took place in a chaparral brush field in the Descanso Ranger District, Cleveland National Forest, San Diego County, in which a wild fire had occurred five years earlier. The dominant shrubs were scrub oak, chamise, cupleaf ceanothus, and eastwood manzanita. Less than two weeks before sampling, an unseasonably early and heavy rain contributed to the growth of herbaceous vegetation (grasses and forbs).

Shrub density, cover, and crown volume measurements were obtained from ten permanent transects. The diets and fecal matter of nine, 1- to 2-year-old (24 to 38 kg) Spanish goat wethers were measured over a two-week period. Before the daily morning collections of diet and fecal samples the goats were confined over night in a coyote-proof pen (supplied with drinking water and salt). After a 1- to 1½-hour collection period the animals foraged freely until sunset. Diet samples were frozen immediately with dry ice and kept frozen until their analysis at Davis. The intake was calculated from the average weights of fecal outputs and the percentage *in vitro* dry matter digestibility (DMD) of diet samples.

Results and discussion

The contribution of grass and forbs was reasonably constant at about 20 percent of the diet throughout the observational period except for higher intakes on the first and third day of sampling. For days 4 to 7 the dietary samples were predominantly composed of scrub oak and at times this was in excess of 80 percent. Chamise was also a major component of the diet and attained 70 percent on the last day of the study, when scrub oak and grass and forbs contribution decreased. Manzanita and ceanothus did not contribute significantly to the diet. Dead plant material, especially from a fallen liveoak tree inside the plot, contributed to a mean of 19 percent of the total dry matter intake. The decline in the contribution of grass and forbs during the period when scrub oak intake was predominant may indicate a change in preference of the goats to scrub oak over other forage components. During the last week of the study an increased contribution from grass and forbs possibly resulted from their increased availability due to growth while grazing pressure on the scrub oak was high. The amount of chamise in the diet was low when scrub oak and grass and forbs were major contributors to the diet. However, browsing on chamise increased when the scrub oak was depleted from the area. Chamise made its greatest contribution to the diet when the percentage intake of both dead material and grass and forbs declined. Manzanita and ceanothus were minor components of the diet and were eaten only when the scrub oak crowns were depleted of shoots.

The change in the total volume of the four shrub species during the sampling period is presented in figure 1. The total volume measurement is the index of the volume occupied by the shrubs but does not necessarily reflect the amount of forage available. Although manzanita and ceanothus had the highest total volume and were the most dominant shrub species in the plot, their contribution to the botanical composition of the dietary samples was very low. This indicates that eastwood manzanita and cupleaf ceanothus are not highly preferred by Spanish goats during the summer months.

The mean *in vitro* percentage dry matter digestibility was 51.6 for the 14-day period but varied in time with the species grazed (fig. 2). A highly significant positive association ($P < 0.01$) was found between dry matter digestibility and the percentage grass and forbs in the samples. Thus, new herbaceous growth when available could contribute significantly to the digestible energy intake of goats. No significant relationships were found between the *in vitro* digestibility and percentage of the other dietary constituents. However, the regression co-efficients for percentage scrub oak and chamise in the diet on *in vitro* digestibility were negative.

Recent comparative studies in Texas indicate that Angora goats have higher dietary requirements than Spanish goats. In our study the average total dry matter intake of five Spanish goats (30 kg body weight) was 61 $g/W^{3/4}$ which is comparable to the requirements cited in the Texas study. As there was only a slight change in the body weight of the goats over the two-week period, it indicates that the energy intake from browse was not grossly different from maintenance. This preliminary observation indicates that browse (scrub oak and chamise) can provide a maintenance diet for goats during the summer if it has an understory of grass and forbs.

The browsing preference of Spanish goats during a limited summer period in a 0.2 ha. plot of a five-year-old chaparral fuel break was highly directed—about 80 percent—toward scrub oak and chamise. Grasses and forbs contributed about 20 percent of the total diet, while eastwood manzanita and cupleaf ceanothus appear to have a negligible contribution. Further work into the effects of season and long-term grazing is needed for more comprehensive deductions.

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The assistance of the Descanso Ranger District of the Cleveland National Forest, USFS, is gratefully acknowledged.

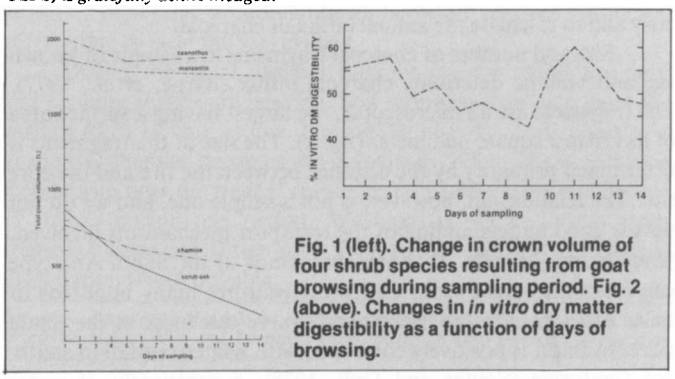

Fig. 1 (left). Change in crown volume of four shrub species resulting from goat browsing during sampling period. Fig. 2 (above). Changes in *in vitro* dry matter digestibility as a function of days of browsing.

Fossil record discloses wildfire history

Roger Byrne

When a wildfire runs through an area of chaparral not all of the plants are reduced to ashes: characteristically, a large number are simply charred. Fortunately for the paleoecologist, the charcoal produced often retains its cellular structure and, in some cases, can be identified (Komarek, *et al.*, 1973). Furthermore, charcoal is remarkably resistant to decay and as a result is commonly found in the sedimentary rocks that comprise the Coast Ranges.

On the northern slopes of the Santa Monica Mountains, for example, siltstones and shales of the Miocene Age (5 to 20 million years old) contain numerous charcoal fragments. Some of the fragments are derived from chaparral species and clearly indicate that chaparral-type vegetation was established in the area at this time (Weide, 1968). Macrobotanical evidence of this kind provides conclusive evidence that wildfires were an important part of the Cali-

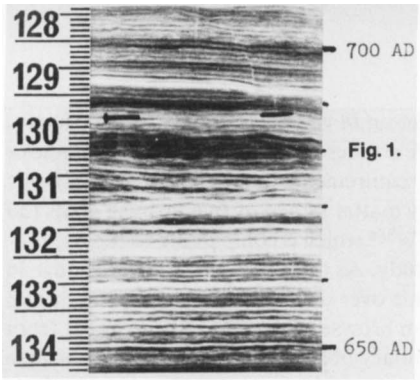

Fig. 1.

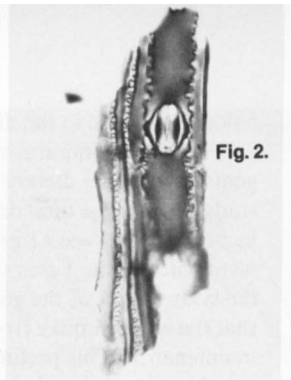
Fig. 2.

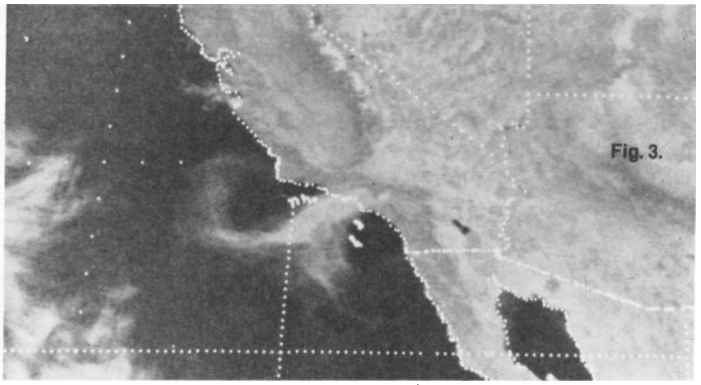
Fig. 3.

An x-radiograph (left) of a section of varved core from the Santa Barbara Basin. This is a contact print of the radiograph so the dark laminations represent the dense winter sediment and the light laminations the spring and summer sediment. The scale on the left indicates the depth below the core top in millimeters. The pin is used as a marker. Center—fossilized grass charcoal. This fragment is approximately one-tenth of a millimeter long. Note the stomatal cell. Right—satellite image showing a smoke plume blowing off-shore from southern California brushfires, November 24, 1975.

fornia environment long before man arrived on the scene, but does not tell us much about wildfire frequency. Fire frequency can only be reconstructed from the fossil record if the rate at which sediments accumulate is accurately known. Unfortunately this is rarely the case. There are, however, exceptions.

Halfway between Santa Barbara and the northern Channel Islands is the Santa Barbara Basin, a submarine basin with a basal elevation of 600 meters below sea level. The sediments that accumulate in the basin are unusual because they are varved, or seasonally layered (see fig. 1). Each varve consists of a dense winter layer and a less dense summer layer, making it possible to date the cores accurately and to calculate the annual influx of charcoal.

Size and number of charcoal fragments in a sample of known age and volume determine charcoal influx (Byrne, *et al.*, 1977). The fragments are all microscopic, the largest having a surface area of less than a square millimeter (fig. 2). The size of the fragments is determined primarily by the distance between the fire and the core site. The relationship, however, is not a simple one, and we do not have a good understanding of the transport mechanisms involved. Satellite imagery (fig. 3) shows that winds of the Santa Ana type can carry the smoke from California wildfires many hundreds of miles offshore. On the other hand, varve thickness in the Santa Barbara Basin is positively correlated with winter rainfall in southern California (Soutar and Crill, 1978); consequently, it seems likely that surface runoff is also an important transport mechanism.

Thanks largely to the efforts of Andrew Soutar of the Scripps Institute of Oceanography, numerous cores have been recovered from the Santa Barbara Basin, two of which have been used in the present study.

The first was taken in 1970 and includes varves that accumulated during the hundred years before 1970. Analysis of annual samples from the period 1931 to 1970 showed that changes in charcoal concentration were primarily a reflection of wildfires in the southern part of the Los Padres National Forest. For example, the highest peak in the charcoal record is attributed to the Refugio Fire which, in 1955, burned over 80,000 acres of chaparral and woodland on the Santa Inez Range northwest of Santa Barbara. The second core is a longer core which includes roughly 5000 years worth of varves representing the period 3000 BC to 1800 AD.

To date, graduate student Joel Michaelsen and I have analyzed 150 varves from the second core, representing the period 1400 to 1550 AD. The main difference between the modern and prehistoric influx values is that the latter are much more variable. We interpret this to mean that during the prehistoric period fires occurred less frequently than during the modern period, but those that did occur were of greater intensity and areal extent. We estimate the recurrence interval for these fires to be anywhere from 20 to 40 years. This estimate, however, only applies to the area as a whole: the time between fires may have been considerably longer.

Current analysis of samples from the period 900 to 1400 AD should confirm or invalidate our preliminary conclusions. We also hope to answer the question as to whether or not changes in climate have had any influence on fire frequency. According to La Marche's analysis of Bristlecone Pine tree-ring data, the period 900 through 1400 AD was characterized by marked changes in climate throughout the southwestern United States (La Marche, 1974). Furthermore, because the thickness of the Santa Barbara varves is positively correlated with winter rainfall, the varves themselves provide a useful index of climatic change.

The Santa Barbara charcoal record offers an unusual opportunity to ascertain prehistoric fire frequency in southern California, and may also throw some light on what determines rate of occurrence. In either case, it should be of interest to anyone concerned with the difficult problem of managing chaparral-type vegetation.

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Persistence of 2, 4-D and 2, 5, 6-T in chaparral

Steven R. Radosevich ☐ Wray L. Winterlin

On appropriate chaparral sites, shrub removal and replacement by grass is necessary to provide wildfire protection, increased forage and water yields, and erosion control. The herbicides 2,4-D and 2,4,5-T have been used for many years to control shrub regrowth on these areas. A vast amount is known about 2,4-D and 2,4,5-T, but recently there has been an increased awareness and concern about the use and persistence of these herbicides in wildland areas. To be effective, the herbicides must persist for a time in the environment of the treated shrubs. The extent of persistence depends upon: chemical properties of the herbicides; physical, chemical, and biological properties of the soil; and climatic conditions. Temperature, rainfall, light, type of soil, and type of plants treated are environmental factors known to influence herbicide persistence.

The chaparral environment is characterized by moist cool winters which are followed by about six months of hot dry conditions. The climatic conditions, combined with coarse soils and steep slopes, make the chaparral a particularly xeric region (a region that is too dry to sustain plant growth). It was the objective of this study to determine the distribution, persistence, and vertical movement in soil of 2,4-D and 2,4,5-T after application to chaparral areas.