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ABSTRACT

The hypothesis is advanced that Yellow-bellied Marmots *(Marmota flaviventris)* are affected in their geographic distribution by seasonality of precipitation in such a manner that their presence in Southwestern archaeological sites indicates a minimum of about two inches of winter precipitation. Application of this hypothesis to past changes in marmot distribution in the Navajo Reservoir District (northwestern New Mexico ,and adjacent Colorado) indicates an early period of high effective moisture produced predominantly by summer rains. At about A.D. 700-800, there occurred a change to dominant winter precipitation which lasted until ca. A.D. 1000 or later. This model agrees with previous work based on faunal analysis but is exactly counter to that proposed on the basis of alluvial and pollen studies.

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Attempts to determine environmental fluctuation during the past 2000 years in the Navajo Reservoir District, northwestern New Mexico and southwestern Colorado, have been made from several different lines of evidence. I tried to elucidate changes in vegetation (and thus climate) by studying vertebrates recovered from archaeological sites (Harris 1963b). Schoenwetter and Eddy (1964) attempted a similar reconstruction by considerations of the palynological record and the alluvial history respectively.

All three studies showed relatively close agreement as to fluctuations in effective moisture, though there are differences in detail (particularly in Schoenwetter's 1966 re-evaluation based on more accurate dates). An early period with effective moisture greater than at present is indicated, followed by a relatively arid time commencing about A.D. 700-800 and lasting to perhaps A.D. 1000 or later. The next period for which data are available occurred during the Navajo occupancy, during which there was at least one period of greater effective moisture than today. The studies are in agreement on these points.

Although there is close correspondence on major events, Schoenwetter and Eddy differ sharply with my interpretation of the proximal cause of the early period of high effective moisture. My hypothesis attributes the early moist period primarily to summer precipitation greater than that of the present. Eddy, however, argues that degradation during the subsequent arid time was due to *initiation* of a summer dominant storm pattern and that the early moist period was a time of dominant winter precipitation; Schoenwetter agrees with Eddy's views and bases his interpretation on similar assumptions.

Recent consideration of factors limiting the geographic range of the Yellow-bellied Marmot *(Marmota flaviventris)* bears on the problem. I originally based much of my Reservoir District interpretation on a group of mammals believed to be sensitive to changes in effective moisture. The marmot frequently has been considered such an indicator, but I found it displayed exactly the opposite characteristics as my other sensitive species: as most indicator animals decreased in number and range (presumably due to decreased effective moisture), marmots increased (Table 1). I was unable to explain this satisfactorily, but suggested "an increase in suitable green fodder, owing to climatic change which is not revealed by other indicators" might be responsible (Harris 1963b: 35). A climatic explanation now seems possible.

Temperature may be ruled out as the factor limiting the southern range of marmots. Before the filling of Navajo Reservoir, marmots were found along Sambrito Creek, 5980 feet above sea level (Harris 1963a: 33). This is far below their normal altitude in northern New Mexico and apparently was made possible by unusually lush vegetation due to irrigation runoff from nearby farmlands. These conditions also favor voles and Nuttall's Cottontails, two of my "sensitives"; their rarity in the later reservoir deposits (Table 1) seems to rule out the increase in marmot numbers in the deposits being due to aboriginal irrigation.

Most of the Southwest characteristically has winter and summer moist periods separated by spring and fall droughts. In areas of scanty winter-early spring precipitation, many grasses and forbs may remain dormant until the beginning of the summer rains; other plants, beginning growth on stored soil water, complete a growth cycle before depletion of early season water supplies. In both cases, little green fodder is available between depletion of stored soil water and the beginning of the summer rainy season. Marmots, being rather large mammals relying primarily on green forage, presumably

Table 1. Relative frequencies by phase of Nuttall's Cottontail *(Sylvilagus nuttalli),* Longtailed Vole *(Microtus* ***longicaudus),*** and Yellow-bellied Marmot *(Marmota flaviventris)* within the Navajo Reservoir District. Figures in parentheses are minimum numbers of individuals recognized from osteological remains (remains from Navajo phases probably are biased toward larger animals).

	S. nuttalli	*M. longicaudus*	*M. flaviventris*
Los Pinos Phase AD 1-400 (122)	3.3% (4)	5.7% (7)	- (0)
Los Pinos-Sambrito Ca. AD 400	17.6% (3)	- (0)	- (0)
Sambrito Phase AD 400-700 (192)	2.1% (4)	2.6% (5)	0.5% (1)
Rosa Phase AD 700-900 (112)	0.9% (1)	- (0)	0.9% (1)
Rosa-Piedra Phase AD 800-900 (58)	1.7% (1)	- (0)	1.7% (1)
Piedra Phase AD 850-950 (336)	0.6% (2)	0.6% (2)	2.4% (8)
Piedra-Arboles Phase Ca. AD 950 (37)	- (0)	- (0)	2.7% (1)
Arboles Phase AD 950-1050 (93)	- (0)	- (0)	6.5% (6)
Navajo Phases 1550-1775 (96)	3.1% (3)	- (0)	- (0)

cannot survive such periods. Only the spring period is critical since hibernation generally begins between the middle of August and the first of October (Howell 1915: 11), thus the fall-winter interval when green foods again are scarce or absent is avoided.

A dependency on winter precipitation also is suggested by comparison of a winter precipitation map (e.g., Kincer 1941: 713) with a range map for *Marmota flaviventris* (Hall and Kelson 1959: 324). This indicates that approximately two inches of December-February precipitation would be sufficient to support *Marmota* in the southern portions of its range (quite likely a minimal spring precipitation would have to be added to this, but such data are more difficult to obtain).

Extensive highland areas in Arizona and New Mexico have the hypothesized necessary winter moisture, but lack marmots. These regions are separated by zones of low winter precipitation from areas now supporting the animals, but at least some of these uplands had marmots in the past. Lange (1956) has reported *Marmota* remains from three places in northeastern Arizona associated with Indian sites variously dated between about A.D. 200 and A.D. 1300; aboriginal transport cannot be ruled out. Other remains (some or all of which may be Pleistocene) are known from caves in the Grand Canyon and Flagstaff areas of Arizona (Lange 1956); from southwestern New Mexico (near Old Fort Tularosa) and the Manzano Mountains (Howell 1915: 55); near Isleta in central New Mexico (Harris. and Findley 1964: 117); La Bajada Hill; south of Santa Fe (Stearns 1942: 869); from the Guadalupe Mountains (Schultz and Howard 1935); and from McKittrick Hill, east of the Guadalupes (Harris 1970). Possibly an interval of winter drought extirpated them from these southern areas—such extermination may have occurred quite recently.

Other moisture sensitive mammals utilized in the Reservoir District interpretation do not require large amounts of green food, but some (e.g., Long-tailed Vole, Nuttall's Cottontail) require dense, low cover for concealment from predators and a large bulk of food plants, though not necessarily fresh and green.

I picture the early moist period as one in which abundant summer rains provided such relatively dense, low cover. The summer moisture plus the winter precipitation was sufficient for at least as good woodland growth as occurs at present. The summer rains resulted in sufficiently abundant low forage and cover to carry voles and other small "sensitives" through to the following growing season, as is the case for voles found in northern portions of the Reservoir District now. The winter-early spring precipitation, probably similar to or less than that of the present, was not sufficient to support marmots over the critical spring period.

About A.D. 700-800, summer moisture began to decrease, but winter precipitation increased slightly. As the trend rather rapidly took hold, changes in mammalian distributions and numbers resulted. The increased winter precipitation stored in the soil allowed plants beginning growth in early spring to remain green until the summer monsoon began; marmots were able to invade the area from the north. Voles and other nonhibernating small mammals reliant on low vegetative cover found themselves in late fall and winter with insufficient summer-produced vegetation to carry them through to spring. An increase in jack-rabbit remains from this time likely indicates increased amounts of Big Sagebrush *(Artemisia tridentata)* (Harris 1963b: 50), a plant reaching its highest development in the Great Basin where winter precipitation tends to dominate.

Accompanying alluvial events may have been affected by two factors. Increased snow pack in the high mountains to the north resulted in increased spring runoff with resultant channeling lowering the regional baselevel. The reduced summer precipitation also decreased the low, protective, plant cover that is so dependent on summer rains in the Southwest. With reduced vegetation, runoff increased and flooding was encouraged.

A recent study by Tuan (1966: 596) indicates that "as a matter of observation, gullying most frequently accompanies heavy, flood runoff that is the result of intense summer rains, even if the rains should temporarily improve the vegetation cover." This statement fits the Schoenwetter-Eddy model. However, the San Juan River differs from those being considered by Tuan in that it is a perennial stream receiving most of its runoff from the high mountain snowpack. Also, Tuan's evidence *might* indicate that only a few exceptionally heavy summer rains would be necessary to produce gullying regardless of overall seasonal pattern of precipitation. Examination of this premise might be a profitable line of inquiry.

Time of moisture availability is of considerable importance in agriculture and thus in affecting aboriginal events. By my model, the post-800 time was one of increasing summer drought. During this period, habitation within the district became increasingly limited to the more northern portions of the area (Dittert, *et al* 1961: 224) where, presumably, summer orographic rainfall would tend to be greater.

The faunal evidence, then, indicates opposite seasonality of precipitation from that hypothesized by Schoenwetter and Eddy. I put this forth as an interpretation of events to be tested further by others (I lack competence, .for example, to judge Schoenwetter's data in terms of this model) and by future investigators.

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