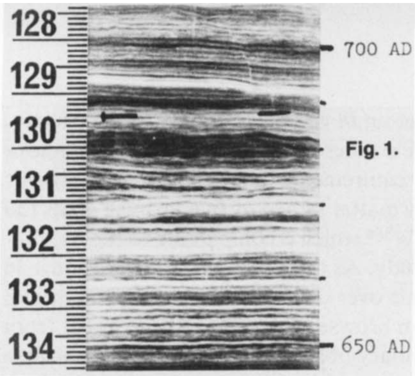

Fig. 1.

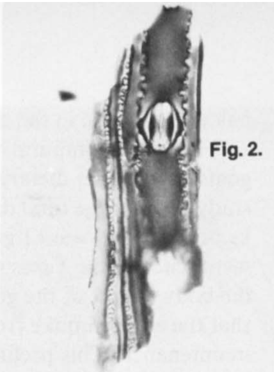

Fig. 2.

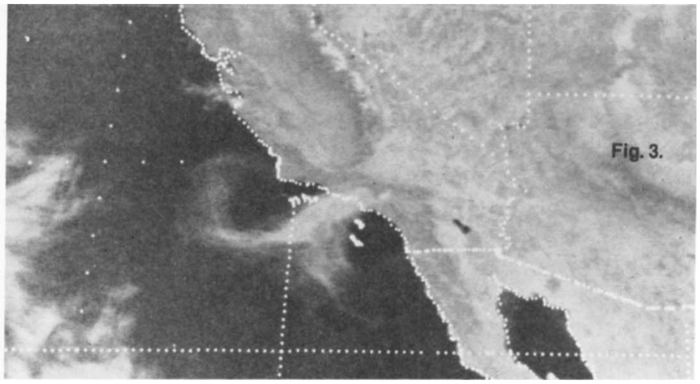

Fig. 3.

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.

Percent 2,4-D and 2,4,5-T Remaining Following Application to Two Chaparral Sites*

	% 2,4-D							% 2,4,5-T						
	0.05	30	60	90	180	360	$LSD_{.05}$	0.05	30	60	90	180	360	$LSD_{.05}$
	(days after application)							(days after application)						
chamise	20.7	5.6	3.3	2.1	1.1	0.01	5.8	18.0	1.3	0.8	1.0	0.8	0.02	3.8
grass and forbs	25.2	2.0	—	—	—	—	6.6	31.2	3.0	—	—	—	—	23.0
litter	54.0	6.0	2.9	2.2	0.7	0.03	8.1	50.7	6.6	3.7	3.3	0.5	0.01	6.2
soil (0-5 cm)	0.1	0.07	0.2	0.17	0.01	0.01	0.15	0.07	0.09	0.11	0.11	0.06	0.01	0.1
TOTAL	100.0	13.7	6.4	4.5	1.8	0.05	7.4	100.0	11.0	4.9	4.4	1.4	0.04	4.4
$LSD_{.1}$	10.1	4.1	2.4	1.0	0.3	0.04		8.3	1.6	0.7	2.2	0.46	0.01	

*Means of four samples taken from two locations: San Diego and Monterey counties. Values are % of the total 2,4-D (1068 μg/gdw) or 2,4,5-T (1023 μg/gdw) recovered immediately after application.

Identical experiments at two sites (near Alpine, San Diego County and Salinas, Monterey County) were established in the spring of 1974. Both experiments were situated at approximately 915 m elevation where the principal vegetation was 3- to 5-year-old crown shoots of chamise (1.9 plants per square meter), grown on areas that had been burned three to five years earlier. Chamise shoots were 0.5 to 1 m high. Plots (186 square meters) were treated with 4.5 kg per ha. of either 2,4-D (butoxypropyl ester) or 2,4,5-T (propylene glycol butyl esters). The herbicides were applied using a constant pressure sprayer in a water emulsion at 234 L per ha. Each experiment contained four replications.

Samples of the terminal 10 to 15 cm of chamise foliage, understory grass and forbs, soil surface litter, and soil (0 to 5 cm deep) were obtained before, immediately following, and at 30, 60, 90, 180, and 360 days after application of the herbicides. Soil samples were also taken at 10 to 15, 25 to 30, and 55 to 60 cm depths at every sampling time except the day of application. Samples were analyzed by gas liquid chromatography.

Results

A vertical pattern of herbicide distribution was observed with soil surface litter being the major receptor of both herbicides (see table). Surface litter contained over 50 percent of the 2,4-D or 2,4,5-T initially recovered after application. The relatively upright and rigid structure of chamise shrubs and the vertical growth habit of the grass and forbs may account for the distribution of herbicide. Similar results have been reported in which forest floors were observed as major receptors of aerially applied 2,4,5-T. Less herbicide was also found in the top-story dominated by brush or weed-trees.

Herbicide residues on foliage and litter decreased rapidly (up to 93 percent) within 30 days after application. Following the initial loss, residues of both herbicides decreased at a slower rate until, after 360 days, residues were 0.01 to 0.03 percent of that applied (see table).

Residues of 2,4-D and 2,4,5-T in the soil immediately after application (0.1 and 0.07 percent respectively) were markedly less than those in surface litter or vegetation. No detectable (0.001 percent) residue was found below 5 cm in the soil profile. These data indicate minimum transport of the herbicides by vertical water movement. The soil residues of both herbicides remained constant (0.07 to 0.2 percent) for 90 days after application. By 180 days for 2,4-D and 360 days for 2,4,5-T, herbicide residues in the soil were 0.01 percent of the amount initially applied (see table). Although some herbicide can be removed by surface-water runoff, these and other data—where 2,4,5-T moved less than 0.3 m downslope with surface water—indicate that contamination of water supplies from residual 2,4-D or 2,4,5-T in soil is unlikely.

At neither experimental site did rainfall occur soon after the 2,4-D and 2,4,5-T were applied. Most of the rain occurred between October 1974 and April 1975. Although unseasonably early rains were recorded in June (Salinas) and July (Alpine), this precipitation occurred 30 days (Salinas) and 75 days (Alpine) after the herbicides were applied. Rapid loss of both herbicides from surface litter and foliage occurred during the initial 30 days of treatment (see table). These results indicate that precipitation was not a factor in initial herbicide decline. Herbicide loss by either volatilization or photochemical degradation might account for the observed herbicide loss.

Sixty to 90 days after application, herbicide residues in chamise and grass and forb vegetation may be accounted for by 2,4-D and 2,4,5-T absorption into the plants since herbicide symptoms were evident. Adsorption to foliage, litter, and soil could also explain the observed residues. Following the initial (30-day) herbicide loss, residues of 2,4-D and 2,4,5-T remained constant (3.7 to 2.2 percent) until the winter rains began in late September and October 1974 (see table). No accumulation of herbicide residues on the soil surface due to litter fall was evident.

During the usual summer drought, annual plants are dead and chamise shrubs are inactive. Soil moisture, especially near the surface (0 to 10 cm), is low. During the winter, when moisture is adequate, chamise becomes physiologically active; thus, herbicide metabolism near the treated shrubs could cause the residue decline in foliage during this period. Washing of the herbicides from treated foliage and litter into the soil coupled with microbial degradation is also possible.

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Measuring chaparral fuels

Ronald H. Wakimoto □ John W. Menke

In future years brushland fuel may prove to be a valuable source of energy. As this resource becomes more useful, the need for accurately measuring the biomass of standing vegetation—or the total weight of living plants including attached dead parts—becomes greater. Brushland fuels can no longer be adequately quantified using visual estimates of tons per acre. Brushland productivity must be measured in the same way as have most of our forest lands.

A project funded by the University of California Water Resources Center was begun in San Diego County to study brushland dynamics and to provide techniques for biomass measurement and productivity estimation. The study site encompassed approximately