Drought During California's Mission Period, 1769-1834

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> *Voltaire to the contrary, history is a bag of tricks which the dead have played upon historians. The most remarkable of these illustrations is the belief that the surviving written records provide us with a reasonably accurate facsimile of past human activity. . . . If historians are to attempt to write the history of mankind, and not simply the history of mankind as it was viewed by the elite and specialized segments of the race who had the habit of scribbling, they must take a fresh view of the records.*
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> –Lynn White (1962:vii)

SEASONAL rainfall fluctuation and drought episodes are an important part of California's mission period human ecology. For example, in a study of Kumeyaay adaptation in the Mission San Diego catchment area, Shipek (1981: 300) explicitly recognized the role of drought, noting that "clearly fecundity, food, and rainfall are closely linked." Drought also plays a prominent role in the Chumash - Mission Santa Barbara conversion model posited by Coombs and Plog (1977), and a recent paper by True and Waugh (1982 : 37), concerning Luiseño settlement patterns on Mission San Luis Rey lands, considered drought-related water supply problems as a possible explanation for relocation.

Although each of these works contributed much to furthering an understanding of aboriginal-mission interaction, each might gain additional value from a reliable drought chronology tying dry episodes to specific times and places, in turn facilitating explication of drought-related impacts and influences. Yet, as helpful as an accurate drought chronology for the mission period might be, there is none. Instead, evidence of historic drought is usually inferred from various qualitative primary and secondary sources, such as the Franciscan letters, journals, and reports (often as they appear in translated and edited versions), or from quantitative mission harvest data, which are then used to identify drought episodes by assuming that low crop yields indicate dry years (e.g., Shipek 1981). Although each of these methods has some validity, each also has weaknesses and distortions – while primary narratives can be biased by individual perceptions and secondary materials distorted by subjective interpretation, not all crop data are reliable indicators of rainfall conditions because various social factors often mask rainfall dependence.

In this article, Spanish narrative material and mission harvest data are evaluated as source materials for historic drought analysis, then a more objective drought chronology drawn from southern California tree rings is offered. After presentation of these data, the paper concludes with a discussion of research themes in mission human ecology linked with drought. The article begins with a brief review of drought definitions, attributes of precipitation variability in the historic mission lands, then moves into a discussion of how this variability might be expressed in the Franciscan narratives.

DROUGHT AND RAINFALL VARIABILITY

Any definition of drought must recognize two interrelated components: the objective departure from statistical norms, which is often called meteorological drought; and,

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equally important, a social dimension that explicitly recognizes the subjective and relative nature of dry periods as they are connected to specific water needs, expectations, and shortages, and the resulting influences on extant systems and activities (Steila 1983; Spitz 1980). Separating meteorological drought from socially induced water shortages is particularly difficult in the historical record because of the range of normal precipitation variability in both time and space, and the behavioral complexities inherent in a frontier experience where the adaptive process involves matching desired activities to available resources.

There are six attributes of California's rainfall that constituted the climatic backdrop for Spanish settlement. Each is discussed only briefly here because, at one level at least, they are commonly recognized components of the environment. On another level, however, they can obscure and confuse drought-related adaptation studies if not explicitly isolated and defined. These attributes are as follows.

1. Narrowly defined, drought can be any period of time when a water imbalance occurs because evaporation and transpiration exceed precipitation. This happens each summer in most of California but, because this is a pervasive and predictable component of the environment, it is not of major importance to this article and, instead, simply forms the broadest framework within which other kinds of rainfall variability are discussed.

2. Within the winter rainfall season, there can be dry spells of short duration that adversely affect human activities if such spells are coincidental with a critical stage of crop maturation or cultivation. These intraseasonal droughts may be bracketed by periods of normal or heavy rainfall that might mask the dry spells within average seasonal accumulations.

3. Seasonal droughts imply a whole winter rainfall period with abnormally low precipitation; obviously, these episodes have severe consequences.

4. When these seasonal droughts extend for more than one rainfall season, or when the cumulative rainfall is below average, dry periods result. However, one should distinguish between well-documented multi-year droughts and those dry periods that are functions of analytic method and scale. While the former may have serious implications for human activities, the latter are often simply constructs based upon cumulative or averaged statistics that may or may not reflect conditions actually experienced by humans.

5. The incidence and configuration of these different kinds of drought are inherently linked to what can be called the normal range of precipitation variability. That is, even without entering the realm of abnormal rainfall, there is extremely high year-to-year variability in the constituent parts, such as the length of the rainy season, number and intensity of rainfall events, runoff conditions, and so forth. The magnitude of this "normal" variability differs with location within the state. Specific to the lands occupied by the Spaniards, the variability coefficient is higher in southern California than in central and northern areas of the state. Granger (1977: 387) calculated the coefficient of variation for 23 lowland California stations and found the four highest to be Los Angeles, Santa Barbara, San Diego, and San Luis Obispo. Put differently, the Franciscan missionaries founded their colonization enterprise in those coastal areas with the lowest level of rainfall regularity and predictability.

6. The high amount of spatial variability in California's rainfall must be recognized. This has several implications for the study of Spanish and aboriginal drought adaptation. First, because drought is not necessarily spatially uniform, some missions may have suffered from a given episode and others not. Second, given the extensive territory covered

by mission lands, rainfall usually varied considerably within the same jurisdictional unit – therefore agricultural conditions could vary greatly. These differential conditions might aggravate or alleviate regional drought conditions, but this environmental diversity would be masked in yearly harvest data because it was part of the same analytical unit.

Having briefly considered these six dimensions of meteorological drought, and the temporal and spatial variability associated with objective and measurable parameters of rainfall, the following discussion examines the subjective interpretation of these events as they appear in the Franciscan narratives.

DROUGHT IN THE MISSION NARRATIVES

The Spaniards left a voluminous archival legacy of letters, journals, and annual reports that contain a wealth of narrative material pertinent to drought, its occurrence, and resultant influences. These narratives should not be used without constraint; rather, they should be subject to certain tests and qualifications necessary to establish an appropriate context. Ideally, use of documentary materials on a reliable basis requires: (1) knowledge of why the information was recorded and how the purposes and experiences of the writer may have biased his perception and selection of climatic data; (2) insight into how the writer categorized meteorological phenomena; (3) some understanding of statements of degree (e.g., the difference between "heavy" and "light" rainfall); and (4) complete information on the dating, duration, location, and extent of the meteorological event (Ingram, Underhill, and Farmer 1981: 196-199). As noted, these are ideal documentary conditions rarely satisfied by archival sources. This is not to suggest that such documents lack research value if they fail some tests, but simply that areas of suspicion and weakness should be made explicit to determine the limits and biases of archival materials.

Most of the Spanish narratives readily pass tests of dating, location, and author identity, but leave researchers with the task of sorting out perceptual bias, categorization criteria, and significance of degree. How that is best done remains a challenge and some thoughts on that matter are offered below. First, however, two typical passages from the mission narratives are presented for those unfamiliar with the nature of these documents – they illustrate the diversity of the material under discussion.

> We have had no rain here since November 25th, not even a drop. This means of course that it has not rained at all thus far this year. You can well imagine the inevitable hardship caused by the resulting lack of fodder and the severe damage to our crops [written April 1809 by Senán from Mission Buenaventura (Archibald 1978: 168)].
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> While in 1820 Fr. Martinez officially reported that a great many cattle, sheep, and horses perished for lack of pasturage due to the long drought, he later speaks of heavy floods. Unfortunately his besetting sin of neglecting to date his unofficial letters renders it impossible to state the season or year [Engelhardt 1963: 70-80].

While the first passage is a direct translation from primary sources by Archibald, the second is Engelhardt's interpretation of the substance contained in the Martinez letters. Taken together, they demonstrate that bias can occur at two levels, first by the original Franciscan author, and second, by 20th-century interpreters and compilers of these primary materials. These concerns, along with several others, are elaborated below.

In evaluating the relative accuracy of narrative statements, some thought should be given to the writer's experience with variable rainfall patterns in California. Recorded perceptions of environmental variability must, to some extent, logically reflect the number of sensed, meteorological events witnessed by the writer. Thus, it is likely that a newly arrived padre would have been less accurate in chronicling drought than one who had been exposed to a fuller range of seasonal rainfall fluctuations. The accuracy of a missionary's statements, therefore, might be weighted according to his residential longevity in California and his experiences before coming to the region. This experience/accuracy equation suggests that, in general, narrative accounts of drought can be differentially weighted for their accuracy – those dating from early in the mission period, written by Franciscans with limited exposure to California rainfall patterns, are probably less reliable than those recorded later by padres with more extensive, local experience.

Further, because the Spaniards did not measure meteorological phenomena, their descriptions of weather and climate were necessarily subjective and socially conditioned by the immediate context. Local factors can bias narratives in various ways. To illustrate, "In this year of drought [1829], when there is no pasturage for the sheep, where shall they be placed?" (Martin, in Engelhardt 1920: 227). Tempting as it might be to take this passage as evidence of widespread drought during 1829, caution must be exercised before expanding the description beyond the specific context of sheep pasturing on Mission San Diego lands in that specific year. In particular, the reference to drought in this case was closely linked to a land dispute and a fear that alternative pasturage would not be available if mission lands were reduced. Rather than an objective chronicle of drought in 1829, a perceived "drought" was used to justify retention of certain mission lands.

A third kind of qualification in weighting the relative accuracy of narrative accounts of drought focuses on the potential distortion of these events as underlying causes of systemic stress when other, non-climatic factors may have played as great or greater role. When reading the passages relating to drought, on occasion one wonders whether the Franciscans sometimes used climatic deterioration as an excuse for larger scale – perhaps even non-specific – ills, shortcomings, and failures. After all, the annual mission reports were the official documents of the system and acted as reference points by which to measure progress toward achievement of the goals of the Spanish Crown. Does it not make sense, then, that at times system failures were blamed by the Franciscans on factors beyond their control? An extreme illustration can be offered. In his history of Mission Santa Barbara, Engelhardt (1923: 167-168) described in detail a "rainfall procession" in December, 1833, wherein prayers and supplications were raised to the Almighty in hope of ending the distress ostensibly caused by drought. Granted, if little or no rain had fallen by late December, there might have been serious consequences for specific activities such as winter wheat planting and winter livestock pasturage, and it might portend widespread spring and summer water shortages. Tree ring analysis, however, indicates that both 1832 and 1833 were years of average (normal) rainfall, although the rings may not have registered a short-lived, early-season drought.

There are no other references to similar "rainfall processions" in the Engelhardt histories, consequently it is not clear how common such ceremonies may have been. Nevertheless, one must ponder whether or not this activity was invented to alleviate problems induced by political causes – namely the threat of secularization and harassment in the form of excessive taxation by the Mexican government. Under stress, communities may invest more heavily in symbolic acts (Rowntree and Conkey 1980); therefore it seems reasonable that something like a drought-focused "rainfall procession" might symbolically reaffirm the mission system's values, goals, institutions, iconography, and methods at a time of widespread systemic stress.

The point here is not to deny the problematic aspects of documenting historic droughts with narrative accounts, but to emphasize the necessarily qualitative nature of the latter and to caution against uncritical use of primary or secondary archival materials to accurately define the role of drought in disrupting the mission system. This author believes that, at times, the Franciscans may have, unknowingly or by design, erroneously attributed agricultural problems to drought. Because they satisfy preconceptions and extant world views of plausible human-environment interaction, the Franciscans' rationalizations have been perpetuated by subsequent, uncritical use of archival materials. (Blatant examples can be found in Lynch [1931]; see Rowntree [1985a] for a criticism of this work.) Effective use of narrative accounts demands careful consideration of alternative explanations for the system failures blamed on drought in these documents.

DROUGHT AND HARVEST DATA

Currently, the most common method found in mission studies for generating a drought chronology involves use of yearly agricultural data. The assumption made is that crop behavior was tightly linked to rainfall fluctuation; i.e., bountiful harvests followed high-rainfall years and, conversely, dry periods led to low yields or crop failures. This approach was first used by Lynch (1931), who assumed such a mechanistic relationship between climatic patterns and agricultural productivity that

> for the purpose of showing the fluctuations in rainfall, they [the mission crop records] are not much less valuable than the more recent rainfall measurements and show with great fidelity the weather conditions at the missions [Lynch 1931:7].

Although Lynch's purpose was to reconstruct rainfall parameters in southern California for the pre-record period (before 1850), and even though there are serious logical and methodological flaws in his work (Rowntree 1985a), his assumptions about rainfall and mission harvest variability have been adopted by other scholars. For example, Gentilcore (1961), using Lynch's data and assumptions, explained annual variation in mission wheat harvests by observing that yearly "peaks and plunges [are] vivid witness to fluctuations in production in a climate marked by extreme variability in rainfall" (Gentilcore 1961: 63-64).

While a correlation of rainfall variability and mission crop yields may be intuitively pleasing, this relationship should not be accepted without qualification because: (1) there are several equally logical reasons why there should not be a simple, direct linkage between crops and climate; and (2) the "peaks and valleys" model has never been rigorously tested. Four important qualifications must be considered in evaluating the relationship between climate and agricultural productivity during the mission period in California.

First, only rarely does a single climatic variable explain annual crop yield variation; therefore, assuming that mission yields were dependent on and reflected seasonal rainfall amounts is questionable (for discussion of contemporary crop-climate models see Baier [1977]; Biswas [1980]; Monteith [1981]; Thompson [1969]; and Warrick [1984]). In most crops, light and carbon dioxide limit the rate at which plants grow, while the duration of growth depends on temperature; growing season, however, can be limited by moisture (Monteith 1981: 769). Contemporary crop-climate models do not completely rule out the possibility that some mission crop-yield variation might be explained mainly by differences in available moisture, they simply underscore the need to test this assumption before its acceptance. Given the vastly different temperature and moisture requirements of winter wheat and corn, perhaps some – but not all – crops can be tied to seasonal rainfall at some times; but to assume simplistic rainfall linkages with all crops at all times seems unwise. Taking low harvest years as indicators of drought, then, assumes questionable causality in terms of crop physiology.

Second, given what is known about the complexities and dynamics of the mission agricultural system, specifically the relationship between the size of the neophyte labor force and harvest success, there are numerous social factors that could well account for poor harvests. For example, an earlier study (Rowntree and Raburn 1980) found that corn yields at Mission San Luis Rey correlated well with population fluctuations, but not at all with rainfall trends (based on tree-ring analysis, see below). More recent studies also substantiate the labor pool/harvest success correlation (Rowntree 1985a, 1985b).

Third, assuming an unqualified, causal relationship between drought, low harvest yields, and economic distress denies the existence of built-in systemic strategies to buffer drought-related impacts, which, in turn, negates a basic premise of cultural adaptation. Yearly wheat-crop-yield ratios from Mission San Gabriel are displayed in Figure 1, along with those years designated as drought episodes based on tree-ring analysis (Meko 1980). Clearly, not all low-yield years are associated with drought, which means other factors must be identified that can explain low-yield years. Elucidating these factors remains a challenge for mission researchers. However, the important point to be stressed here should be clear: years of low harvest yields are not always associated with episodes of drought.

Fourth, even if there are apparent correlations between low harvest yields and drought episodes (the latter being drawn from either documents or rainfall proxy data [e.g., tree rings]), mere time-space coincidences must be distinguished from actual, causal relationships. Assumptions of causality when crop and rainfall records simply and un-relatedly coincide in an otherwise intuitively satisfying fashion remain a major problem in climate history research, although a more rigorous methodology, emphasizing a deductive logic that can better establish causal relationships, is gradually emerging (see Parry 1981, 1982; Ingram, Farmer, and Wigley 1981; de Vries 1981).

In sum, use of mission harvest data as unquestioned indicators of seasonal rainfall fluctuation in early historic California is untenable and dangerous. It contradicts evidence from crop physiology about climate and plant behavior; it denies evidence that social variables explain some kinds of harvest variability; it overlooks the possibility of systemic buffering against climatic variability; and finally, the necessarily simplistic assumption of causal relationship violates principles of sound logic and reasoning.

Yet, notwithstanding the concerns raised above, when their relevance can be shown mission harvest data do constitute a valuable source of information on the nature of cultural responses to drought and, if carefully treated, these data can provide insight into early historic patterns of annual (and seasonal) rainfall variability in California. Indeed, the extensive agricultural records maintained by the Franciscans represent a promising data set with which to test ecological concepts. Crucial in both historical and theoretical regards is the acquisition of objective, accurate data on annual precipitation that can complement deductive approaches to the explanation of cultural behavior during the mission period. Climatic reconstruction based on tree-ring analysis offers such a possibility and is discussed further below.

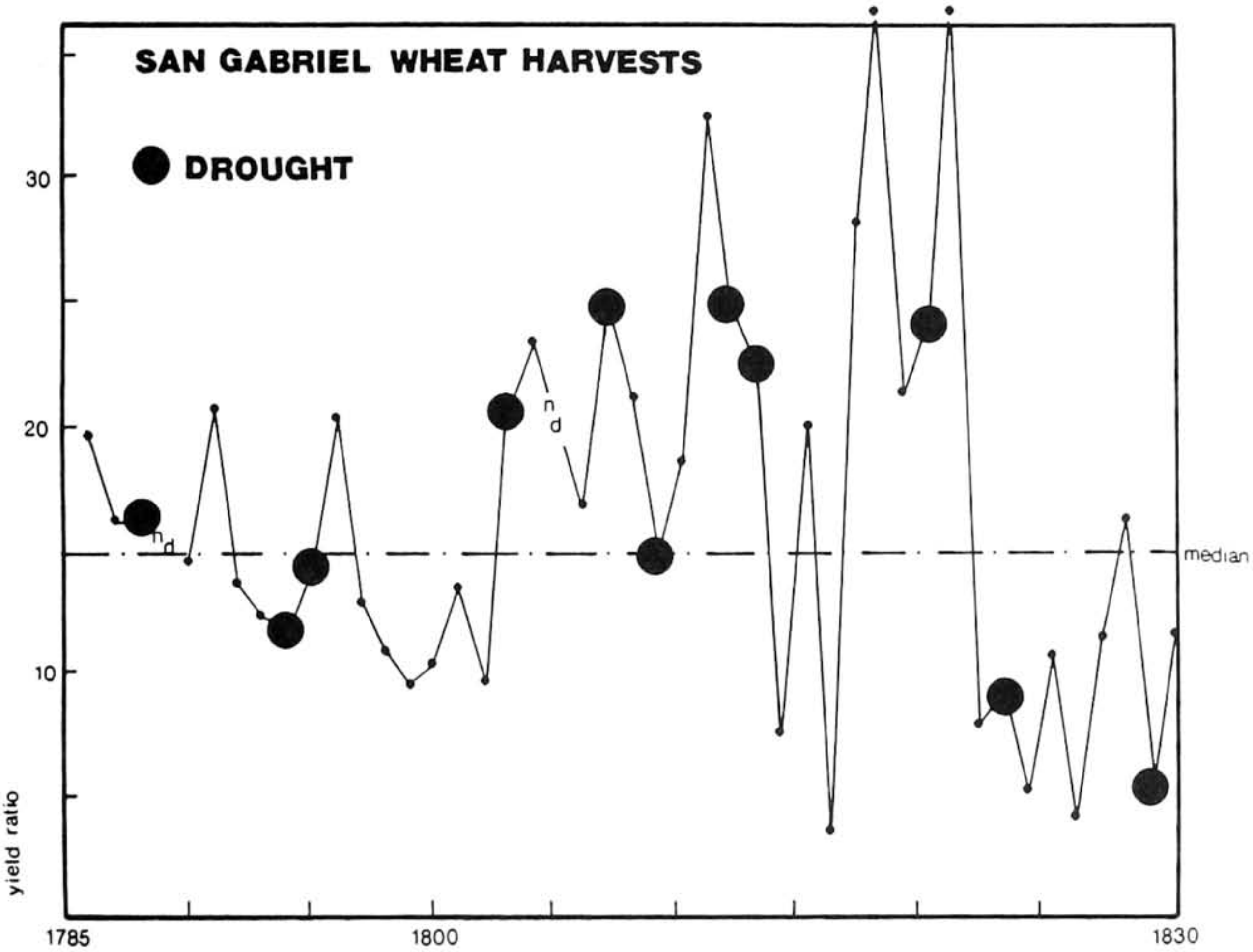

Fig. 1. Yearly wheat harvest yield ratios for Mission San Gabriel and PDSI-identified drought years (see Table 1). The harvest yield ratios are calculated by dividing the amount harvested by the amount planted, thus the resulting yield ratios are not highly influenced by year-to-year changes in the amount of wheat planted. The unit of measurement is the *fanega*, which is close to 1.6 bushels. Wheat data are for the crop year and are found in Engelhardt (1927: 273-275).

MISSION PERIOD CLIMATE FROM TREE RINGS

The annual growth rings of a tree often contain reliable information on such climatic parameters as temperature and moisture. Various techniques have been developed over the past decade to refine parametric data collection and, as a consequence, tree-ring analysis has emerged as a vital tool in climatic reconstruction. Because the methods of dendroclimatology have been described in detail elsewhere (see Fritts, Lofgren, and Gordon 1979, 1981; Fritts 1976), only a brief introduction is presented here and emphasis is given to specific chronologies useful to mission-period research.

Many dendroclimatic reconstructions (e.g., Fritts and Gordon 1982; Lawson and Stockton 1981; Fritts, Lofgren, and Gordon 1979) are undertaken to elucidate broad patterns of climatic change or fluctuation, and the results are often expressed in relative terms (e.g., moist or arid, cool or warm intervals) and on an areally expansive scale (e.g., California, western United States, Great Plains). Within these general reconstructions, specific climatic periods pertinent to mission history can be isolated, as was done successfully by Shipek (1981) and True and Waugh (1982). However, because an appropriate spatio-temporal scale is always an issue in adaptation studies (cf. Kirch 1980; Orlove 1980; Winterhalder 1980), mission-period researchers may wish a more areally specific climatic context within which to spatially and temporally frame their investigations. This can be accomplished in two ways: using species-specific dendrochronologies that provide year-to-year information, or with an analysis of tree rings from a purposely limited time-space matrix. Two examples follow.

Douglas (1976: 163) constructed several tree-ring chronologies for Baja and southern Alta California. Usually, two cores were taken from each tree and each chronology was based on between 10 and 20 samples. One of the chronologies was derived from *Pseudotsuga macrocarpa* (big-cone spruce) in the Santa Ana Mountains. This chronology is particularly important to the reconstruction of past rainfall patterns in southern (Alta) California south of the Transverse Ranges because it correlates strongly (>0.01) with measured precipitation in San Diego, Los Angeles, and Santa Barbara. As with all dendrochronologies, the refined data are presented as three-digit, yearly indices with 1.00 representing mean annual growth in the tree-ring series of a given species. Numbers considerably higher or lower than 1.00 represent significant departures from average growth conditions. Dates connected to the indices represent the end of a tree's growing season which, in California, is essentially the end of the rainfall season. For example, the tree-ring index value for 1772 is 0.67; theoretically, this value indicates that rainfall during the winter of 1771-1772 was subnormal.

Table 1

TREE-RING BASED CHRONOLOGY OF DRY YEARS DURING MISSION PERIOD, 1769-1834*

Year	Tree-Ring Index	PDSI
1772	.67	-1.1
1777	.39	-5.5
1778	.66	-0.1
1782	.28	-6.0
1783	.63	2.1
1786	.71	1.2
1788	.65	-3.0
1789	.71	1.4
1790	.76	-1.2
1794	.73	-2.5
1795	.29	-3.7
1796	.77	0.64
1803	.53	-4.2
1807	.83	-3.6
1809	.22	-5.2
1812	.85	-2.0
1813	.65	-2.5
1820	.76	-4.3
1822	.49	-1.7
1823	.36	-3.3
1824	.40	-0.84
1829	.55	-3.7

*Tree-ring data taken from Douglas (1976: 163); PDSI data are described in Meko, Stockton, and Boggess (1980); Yearly data supplied by C. Stockton (personal communication 1980).

Tree-ring indices (based on *Pseudotsuga macrocarpa* [Douglas 1976]) suggestive of relatively dry years during the mission period in southern California are displayed in Table 1. An index value of less than 0.80 was somewhat arbitrarily defined to indicate below-average precipitation. Higher values clearly suggest normal or above-normal moisture regimes. The lower the value given in Table 1, consequently, the narrower the annual growth ring – with the implication that the tree was stressed by some growth-limiting factor. In most, but not all cases, growth limitation probably stemmed from a lack of effective moisture. Tree-ring data, however, should not be thought of as surrogate rain gauges for, despite the tedious statistical refinement necessary before any chronology can be considered valid, there are other ecological factors to be taken into account that could have brought about tree-growth stress and, as a result, retarded tree-ring development. Conversely, factors other than elevated rainfall amounts could well nurture tree growth. Ultimately, a year-by-year comparison of measured annual precipitation against species-specific tree-ring development will serve to clarify apparent correlative discrepancies. On the whole, the Santa Ana Mountains dendroclimatological chronology presented by Douglas (1976) seems to be a fairly reliable record of drought episodes in southern California. It does not, however, correlate well with rainfall records for areas north of the Transverse Ranges and cannot be used in the explication of agricultural strategies and conditions at central and northern California missions.

Another extremely useful tree-ring data set can be drawn from eight southern California dendrochronologies (including the Santa Ana Mountains record discussed above) and, because its purpose is to measure the incidence of drought back to A.D. 1700, its characterization consists of a computerized reconstruction of Palmer Drought Severity Indices (Meko, Stockton, and Boggess 1980). Palmer Indices (hereafter referred to as PDSI) are a standardized scheme used by the National Weather Service and other agencies to measure drought and wetness on a weekly, monthly, or yearly basis. Indices are computed on the basis of precipitation, temperature, evaporation, and antecedent soil moisture data so that numeric expressions result that are pertinent to conditions of crop growth (Palmer 1965). The PDSI categories are:

+4.0 or greater	extreme wetness
+3.0 to 3.9	severe wetness
+2.0 to 2.9	moderate wetness
- 2.0 to +2.0	normal conditions
- 2.0 to - 2.9	moderate drought
- 3.0 to - 3.9	severe drought
- 4.0 or less	extreme drought

Tree-ring PDSI reconstruction is based on both temperature- and precipitation-sensitive dendrochronologies, and produces one monthly value for July that indicates wetness for the preceding rainfall season. For example, a PDSI value of -5.5 for the year 1777 represents the previous rainfall season, and theoretically expresses rainfall (or lack thereof) that fell from autumn 1776 through spring 1777.

The advantages of the PDSI chronology over a single tree-ring index chronology are twofold. First, because the former combines eight sites in southern California, its regional reliability is enhanced; correlation with measured rainfall is even higher than with the Santa Ana data (>0.001). This is not unexpected in that the Santa Ana chronology comprises one of the eight data sets used in PDSI reconstruction. Second, the PDSI values provide a ready-made drought chronology (Table 1). Although only PDSI values less than -2.0 are considered indicative of drought conditions, PDSI values greater than -2.0 are also shown for those years with low (less than 0.80) tree-ring index values. PDSI values suggestive of drought also are given for two years, 1807 and 1812, for which tree-ring indices greater than 0.80 were obtained.

In comparing the two chronologies (Table 1), it can be seen that the Santa Ana tree-ring index sequence indicates 20 dry years during the mission period, whereas the PDSI data identify only 13 dry years. Obvious questions, then, are which of the chronologies is the more reliable, and why is there a difference in the number of designated dry years? Many of the dry years determined with the tree-ring indices occur in series, e.g., 1777-1778, 1782-1783, and so forth, suggesting that the effects of drought in one year may have carried over into the next. Although statistical methods are used to eliminate this sort of time lag or autocorrelation between years, they might not always be successful. Local site and ecological factors, such as the vulnerability of moisture-stressed trees to other growth-limiting factors (e.g., parasitic infestation), could also account for this phenomenon. If the multiple-dry-year series can be explained by factors specific to the Santa Ana sampling site, then there is little disparity between the two chronologies. There is no question, though, that the PDSI chronology has greater authority given its larger and spatially dispersed samples. Consequently, the PDSI chronology should better reflect regional climatic conditions during the mission period in southern California.

With this tree-ring based chronology, researchers into mission-period human ecology have a more objective and accurate record of drought in southern California than can be inferred on the basis of narrative or crop-harvest data. Unfortunately, at least at this writing, there are no similarly reliable tree-ring data for central and northern California; however, these data are forthcoming from the University of Arizona Laboratory for Tree Ring Research (R. Holmes, personal communication 1984).

SUMMARY AND CONCLUSION

The major points of this paper are summarized below.

1. As important as a reliable drought chronology is to research into the human ecology of the Spanish mission period, there is none. Instead, extant materials rely on Franciscan narratives, crop data, or regional dendrochronological generalizations hardly appropriate for small-scale adaptation studies.

2. Because of the subjective nature of the narrative archival material, there is inherent potential for bias and distortion, both by the primary authors and also by the secondary translators and users. However, when placed in their proper perspective and context, these qualitative materials offer much valuable information on the social responses to drought, such as perception of climatic hazards, impacts on specific subsistence activities and, at times, insights into drought-buffering strategies.

3. Mission agricultural data have been misused in the past to define drought periods. This resulted from questionable assumptions being made that all crops yields were tightly linked to seasonal rainfall amounts; therefore, high harvests were considered to denote high rainfall and, conversely, low yields to indicate years of low rainfall. Recent analysis shows this was not always the case, and that crop information should be used as rainfall proxy data only under controlled and constrained circumstances (Rowntree 1985a).

4. Two specific tree-ring-data sets are offered that provide a more accurate chronology of yearly droughts in southern California. These data can be used as a framework for deductive analysis, particularly when complemented by specific information derived from mission narratives and agricultural data.

By combining information from Franciscan narratives and agricultural data with climatic proxies from tree rings, an exciting analytical framework is created for elucidating the diverse and complicated interactions among Spanish missionaries and their subsistence strategies, the aboriginal population, and yearly precipitation. This article concludes with brief commentary linking preliminary research results with themes pertinent to further study of the drought ecology of the Spanish mission system.

Regression analysis of the relationship between yearly crop yields (measured by the amount of a crop harvested divided by the amount planted) and tree-ring-constructed climatic records for southern California show that there is a wide spectrum of rainfall dependence both among crops and also at different mission sites (Rowntree and Raburn 1980; Rowntree 1985b). Put differently, some crops, at some missions, during some periods of time, correlate strongly with yearly tree-ring indices, while at other missions, this is not the case.[1] This is of interest because it suggests some missions may have been buffered against annual climatic variability, and that they were able to dampen out the influences of drought and flood more successfully than other missions. Why this was the case is not clear. The presence or absence of an elaborate irrigation system does not always explain this differential vulnerability and resiliency for, as Shipek (1981: 301) suggested, the efficacy of some mission irrigation systems was temporary. Yet, whatever the reasons for the varying forms of adaptation, the benefits to the mission system were clear: because not all missions suffered equally from drought, some were able to produce relatively high yields while others harvested little, consequently a regional food-sharing network was a major drought-buffering strategy.

An obviously important component of the mission complex was the neophyte Indian population, and the dynamic quantity and nature of this variable could help explain at least some of the instances of differential farming success. Already noted was the relationship found between corn yields and the size of the labor force at Mission San Luis Rey (Rowntree and Raburn 1980), and further investigation may find this to have been the case at several other – but not all – southern California missions. A causal relationship between corn yields and population sizes may reflect the importance of irrigation practices. For example, a highly effective watering system may have been possible only with a relatively large labor force to build and maintain elaborate water-control devices. This supposition should be explored further because of its obvious implications for better understanding the ecological structure of the mission system.

Finally, the ties between drought, food surplus, and aboriginal mission conversion should be examined further. Yearly climatic data found in both the Santa Ana and PDSI chronologies can facilitate refinement of explanatory models. Dendroclimatological data can be used to link drought to mission harvests for a specific year, and incorporated with demographic and ethnographic data relevant to the research questions being addressed. Although this author can claim no expertise with neophyte conversion models, several issues seem to demand further consideration. For example, potential drought episodes should be carefully examined in light of the types of concurrent food stress they may have imposed on aboriginal subsistence systems. Inasmuch as these systems had been in operation for many millennia, it cannot be summarily assumed that historic droughts brought about significant systemic stress (cf. Shipek 1981). Moreover, if neophyte conversion was tied in some way to the lure of mission food supplies, then just how the mission(s) was able to generate a food surplus during a drought episode needs to be determined. Generally, it would seem that mission conversion was the least successful during drought episodes when aboriginal populations were better off pursuing traditional subsistence strategies. This is evidenced by documented neophyte "expeditions," occasions when converted Indians were allowed to leave mission control in order to conduct hunting and gathering activities because the Spanish agricultural system was unable to adequately feed the neophyte population.

In conclusion, California's highly variable rainfall regime was an important dimension to both Spanish and aboriginal adaptation and may have played an important role in the interaction between colonizers and the indigenous population. Explication of these relationships demands a reliable drought chronology for the mission period. This has been presented here, along with guidelines for use of complementary documentary materials.

NOTE

1. Yearly climatic data based on tree-ring analysis (Douglas 1976) were correlated with yearly harvest-yield ratios for the two major crops, wheat and corn, at seven southern California missions. The following results were obtained:

Mission	Wheat	Corn
San Diego	*.383*	*.367*
San Luis Rey	*.478*	.248
San Juan Capistrano	.171	.021
San Gabriel	.064	.076
San Fernando	.335	.192
San Buenaventura	.183	.070
Santa Barbara	*.356*	.197

Those correlation coefficients significant at 0.05 or better are italicized. Sample sizes differ between missions because of differential histories and harvest data availability; however, all are for the longest record available at each mission and all represent more than thirty years. Because of their later founding, the smallest samples are from San Luis Rey and San Fernando.

Further analysis shows some important qualifications to these data that can be summarized as follows: (a) the strength of the rainfall-crop relationship changes through time because of social factors; (b) wheat harvest yields are often highly influenced by the amount of that crop planted; (c) the overall correlation between tree rings and crops masks important linkages between drought and agricultural production at certain times and at certain missions; and (d) corn yield ratios show significant ties with population (labor force) sizes at certain missions at certain times. Discussion of these points is found in Rowntree (1985b).

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