



IEP NEWSLETTER

VOLUME 14, NUMBER 3, SUMMER 2001

Of Interest to Managers 2

Interagency Ecological Program Quarterly Highlights: April-June 2001 3

News from Around the Estuary

First Observation of an Exotic Water Flea in the Delta: *Daphnia lumholzi* 12

Preliminary Validation of Daily Otolith Ring Deposition in Juvenile Splittail 15

The Chinese Mitten Crab (*Eriocheir sinensis*) in Great Britain 16

Contributed Papers

Tahoe and the Delta: Some Fundamental Differences in Conservation and Restoration Issues 18

Global Climate Change: Potential Effects on the Sacramento-San Joaquin Watershed and the San Francisco Estuary 23

Differences Among Hatchery and Wild Steelhead: Evidence from Delta Fish Monitoring Programs 30

Responses and Recovery in Delta Smelt Exposed to Handling Stress During Fish Treadmill Experiments at Winter Temperature 38

Food Habits of Larval Splittail 40

Fish Assemblage Structure and Associations with Environmental Variables in the Southern Sacramento-San Joaquin Delta 42

CALFED Corner

Science and the CALFED Bay-Delta Program's Environmental Water Account 46

CALFED and IEP Workshop Planned for September 2001 50

Meeting Review

Droughts, Epic Droughts and Droughty Centuries—Lessons from California's Paleoclimatic Record:
A PACLIM 2001 Meeting Report 51

Announcements 54

Delta Water Project Operations 55

MEETING REVIEWS

Droughts, Epic Droughts and Droughty Centuries—Lessons from California's Paleoclimatic Record: A PACLIM 2001 Meeting Report

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During the early 1990s (but echoing studies by S.T. Harding at the University of California, from as early as the 1930s), several lines of paleoclimate evidence in and around the Sierra Nevada Range have provided the water community in California with some real horror stories. By studying ancient tree stumps submerged in Lake Tahoe and Tenaya Lake, stumps that were emerging from Mono Lake during its recent decline, and stumps that were exhumed in the Walker River bed during the floods of 1997, paleoclimatologists like Scott Stine of California State University, Hayward, assembled a picture of epic droughts in the central Sierra Nevada during the medieval period. These droughts had to be severe to drop water levels in the lakes and rivers low enough for the trees to grow in the first place, and then had to last for hundreds of years to explain tree-ring counts in these sizeable stumps. Worse yet, the evidence suggested at least two such epic droughts, one ending close to 1100 and the other close to 1350. These epic droughts challenged paleoclimatologists, as well as modern climatologists and hydrologists, to understand and, ultimately, to determine the likelihood that such droughts might recur in the foreseeable future. The first challenge, however, was to verify that such droughts were more than local events and as extreme as suggested.

At this year's Pacific Climate (PACLIM) Workshop, held March 18–21, 2001, at Asilomar (Pacific Grove, Calif.), special sessions brought together scientists to compare paleoclimatic reconstructions of ancient droughts and pluvial (wet) episodes to try to determine the nature of decadal and centennial climate fluctuations in western North America, with emphasis on California. A companion session brought together modern climatologists to report on the latest explanations (and

evidence) for decadal climate variations during the instrumental era of the 20th century.

PACLIM is an annual workshop that, since 1983, has brought together specialists from diverse fields, including physical, social, and biological sciences, to discuss and investigate climate and climate effects in the eastern Pacific and western America. This year's PACLIM was sponsored by the U.S. Geological Survey, NOAA Office of Global Programs, California Department of Water Resources, and, for the first time, the CALFED Science Program. In addition to the presentations summarized here, sessions at this year's PACLIM covered topics as varied as the North American monsoon system; recent economic and political effects of California's climate variations, including a presentation on climate and CALFED by Sam Luoma (U.S. Geological Survey, Menlo Park); and research into daily-to-seasonal weather variations. Information about this year's and next year's meetings can be found at <http://meteora.ucsd.edu/paclim/>.

Prehistoric Droughts and Floods

Recent developments and comparisons of paleoclimatic time series from a variety of sources and settings in the California region were an important focus of this year's PACLIM. Sediment layers from the offshore Santa Barbara Basin and Gulf of California; isotopic, chemical, and paleomagnetic signatures in cores from Pyramid Lake in northwestern Nevada; and tree rings from numerous locales around the western states—along with many other paleomarkers from ocean sediments, marshes, and lakes, and other sources—were analyzed to develop high-resolution paleoclimate reconstructions (often cataloging year-by-year climate variations). The overall picture of decadal and centennial climate variations in California during the last several millennia that emerged from comparison of these various reconstructions is that long-term decades to centuries-long excursions of California's climate, and in particular, of its precipitation regimes, have indeed occurred in the not-too-distant past (for example, during medieval times).

For example, Larry Benson (USGS, Boulder, Colo.) reported that major oscillations in the water balance of Pyramid Lake have occurred irregularly but, on average, about every 150 years during the last 8,000 years. Among the paleodroughts that affected the lake were the medieval epic droughts inferred elsewhere in the Sierra Nevada. A major relocation of Anasazi populations in the Four Corners region occurred in the middle of the second of these prolonged droughty periods, which took place in the 1280s. Numerical simulations of the lake's water balance (as inferred from the geochemical variations in its sediments) suggest extended droughts could have involved greater than 30% reductions in the wetness of the Sierra Nevada, on average, over multidecade and even century time scales. Remarkably close, but quite independent, corroboration of many of these paleoclimatic changes came from Douglas Kennett's (California State University, Long Beach) report on the foraminifera and geochemistry of ocean sediments from the Santa Barbara Basin. The Santa Barbara Basin sediments indicate important sea-surface temperature variations along the California coast over the last several thousands of years that coincided with droughts and wet periods identified far inland in White Mountains bristlecone tree rings. Malcolm Hughes (The University of Arizona Laboratory of Tree-Ring Research) used new precipitation-sensitive tree-ring reconstructions, each over 1,000 years long, from around the West to show long-term droughts in exquisite detail. In the Southwest, the 1950s drought ranked as probably the most extensive intense decadal-scale drought in the last 1,000 years, but closer to home, the medieval droughts (especially the later one) was clearly evident in the tree rings. Similarly, Lisa Graumlich (Montana State University) found evidence of persistent (but not unbroken) drought conditions in 1,000-year tree-ring reconstructions from the Greater Yellowstone Region. David Meko (The University of Arizona Laboratory of Tree-Ring Research) and others showed evidence that the epic medieval droughts coincided with wet intervals farther north in Oregon, perhaps indicating persistent reroutings of storm tracks to the north of California during the drought periods.

Each of these climate reconstructions also included sustained, wetter-than-normal intervals of durations comparable, in some cases, to the epic droughts. Ominously, several of the climate reconstructions presented showed that the 20th century has yielded fewer droughts in California than in previous centuries. At the wet hydrologic extreme, past megafloods in coastal

southern California were inferred from distinctive clay-rich layers in the Santa Barbara Basin. Megafloods occurred in 212 AD, 440 AD, and 1418 AD, and 1650 AD, according to Arndt Schimmelmann (Indiana University). To put these episodes in perspective, Schimmelmann noted that historical wet years have left no signs comparable to these prehistoric megafloods.

Overall, the intercomparisons of paleoclimate reconstructions presented at the workshop suggest epic droughts (decades and centuries long) did afflict central California during the last several millennia, including, in particular, the medieval droughts. The drought periods were vastly longer than we have experienced, but not necessarily more severe than historical droughts. There are tantalizing suggestions of almost periodic recurrences of some of the inferred droughts, with periods ranging from 20 to 150 years and more. The general consensus from the PACLIM Workshop, was that these droughts should not be envisioned as unbroken spells of uninterrupted dryness, but rather as extended intervals during which droughts were significantly more common. The "six-year" drought in California during the late 1980s and early 1990s may provide a much reduced model for such droughts; that drought was broken by a year of normal wetness at its midpoint and occurred despite year-to-year changes in the large-scale climate state (for example, El Niño conditions, La Niña conditions, and in-between conditions prevailed at various times during the course of this event). Thus it may be best to imagine that the epic droughts corresponded to long intervals with greater-than-normal propensities towards drought in California, quite possibly with droughts more persistent than usual. Thus these dry intervals probably reflect prolonged shifts to more droughty conditions rather than single "continuous droughts." Finally, Malcolm Hughes concluded that the various paleorecords presented at this year's PACLIM, along with many others, are now mature enough to support a major case study of one or both of the medieval droughts in far greater detail than has previously been possible. A wide range of paleoclimate indicators from the entire western North American region can now be brought together to provide constraints on the conditions, spatial extent, and persistence of those droughts, as well as compare these paleodroughts. Such comparisons would provide a much clearer depiction of epic droughts in California than is possible in a single workshop.

Modern Decades-long Climate Fluctuations

In an attempt to understand the climate mechanisms that might drive such long-term fluctuations, particularly in the Pacific Ocean basin and western Americas, several climatologists were asked to present some of the most recent views of decadal climate processes in the Pacific. Michael Evans (Harvard University) and Mark Lyford (University of Wyoming) used regional syntheses of paleoclimatic reconstructions to argue that the paleoclimatic versions of decadal and centennial climate variations form climate patterns that are recognizable in the modern climate system. Evans argued, in particular, that paleoclimatic reconstructions of decade-scale El Niño-Southern Oscillation (ENSO)-like climate variations show much the same pattern as that associated with current ENSO-like variations; furthermore, those variations are so symmetric around the equator in the Pacific Ocean basin that they must be of tropical origins. David Pierce (Scripps Institution of Oceanography) and Matthew Newman (Climate Diagnostics Center, Boulder, Colo.) used climate-model simulations and the last century of records of year-to-year and decadal climate variations to draw much the same conclusion: the decadal variations of Pacific, and thus western North American, climate witnessed during the last 50 years are driven by slow variations in the chaotic evolution of tropical Pacific ENSO episodes, with some amplification of the decadal parts by the long, slow responses of the extratropical Pacific Ocean to those year-to-year ENSO variations. In this view of the decadal variations of the Pacific climate, the decadal (and longer) climate spells are artifacts of slowly varying but essentially random variations of the global climate, termed “red-noise climates.” The conclusions of these speakers reflect a growing belief among many climatologists that the so-called Pacific Decadal Oscillation (PDO) has its roots in the tropics, rather than reflecting independent climatic oscillations from the extratropical North Pacific. The PDO remains an interesting index to correlate to and reconstruct back through time; however the predictability of the PDO is limited.

Others at the workshop, notably David Keeling (Scripps Institution of Oceanography) and Alan Hunt (Pacific Northwest Laboratory), were more inclined to explain the long-term climate variations in terms of slow “external” forcings, like tidal mixing of the deep ocean, solar-irradiance variations, or greenhouse gas accumulations. At this workshop, the least popular among

explanations of decadal climate variations were various, previously proposed extratropical ocean-air mechanisms. The chaotic-tropics versus external-forcings camps continue to debate the sources of decadal to centennial climate variability as this article is published (and probably for a long time to come).

Summary

This year’s PACLIM Workshop presented a picture of California’s long-term climatic history that includes significant epic “droughty” periods spanning hundreds of years, with water balance deficits as large as any we have suffered historically. Wetter-than-normal periods have also persisted at times in California prehistory, and extremely large floods during the last 2,000 years occasionally have left their marks offshore. Although competing plausible explanations for the origins of California’s long decadal to centennial paleoclimate variations have been offered, the origins remain uncertain—especially since it is not clear that we have ever seen even mild versions of this form of climate variation in our time in California. **As** a result, our ability to predict the recurrence of such disasters is minimal. We can, however, advise that such events have happened before and thus may happen again.