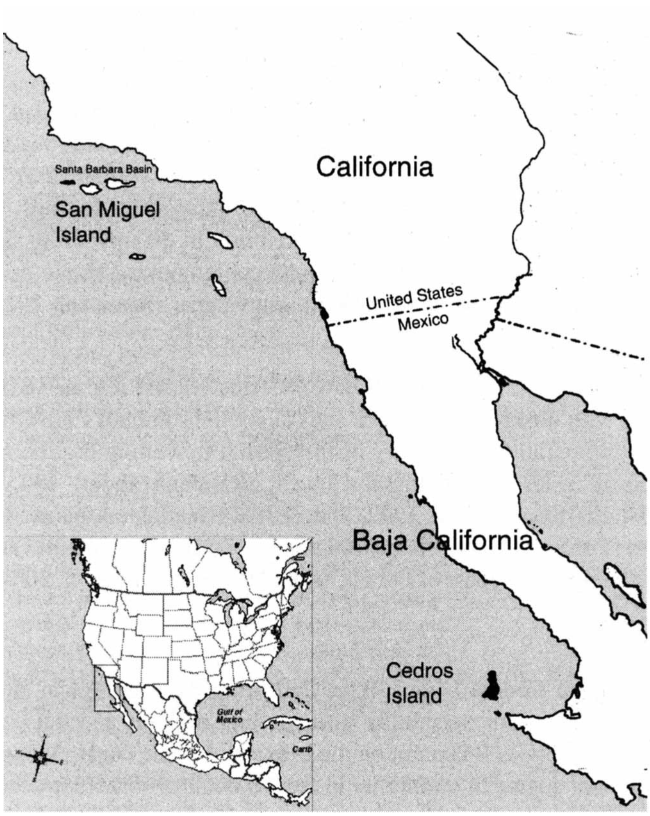


Figure 2 Location of Cedros Island, Baja California (Mexico) and the southern California coast (USA) from which originate the ΔR values discussed in this paper. Inset: location of portion of Baja California (Mexico) and California (USA) in relation to North America.

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Cedros Island ΔR values were calculated using the procedure outlined in Stuiver and Braziunas (1993: Figure 15) utilizing $^{14}C$ values obtained at the Keck Carbon Cycle Accelerator Mass Spectrometry Laboratory, University of California, Irvine (Southon et al. 2004). The $^{14}C$ values used were expressed as conventional $^{14}C$ values incorporating standard $\delta^{13}C$ normalization (Stuiver and Polach 1977). The $\delta^{13}C$ values used were obtained by accelerator mass spectrometry (AMS), which can vary between 1–3‰ from that obtained using a conventional mass spectrometer. A detailed discussion of the nature of the samples used in this study and the contexts from which they were derived including representations of stratigraphic relationships can be found in Des Lauriers (2006).

## REGIONAL ΔR VARIABILITY

Based on the data reported here, there appears to be the equivalent of about an 800-yr range in inferred ΔR values—from –400 to 400 yr—during the Holocene at this point along the central Baja California coast. This range in ΔR values for this region can be compared with that previously reported from localities located approximately 800 km north of Cedros Island on the southern California coast (see Figure 2 for locations).

Open circles in Figure 1 represent inferred ΔR values reported by Kennett et al. (1997) based on associated marine shell and carbonized plant materials from stratified archaeological sites on San Miguel Island, one of the Santa Barbara Channel islands. Open squares are inferred ΔR values reported by Schimmelmann et al. (2006) based on $^{14}C$ determinations on foraminifera from varved sediment cores collected from the Santa Barbara Basin. The inferred maximum dispersal in ΔR values reported from San Miguel Island is about 700 $^{14}C$ yr (–400 to 300 yr), while that from the Santa Barbara Basin is about 600 $^{14}C$ yr (100 to 700 yr).

In making these comparisons, we note that Cedros Island lies directly in the path of the California Current, whereas San Miguel Island and the Santa Barbara Basin are located at the northern end of the Southern California Bight, where the shoreline trends eastward below Point Conception. We are aware that locations in the Bight are influenced by an counterclockwise gyre circulation inshore of the California Current, and ΔR differences may reflect these different oceanographic settings, as well as temporal variations. We are also aware of the possibility of variability in the upwelling signature that might be contained in different parts of the same shell and contemporary shells from identical contexts reflecting seasonal variability in the coastal $^{14}C$ marine signal (Robinson 1981; Culleton et al. 2007).

The ~100 yr greater variation in ΔR values from the central Baja California coastal regime in the vicinity of Cedros Island in comparison with those reported from sites along the southern California coast is viewed as consistent with the comparable complexity of the coastal upwelling regime for this portion of the Mexican Pacific coastal zone. We note that the lowest ΔR values (about –400 yr) are exhibited in both the San Miguel Island (Kennett et al. 1997) and Cedros Island data (this study) at about 9000 $^{14}C$ yr BP. Other Western Hemispheric Pacific coastal zones reporting significant variability in ΔR values over time include the southern coast of Peru (Owen 2002; Fontugne et al. 2004).

## CONCLUSION

Paired charcoal and marine shell pairs from Cedros Island, Baja California, archaeological sites have been employed as proxy materials to examine variability in upwelling regimes and thus ΔR values for marine shells over the entire Holocene at this point on the Mexican Pacific coast. Assuming this data set accurately reflects the actual degree of variability in the $^{14}C$ content of surface ocean water over this period in this region, there appears to be the equivalent of about an 800-yr range in indicated ΔR values during the Holocene along the central Baja California coast. ΔR variability in this area can be compared to the 600- to 700-yr ranges previously reported for the southern California coast.

The temporal range in ΔR values documented for various regions and among contemporaneous shells from the same locality must be factored into the evaluation of age estimates obtained from marine shells when these are being compared to $^{14}C$ age estimates obtained from terrestrial sample types. Regionally specific inherent "noise" in the marine upwelling signal reflected in the variability in ΔR values sets limits to the precision possible in inferring temporal placement based on marine shells for a given coastal locality.

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