Ice Ages, Packrats and Ancient Trees: Climatic Environmental Change in the Salton Sea Region and Colorado River Basin

(DRAFT 2)

Glen M. MacDonald

Department of Geography

UCLA

Any consideration of environmental change and the Salton Sea and vicinity must take two factors into account. The first is the local climate and environment of the Salton Sea Trough. As we shall see the climate and vegetation of this area of southern California has experienced marked changes in the geological past and in recent centuries. The second factor that must be considered is the flow of the Colorado River. The present Salton Sea is a creation of the river and the amount of water available to replenish the sea if so desired is dependent upon the flow of the Colorado. We will examine evidence of how the flow of the Colorado has varied in the last few hundreds of years.

The modern Salton Sea Trough lies at the intersection of two great deserts, the Mojave lies to the north and the Sonoran dominates the trough and areas to the south and west. The Mojave is typified by hot and dry summers. The winter brings rain, but also cold temperatures. Many places in the Mojave experience freezing during parts of the winter. Summers are also hot in the western Sonoran Desert, but they can also experience monsoon rains. Winter brings additional rain, but is not as cold as in the Mojave. Both desert regions can experience large variations in annual precipitation. In some years the winter rains fall far short of their normal amounts and the desert becomes even more inhospitable to plant and animal life. If the temperatures are high, evaporation rates increase and remove more water than usual from the lake and surrounding soils. Because of the aridity and annual variability in precipitation, the vegetation of both deserts is sparse and dominated by plants such a creosote bush, brittle bush, pygmy cedar and cacti that are adapted to dry conditions.

Today the Salton Sea Trough lies in a sparsely vegetated desert – but this desert has changed over time. The environment of the southern Mojave and western Sonoran deserts have experienced profound changes in climate and vegetation over the past 2 to 3 million years. During this time the climate of the entire planet has periodically shifted from ice age conditions, during which the average temperature at the surface of the earth was several degrees cooler than today and much of Canada and northern Europe was covered by ice, to the relatively warm conditions we experience now. This time of alternating climate is called the Pleistocene geologic era. The shift, from cold glacial conditions of the late Pleistocene to the modern climatic conditions of today occurred some 10,000 to 13,000 years ago (the ages in this section refer to radiocarbon years and do not exactly equal calendar years) was caused by natural changes in the orbit of the earth. We refer to the past 10,000 years or so as the Holocene geologic era. Although the Salton Sea Trough and adjacent Sonoran and Mojave deserts were certainly not covered by glacial ice during the Pleistocene, the region did experience large changes in climate and vegetation during the transition between the end of the Pleistocene and the start of the Holocene. The January and July average temperatures are likely some 2° C to 8° C cooler than today and it was moister than today. The vegetation was also different. Lets take a look at how the changes in climate and vegetation in the deserts are reconstructed and what the environment of the Salton Sea region was like 20,000 years ago.

Scientists have had a rather remarkable group of helpers when it comes to collecting and archiving information on the past vegetation and climate of desert regions in the southwest. Those helpers are the members of the packrat genus *Neotoma* (Fig. 1). Packrats collect small pieces of plants, such as twigs, leaves and seeds from the vegetation that surrounds their nests. They bring these bits and pieces to their nests, which often occupy small crevices and caves in rocky exposures. Within in the protected nests, the urine of the packrats forms a solid crystalline material called that glues the plant matter together and protects it from deterioration. The crystalline material is called amberat because its color and texture are like amber. The hard masses of amberat and plant remains are called packrat middens. The middens can be preserved very long periods of time in dry desert conditions. In some cases, radiocarbon dating has shown middens to be over 40,000 years old. Scientists moisten the middens to break down the hard amberat and release the plant remains for identification and analysis. Each midden is radiocarbon dated to determine its age. When many middens from the same region are analyzed and radiocarbon dated, a history of vegetation change from ~40,000 years ago to the present can be reconstructed. Many such analyses have been conducted in the Sonoran and Mojave desert by scientists such as Geoff Spaulding, Julio Betancourt and Tom Van Devander.

The analysis of packrat middens from the Sonoran and Mojave deserts around the Salton Sea tell a fascinating story. In general, the Sonoran sites show that the vegetation during the last glacial period contained plants more typical of moister deserts. The analysis of packrat middens from the Whipple Mountains and Pichacho Peak regions of southeastern California show that from at least 13,000 years ago to 10,000 years ago the Californian Sonoran Desert was moister than today and some sites contained species typical of less arid regions of the Mojave. Such species included single needle pinyon pine, California juniper and joshua trees (Fig. 2). Today, Joshua trees do not grow any closer than 100 to 150 km to the northwest of areas such as the Salton Sea and Pichacho Peak. By 10,000 to 9,000 years ago this vegetation was replaced by typical eastern Sonoran species such as creosote bush, brittle bush and catclaw acacia. The vegetation that existed in the Californian Sonoran Desert suggest that precipitation prior to 10,000 years ago was perhaps as much as 50% higher than today. Packrat middens from the Mojave Desert tell a similar story. The vegetation of the late Pleistocene, some 20,000 to 13,000 years ago, was typified by extensive open dry woodlands containing some oaks, pinyon pine, limber pine and juniper. Treeless desert did exist in some low elevation locations at this time also. More arid vegetation, similar to today, was established in the Mojave between 10,000 and 9000 years ago. Geologic evidence shows that during the late glacial period many of the dry playas found in the Sonoran and Mojave deserts contained deep and permanent bodies of water. This is consistent with the evidence from packrat middens that suggests moister conditions.

Taken together, the analysis of packrat middens indicates that during glacial periods the environment of the Salton Sea region has been moister and cooler than today. It has probably never been so cool and moist as to have supported low elevation forests. Rather, the vegetation of 20,000 years ago represented desert conditions, but was less arid than today and may have contained more plants typical of the Mojave Desert. Evidence from packrat middens also tells us that there have been some smaller shifts in climate and vegetation in the Sonoran and Mojave deserts over the past 10,000 years. However, these shifts seem to vary from region to region and are relatively minor compared to the differences between glacial and non-glacial vegetation.

What can we say about the recent climate and annual variability in climate, particularly in precipitation, that occurs in the Salton Sea region? Instrumental records of precipitation from weather stations extend back in time only about 100 years or so. These records show that the area has experienced annual fluctuations in precipitation, but has always been relatively dry. In terms of climatic variability, 100 years is a very short period of time. How can we produce longer records of annual precipitation or drought variability to see if the last 100 years are typical? The answer lies in the mountains high above the Salton Sea. At the highest elevations of mountains such as San Jacinto, San Gorgonio, San Antonio and Baden-Powell there are ancient groves of limber pine trees (Fig. 3). These trees grow on rocky slopes at elevations of between 9000 and 11,000 feet. The trees grow in very open and scattered groves that do not carry fires or burn very often. In the absence of fires, these slow growing trees can live for over 1000 years. Each year the trees put on a new ring of growth between the outer bark and the inner wood. In years with high snowfall and rainfall, there is sufficient moisture for the trees to grow well and put on large rings. During drought years the trees do poorly and the rings are very small – often far less than 1 mm in width. By counting these rings we can determine the age of trees. By measuring each ring we can produce a record of precipitation or drought that extends back over 1000 years (Fig. 4). A reconstruction of drought severity in southern California from A.D. 653 to A.D. 1998 shows that the dryness and annual variability in precipitation and drought of the last 100 years is fairly typical of conditions over the past 1300 years. However, there have also been relatively long periods when conditions were moister, such as between A.D. 700 to 800 and A.D. 1450 to 1550. In addition, there have been relatively long dry periods such as around A.D. 900 and between A.D. 1100 and 1200. It is likely that such long-term episodes of generally wetter and drier conditions will affect the Salton Sea region in the future.

The present Salton Sea was created by a diversion of the Colorado River during a period of high flow in 1905. This is not the first time this has occurred in the last few thousand years other large water bodies created by flow from the Colorado River have filled the basin and then disappeared. One of the largest occurred about 1500 years ago. Much of the water used in southeastern California, including the irrigation waters that flow into the sea today are largely derived from the Colorado River. Water to replenish the Salton Sea, either by human design or through natural processes, would also come from the Colorado. As the Colorado is so important to the Salton Sea and vicinity we might ask two questions. First, how variable is the flow of the Colorado over long periods of time? Second, was the creation of the Salton Sea in 1905 in anyway associated with unusually high flows by the river? Hydrological monitoring along the lower Colorado only extends back to the early to mid 20th Century at most gauging stations. How then can we reconstruct a truly long record of Colorado River flow? The answer is tree-ring analysis.

Trees such as douglas fir, pinyon pine, limber pine and other species growing in some areas of the Colorado River basin are relatively moisture stressed and sensitive to variations in precipitation. Years with high amounts of rain and snowfall produce large tree-rings and drought years produce small rings in these trees. Flow in the Colorado River also responds to such annual variations in precipitation. Years in which rain and snowfall over the basin are high result in high flows of the river. SInce both the tree-rings and the river are responding to the same forcing factor, precipitation, we can use tree-ring analysis to produce long records of flow in the Colorado River.

A number of tree-ring based reconstructions have been made for flow of the Colorado River (Fig. 5). These are based on tree-rings from several sites around the basin and all show generally similar trends. The reconstructions are for flow of the Colorado at Lees Ferry, Arizona. The flow for the recent decades is a model for what the rate would be if there were no large dams on the river above Lees Ferry. Of course, this is not the case today.

The tree-ring based reconstructions for the Colroado River extend back about 500 years and suggest there have not been any general trend of either increasing or decreasing flow over that period. The reconstructions show that flow has varied considerably from year to year, decade to decade and century to century. The average flow of the 20th Century, which is roughly 15 billion cubic meters of water per-year, is relatively high compared to many other centuries. It is clear that the flow has been impacted by long periods of substantial drought and low river flow. One of the most intense of these occurred in the late 16th Century when river flow at Lees Ferry dropped to about 10 billion cubic meters per-year. The 20th Century, during which time the Salton Sea has existed and when many water resource plans have been developed, has not experienced such a pronounced decline in the flow of the Colorado River as occurred duringt he late 16th Century.

The diversion that created the Salton Sea in 1905 occurred during a period when the flow of the river was increasing following a long period of low flow in the late 19th and early 20th Century. The creation of the lake is not associated with a particularly high rate of annual flow. It is uncertain how changing overall annual flows in the Colorado may have influenced the timing of diversions that create water bodies in the Salton Sea Basin. It may well be that short term flow events and local channel changes in the delta region are more important than overall annual flow rates in creating such diversions.

From the information that we can gather from packrat middens, ancient trees and other sources we can say a few things about the environment of the Salton Sea, past, present and future. First, over 1 million years the area has been a desert. During this time there have been shifts from a warm and very dry desert such as the eastern Sonoran is today to a moister and cooler desert such as the Mojave to the north. These shifts have occurred in synchrony with worldwide fluctuations between ice ages and warm periods such as present. From about 9,000 to 10,000 years ago the general climate and vegetation of the Salton Sea region has been as it is today. Over the past 1000 years the yearly weather conditions of the Salton Sea have been much like they are today. However, in the past there have been decades long periods of drier and moister conditions that we can expect to be repeated at some point in the future. Similarly, there has been no overall trend in the flow of the Colorado River. However, the flow of the river is prone to large variations from year to year, decade to decade and century to century. In general flows in the 20th Century were realtively high and we have not experienced the most severe drought induced reduction in Colorado River flow that might be expected to occur due to natural variability.

Fig. 1 A picture of a packrat of the genus *Neotoma.*

Fig. 2 The history of vegetation change in the Californian Sonoran Desert from packrat middens found in the Whipple Mountains of California (from Van Devender, 1990).

Fig. 3 Ancient limber pines that live in the high mountains to the west of the Salton Sea.

Fig. 4 A reconstruction of the Palmer Drought Severity Index for southern California based upon tree rings from limber pines (MacDonald, unpublished). Low values represent droughts and high values represent moist periods. The drought index incorporates both precipitation and evaporation measurements.

Fig. 5 A reconstruction of Colorado RIver flow at Lees Ferry based upon tree ring records (after Stockton and Jacoby, 1976 and Hidalgo et al., 2000).

References

Hidalgo, H.G., Piechota, T.C. and Dracup, J.A. 2000. Altenrative Principal components procedures for dendrohydrologic reconstructions. Water Resources Research 36: 3241-3249.

Spaulding, W.G. 1990 Vegetational and climatic development of the Mojave Desert: the last glacial maximum to present in Betancourt, J.L, Van Devender, T.R. and Martin, P.S. editors, Packrat Middens, University of Arizona Press, Tucson, pp. 166-199.

Stockton, C.W. and Jacoby, G.C. Jr. 1976. Long-term surface water supply and streamflow trends in the upper Colorado River basin based on tree-ring analysis. Lake Powell Research Bulletin 18.

Van Devender, T.R. 1990. Late Quaternary vegetation and climate of the Sonoran desert, United States and Mexico. in Betancourt, J.L, Van Devender, T.R. and Martin, P.S. editors, Packrat Middens, University of Arizona Press, Tucson, pp. 134-165.