California's Brushlands

Brushland management

Theodore E. Adams, Jr.

Brush is a major vegetation type in California. In pure stands, such as chaparral, and mixed with other types of vegetation, it covers more than 20 million acres in California—nearly one quarter of the state.

Our brushlands are a dynamic system which developed with the aid of fire over millions of years. The many life forms, plant and animal, that live in our brushlands are adapted to and dependent on recurring fire. Fire is a natural part of the environment and rejuvenates our vast brushlands. Evidence of recurrent fire has been recorded by nature.

In the past, concern with wildfire has provided the central focus for brushland-related research. Traditional views hold that our vast brushlands are a management problem, a wildfire hazard which threatens commodities and the environment.

Fire is now an effective management tool, used alone and in combination with other devices. Since 1945, more than 2 million acres of brushlands have been burned by ranchers in California for improvement of livestock grazing and wildlife habitat. It has been estimated that about 8.75 million acres of land with brush management problems are sufficiently productive to warrant brush control for purposes of range improvement. Where brush is the dominant vegetation, about 3.25 million acres could be converted to grass for livestock forage, improved wildlife habitat, and better fire and erosion control and watershed protection.

The impact of brush management on other values has been demonstrated. Reduction of woody vegetation (density exceeding 50 percent canopy) to a canopy cover of 20 to 25 percent can improve water yield on northern California watersheds. Quantitative hydrologic studies of the effect of these changes within the 18- to 45-inch rainfall range are impressive. Consistent increases in annual runoff—up to 50 percent or more (about 3 to 5 acre-inches per acre)—have taken place over long periods where deep-rooted plants and stream-edge vegetation together with adjacent brushed slopes have been managed.

Burning brushlands in a pattern and sequence has proved beneficial to wildlife. In brushlands of the northern coastal mountains, deer populations increased from 20 deer per square mile to 75 per square mile when brush was managed with fire. Other studies have revealed increases in the variety and number of animals present in managed over mature, aging brush.

Improving harvest of brush to utilize this storehouse of the sun's energy is a prospect. At the moment, goats show promise of grazing brush, producing meat and fiber (mohair from Angora goats) for human use. Animals may be used in brush management programs to help reduce wildfire hazard and provide for human needs in an energy-efficient program.

Methods to enhance and protect our brushlands resource are being investigated. Efforts are under way to develop better criteria on which to base management programs.

Research opportunities are developing in several California locations. There is a growing need for information on plant production and nutrient budgets in different brushland communities. Studies are being initiated to determine the response of brushland communities and brushland soils to various management programs to produce multiple effects. Information from these efforts will help improve management techniques that protect and enhance brushlands.

In the following pages, summaries of past and present research are presented which suggest the wide spectrum of values and interests represented in California's brushlands.

Theodore E. Adams, Jr., is Extension Wildlands Specialist, Davis, and is technical coordinator of this special section.

Responses of bird and mammal populations to fire in chaparral

William M. Longhurst

Many species of wildlife inhabit chaparral, depending on it for food and cover. To appraise the effects of chaparral fire on wildlife, it is useful to have some estimate of probable trends which can be expected in populations of birds and mammals.

UC's Hopland Field Station was selected for study because of the backlog of information on wildlife that has been collected there since 1951. Chaparral on the field station and adjoining Cow Mountain Recreational Area is composed of a mixture of species: chamise, chaparral pea, and knobcone pine, as well as various species of oaks, ceanothus and manzanita, plus a number of other minor brush species.

On the field station, 55 species of birds and 25 species of native terrestrial mammals inhabit chaparral to some extent. Because of their general distribution in the state, several other kinds of birds and mammals might be expected to occur in this area, but only the species that have actually been collected are included in this evaluation. The responses of individual species of birds and mammals to chaparral fire are determined by their respective habitat preferences and by their movement patterns, reproduction, and food habits. For example, relatively few species seem to be adapted to extensive stands of mature chaparral. However, many thrive in younger chaparral stands, particularly if there is an interspersion of age classes of brush, or if there are openings with grass and herbaceous plants present. As shown in tables 1 and 2, only two species of mammals and three species of birds are considered to be especially adapted to extensive stands of mature chaparral to the extent that their populations would increase. In contrast, 23 mammals and 50 kinds of birds are better adapted to younger aged stands of

TABLE 1. Chaparral Mammals—Their Habitats, Behavior, and Successional Relationships

Species	Habitat*						Behavior†		Successional Relationships§			
	Mature chaparral, 10 yrs. +	Recent burn, 1 yr.-	Young chaparral, 2-3 yrs.	Intermediate chaparral, 4-9 yrs	Grassland from type conversion	Ecotone chaparral/grassland	Home range	Food habits	Population trend in mature chaparral	Increase in young or intermediate chaparral	Increase in extensive grassland	Increase in grassland chaparral interspersion
Vagrant shrew	FR		FR	FR	FR	FR	S	I	D	YIn		X
Broad-handed mole		Fos	Fos	Fos	Fos	Fos	S	I	D	Y	X	X
Black-tailed jack rabbit		F	FR	FR	FR	FR	L	H	D	Y	X	X
Brush rabbit	R			FR		FR	S	H	D	In		X
California ground squirrel					FR P-Fos	FR P-Fos	S	HI	D		X	X
Townsend's chipmunk	FR			FR			S	HI	U			
Valley pocket gopher		Fos	Fos	Fos	Fos	Fos	S	H	D	Y	X	X
Heerman's kangaroo rat			P-Fos	P-Fos	P-Fos	P-Fos	S	H	D	Y		X
Western harvest mouse					FR	FR	S	HI	D		X	X
Deer mouse	FR	FR	FR	FR	FR	FR	S	HI	D	YIn		X
Brush mouse	FR	FR	FR	FR	FR	FR	S	HI	D	YIn		X
Pinyon mouse	FR	FR	FR	FR	FR	FR	S	HI	D	YIn		X
Dusky-footed wood rat	FR			FR			S	HI	U			
California meadow mouse					P-Fos	P-Fos	S	H	D		X	X
Coyote	FR	FR	FR	FR	F	FR	L	O	D	YIn		X
Grey fox	FR	F	FR	FR	F	FR	L	O	D	YIn		X
Black bear	FR	F	F	FR	F	F	L	O	D	YIn		X
Ring-tailed cat	FR	F	F	FR		FR	L	O	D	YIn		X
Racoon	FR	F	F	FR	F	F	L	O	D	YIn		X
Badger		P-Fos	P-Fos	P-Fos	P-Fos	P-Fos	L	C	D	Y	X	X
Spotted skunk	FR	F	F	FR	F	F	L	O	D	YIn		X
Striped skunk	FR	F	F	FR	F	F	L	O	D	YIn		X
Mountain lion	FR	F	F	FR	F	F	L	C	D	YIn		X
Bobcat	FR	F	F	FR	F	F	L	C	D	YIn		X
Black-tailed deer	FR	F	FR	FR	F	FR	L	H	D	YIn		X

SOURCE: Information drawn from personal observations and the following principal reference: Ingles, L. G. 1954. *Mammals of California and its coastal waters*. Stanford Univ. Press. Stanford, CA. 396 pp.

*F = feeding
R = resting
Fos = fossorial
P-Fos = partially fossorial

†*Home range:*
L (large) = >10 acres
S (small) = <10 acres

Food habits:
I = insectivore
H = herbivore
O = omnivore
C = carnivore

§*Population trend in mature chaparral:*
U = up
D = down

Increase in young or intermediate chaparral:
Y = young
In = intermediate

chaparral regrowth, or to such situations as clumps of chaparral interspersed with grassy openings.

At the Hopland Field Station and Cow Mountain Recreational Area, where precipitation averages between 35 and 50 inches annually, depending on elevation, chaparral grows back rapidly after it is burned: within ten years it is difficult to determine to what extent most plants were burned. To evaluate where the various kinds of birds and mammals fit into this pattern of regrowth, chaparral was arbitrarily divided into categories: new burn (less than one year old); young (two to three years old); intermediate (four to nine years old); and mature (over ten years old).

Many species of mammals and birds use brush for escape or resting cover but feed in nearby clearings. The boundary between brush and grassland or between different age classes of brush is known as an ecotone or "edge," and the animals whose habitat it is are known as edge-adapted species. If the boundary is irregular or if clumps of brush are interspersed through grassland, the amount of edge increases, resulting in especially favorable conditions for the edge-adapted animals.

In dense stands of brush there is little undergrowth of grass or herbaceous plants because of the shade competition for moisture, and various allelopathic chemicals which certain brush plants produce that are toxic to grasses and herbaceous species. The openings, therefore, where grasses and the seed-bearing, broad-leafed, herbaceous plants can exist are the primary feeding areas for the mammals and birds that depend on these kinds of food.

A number of birds and mammals consume insects either as their primary food source or in combination with other kinds of

Species	Habitat*							Behavior†			Successional Relationships§			
	Mature chaparral, 10 yrs. +	Recent burn, 1 yr.	Young chaparral, 2-3 yrs.	Intermediate chaparral, 4-9 yrs.	Grassland from type conversion	Ecotone grassland/chaparral	Wide-ranging	Brush nesting	Ground nesting	Food habits	Population trend in mature chaparral	Increase in young or intermediate chaparral	Increase in extensive grassland	Increase in grassland chaparral interspersion
Turkey vulture	F	F	F	F	F	F	X		X	Sc	D	Y	X	X
White-tailed kite					F		X			P	D		X	
Sharp-shinned hawk	F	F	F	F		F	X			P	D	YIn		X
Cooper's hawk	F	F	F	F		F	X			P	D	YIn		X
Red-tailed hawk	F	F	F	F	F	F	X			P	D	Y	X	X
Golden eagle	F	F	F	F	F	F	X			P	D	Y	X	X
Marsh hawk		F	F		F	F	X		X	P	D	Y	X	X
Pigeon hawk	F	F	F	F	F	F	X			P	D	Y	X	X
Sparrow hawk	F	F	F	F	F	F	X			PI	D	Y	X	X
California quail	R	F	F	R	F	F			X	VSI	D	Y		X
Mountain quail	FNR		F	FR		F			X	VSI	D			X
Band-tailed pigeon	F			F			X			VFrS	D			
Mourning dove		F	FN		FNR	FN	X	X	X	S	D	Y	X	X
Road runner		F	F		FNR	FNR	X		X	PI	D	Y	X	X
Barn owl		F	F		F	F	X			P	D	Y		X
Screech owl		F	F	F	F	F				PI	D	YIn		X
Great horned owl		F	F	F	F	F	X			P	D	YIn		X
Long-eared owl	FR	F	F	FR	F	F	X			P	D	YIn		X
Poorwill	F	F	FNR	FR		F			X	AI	D	YIn		X
Nighthawk	F	FNR	FNR	F	F	F	X		X	AI	D	Y	X	X
Anna's hummingbird	FNR		F	FNR		F		X		N	U	IN		X
Allen's hummingbird	FNR		F	FNR		F		X		N	U	IN		X
Violet-green swallow	F	F	F	F	F	F	X			AI	D	IN		X
Scrub jay	FNR	F	F	FR		F		X		SIP	D	YIn		X
Raven		F	F		F	F	X			SCI	D	YIn		X
Crow		F	F		F	F	X			SCI	D	YIn		X
Plain titmouse	FR			FR		F				I	D	IN		X
Common bushtit	FNR			FNR		F		X		FrI	D	IN		X
Wrentit	FNR			FNR		F		X		FrI	D	IN		X
Bewick's wren	FNR		F	FNR		FNR			X	I	D	IN		X
Mockingbird	FNR			FNR		FNR		X		FrI	D	IN		X
California thrasher	FNR			FNR		FNR		X		FrSI	D	IN		X
Robin	FR	F		FR	F	FR		X	X	FrI	D	IN	X	X
Western bluebird	FR	F	F	FR	F	FR				FrI	D	Y	X	X
Blue-grey gnatcatcher	FNR			FNR		F		X		I	D	IN		X
Cedar waxwing	FNR			FR		F	X	X		FrV	D	IN		
Loggerhead shrike		FR			FR	FR	X	X		IPSc	D		X	X
Starling					F	F	X			ISFr	D		X	X
Western meadow lark					FN	FR	X		X	SI	D		X	X
Brewer's blackbird						F	X			SI	D		X	X
Brown-headed cowbird						F	X			SI	D		X	X
Western tanager	FR			FR		F	X			VFI	U	IN		
Purple finch	R	F	F	R	F	FR	X			FS	D	Y	X	X
House finch	'R	F	F	R	F	FR	X			FS	D	Y	X	X
American goldfinch		F	F		F	FR	X			SI	D	Y	X	
Green-backed goldfinch		F	F		F	FR	X			SI	D	Y	X	
Lawrence's goldfinch		F	F		F	FR	X			SI	D	Y	X	
Rufous-sided towhee				FR		FR			X	FSI	D	YIn		
Brown towhee						FR			X	FSI	D	YIn		X

TABLE 2. Chaparral Birds—Their Habitats, Behavior, and Successional Relationships

continued . . .

TABLE 2. Chaparral Birds—Their Habitats, Behavior, and Successional Relationships (continued)

Species	Habitat*: Mature chaparral, 10 yrs. +	Recent burn, 1 yr. –	Young chaparral, 2-3 yrs.	Intermediate chaparral, 4-9 yrs.	Grassland from type conversion	Ecotone grassland/chaparral	Wide-ranging	Behavior†: Brush nesting	Ground nesting	Food habits	Successional Relationships§: Population trend in mature chaparral	Increase in young or intermediate chaparral	Increase in extensive grassland	Increase in grassland chaparral interspersion
Savannah sparrow					FN				X	SI	D		FN	
Lark sparrow		F			F	FR	X		X	SI	D		X	X
Sage sparrow			F		FNR	FN				SI	D			
Oregon junco						FR				SI	D			X
White-crowned sparrow			F			FR				VSI	D			X
Golden-crowned sparrow			F				FR			VSI	D			X

SOURCE: Information drawn from personal observations and the following principal references:

Bent, A.D. 1932-1968. *Life histories of North American birds.* Smithsonian Institution, U.S. National Museum Bulletin Nos. 162, 167, 170, 174, 176, 179, 191, 195, 196, 197, 203, 211, 237.

Smith, D. R.(Tech. Coordinator). 1975. *Proceedings of the symposium on management of forest and range habitats for nongame birds.* USDA Forest Service, Gen. Tech. Report WO-1, 343 pp.

*F = feeding
R = resting
N = nesting

†*Food habits:*
V = vegetation I = insects
Fr = fruits P = predator
S = seeds

§*Population trend in mature chaparral:*
U = up
D = down

Increase in young or intermediate chaparral:
Y = young
In = intermediate

food such as seeds or vegetation. The diet of some of these insectivores may be restricted to only a few kinds of insects, whereas others may consume a large variety. Insects in turn are adapted to certain environmental conditions: various age classes of chaparral favor different groups of insects. In general, however, in brush of diverse age classes, especially if grass is mixed in, a greater variety of insects will be supported providing food for more kinds of insectivorous birds and mammals.

When a fire occurs in a stand of chaparral, most of the vegetation above the ground level is usually consumed or killed. Depending on the intensity of the fire and the atmospheric conditions at the time, islands of brush are often left unburned. If the fire follows an irregular course, the margin between the burned and unburned brush will be more complex, the amount of edge will increase, and the habitat for a number of mammals and birds will improve.

Most chaparral brush species are replaced after a fire either by seedlings or sprouts that grow from any surviving subterranean root crowns. The heat of the fire seems to aid in breaking the dormancy of seeds that have accumulated in the soil since the last fire without germinating. This abundant crop of seedlings and sprouts, together with numerous kinds of grasses and herbaceous plants which grow in burned areas, furnish a new and abundant supply of food for deer, rodents, and a number of birds. Also, the new growth is significantly more nutritious than the old-growth brush. The increase in carrying capacity for deer is especially dramatic: in the Hopland area, census data indicate that deer numbers will increase from about 20 per square mile in mature chaparral to 50 to 60 per square mile in chaparral that has been opened up by fire.

In some cases chaparral has been completely converted to grassland either by repeated burning over a few years, or by following up an initial burn with herbicidal chemical treatments to kill the brush sprouts and seedlings. If an extensive area of grassland is created in this way, birds and mammals that are adapted to grassland will thrive. However, extensive, unbroken areas of grassland will not be favorable for the edge-adapted animals except around the margins where ecotones exist.

Chaparral cannot be studied in isolation. The important relationships which exist between chaparral and grassland, either natural grassland or grassland produced from type conversion from chaparral, have been pointed out. Likewise, in many situations chaparral and oak woodland are also contiguous or interspersed cover types. A large array of wildlife finds its habitat niche in oak woodland, many overlapping into both chaparral and grassland. A breakdown of the range of habitats that individual species utilize is given in tables 1 and 2.

Another important factor to consider in these relationships is the mobility of wildlife. Species that have limited home ranges, restricted to a few acres, are more apt to be affected significantly when fire occurs in chaparral. In contrast, the wider ranging animals have the ability to move about to seek the habitat conditions they require.

William M. Longhurst is Professor, Department of Agronomy and Range Science, UC, Davis.

An assessment of goat grazing in chaparral

A.E. Sidahmed ☐ S.R. Radosevich
J.G. Morris ☐ W.L. Graves

Goats may be the all-purpose machine, the biological, ecologically acceptable alternative to mechanical, chemical, or prescribed burning methods of managing brushland. They produce minimal pollution, are self-perpetuating, provide animal protein for human consumption, and from the Angora goat, fiber for clothing.

In the summer of 1977 a study was initiated to assess the browsing preference, intake, and shrub suppression of Spanish goats, and the digestibility of certain shrubs by goats. The study 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.

A. E. Sidahmed is Graduate Research Assistant, S. R. Radosevich is Assistant Professor of Botany, and J. G. Morris is Professor of Animal Science, U.C., Davis; and W. L. Graves is Farm Advisor, Cooperative Extension, San Diego County.

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

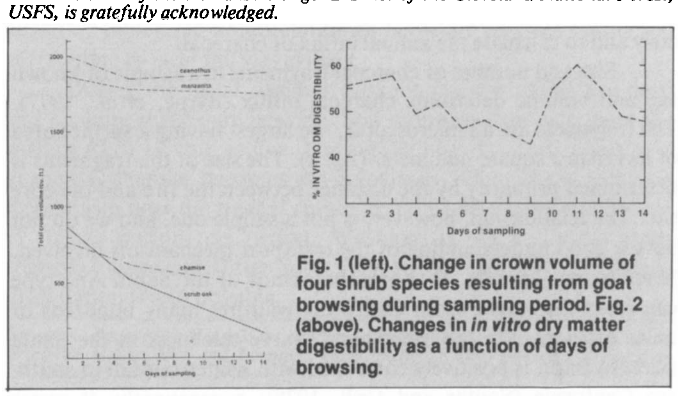


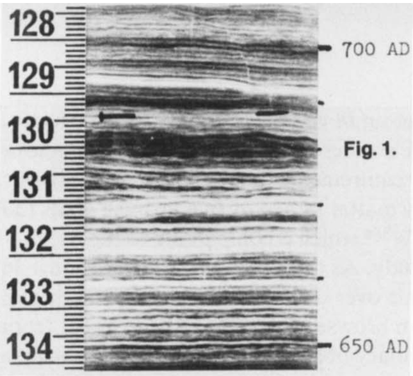
Fig. 1 (left). Change in crown volume of four shrub species resulting from goat browsing during sampling period. Fig. 2 (above). Changes in *in vitro* dry matter digestibility as a function of days of browsing.

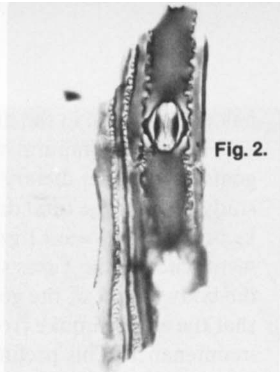
Fossil record discloses wildfire history

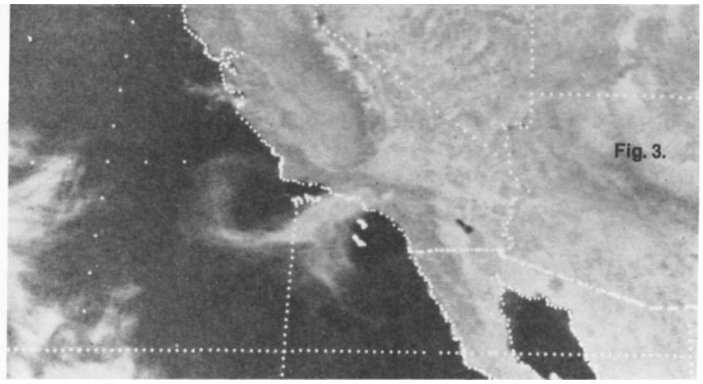
Roger Byrne

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-







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.

Roger Byrne is Assistant Professor of Geography, University of California, Berkeley.

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.

Steven R. Radosevich is Assistant Professor, Department of Botany, and Wray L. Winterlin is Specialist and Lecturer, Department of Environmental Toxicology, University of California, Davis.

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

51,400 hectares of chaparral vegetation, primarily chamise (*Adenostoma fasciculatum* H. & A.), red shanks (*Adenostoma sparsifolium* Torr.), Eastwood manzanita (*Arctostaphylos glandulosa* Eastw.), cupleaf ceanothus (*Ceanothus greggii* var. *perplexans* [Trel.] Jeps.), western mountain mahogany (*Cercocarpus betuloides* Nutt. ex. T. G.), California buckwheat (*Eriogonum fasciculatum* Benth.), and scrub oak (*Quercus dumosa* Nutt.). The elevation of the area ranges from 900 meters to over 1,800 meters at the top of Laguna Mountain.

To avoid the tedium of clipping, sorting, drying, and weighing, a linear regression approach was chosen to estimate plant biomass. Individual plant crown dimensions, basal stem numbers by diameter, plant age, and crown volumes were measured.

Methods

Representative plants of each species were selected. Plants on or near fuel breaks subjected to excessive browsing or mechanical damage were rejected. All plants up to 10 years old were open-grown plants found on fuel breaks or recently burned areas. Older plants were collected from unaltered stands which had germinated or resprouted following past fires. Such plants had grown after crown closure and competed for light and water.

Before plants were cut, crown dimensions were measured and basal stems were categorized by diameter. Three measurements were taken: HEIGHT (the over-all plant height); DIAMETER (the average of the maximum crown diameter and the crown diameter taken at a right angle to it); and the variable HTMAXD (the height above the ground at which maximum crown diameter occurs).

Harvesting consisted in cutting plants off at the ground level or immediately above the root crown. The plants were placed in labeled plastic bags and transported to the laboratory. Representative portions of exceptionally large plants were cut and immediately weighed in the field—as was the remainder of the plant—and bagged. In this way the percentage of the total plant weight actually sampled and processed was determined. For all plants, age was determined by growth-ring counts and fire or fuel manipulation history.

The number and diameter of basal stems may give some indication of plant vigor before the last disturbance and constitute a high percentage of plant biomass. All basal diameters were taken at ground level or immediately above the root crown. The basal stem diameters were grouped in the following classes: 0.0 to 0.5 cm; 0.6 to 1.0 cm; 1.1 to 2.5 cm; and greater than 2.5 cm.

The plant measurements HEIGHT, DIAMETER, and HTMAXD are used in estimating individual plant biomass, along with crown volumes that are determined by the crown shape of the species studied. Five additional independent variables (crown volumes) were created using the plant measurements of HEIGHT, DIAMETER, and HTMAXD.

Results

The linear crown measurements, HEIGHT, DIAMETER, and HTMAXD, were appropriate estimators for biomass of young, rapidly growing shrubs. They did not reflect the change in shrub weight due to stem increment growth in large mature plants. Basal stem diameter tallies, while accounting for stem increment growth in large plants, could not predict biomass for young upright plants. These estimators gave even poorer results when measuring species with extensive secondary branching. Crown volumes indicated more variation in biomass over a greater range of plant sizes for all species than either linear crown measurements or basal stem tallies. But volumes, like the crown measurements, often failed to account for biomass variation due to stem increment growth in the largest plants.

Crown volumes and basal stem tallies were combined in a multiple regression, giving excellent predictive results. For five of the seven species studied greater precision was obtained using the multiple linear regression than a simple linear regression. The combination of calculated crown volume and basal stem tallies accounted for crown expansion in various plant densities and increment growth in basal stems.

Forest managers often use yield tables for estimating timber volume in forests of particular ages and stocking densities. Chaparral managers could likewise use tables of fuel loading (weight per hectare) after an inventory of plant density and stand age (see table). Given that such tables existed for various site productivity classes, a manager could rapidly estimate fire intensity for a range of weather and fuel conditions. Such information could be used for making prescriptions for controlled burns or determining fire hazard.

Needs for further research

The research results reported here are merely the beginning of a long list of research findings needed to manage California's chaparral land. Two primary needs are: (1) a chaparral site classification system based on fuel biomass productivity potential; and (2) a determination of the impact of fire frequency alteration on the maintenance of natural chaparral communities.

Refinement of fuel biomass predictive models of the kind presented here, for numerous sites in California, should provide the data base necessary for developing a chaparral site classification system. Such a system would provide managers with information needed for the establishment of fuel break systems, greenbelts, rotational prescribed burning schedules, and general fire hazard reduction programs.

Chaparral land managers have discovered that they cannot prevent fires in chaparral, but they can alter their frequency. Because the effect of fire on the biotic community is most directly related to fuel loading at the time of ignition, we must understand more fully the interrelationships between fuel loading, energy release, and nutrient cycles to maintain the protective cover of some of California's most fragile watersheds.

Ronald H. Wakimoto is Assistant Professor of Forestry and John W. Menke is Assistant Professor of Forestry and Range Management, Department of Forestry and Resource Management, UC, Berkeley.

Financial support under Water Resources Center Project W-490 and AES-2936MS.

Results of Computer Simulation of Fuel Loading of Chamise (*Adenostoma fasciculatum*) Utilizing a Logistic Growth Function* of Weight (Y) Versus Age (X)†

Initial stocking (lb/ha.)	Plant spacing§ (m)	Total standing biomass (kg/ha.) 2nd year	4th year	6th year	8th year	10th year
14000	0.9	3159	5924	10073	15024	19543
12000	1.0	2708	5078	8634	12878	16751
10000	1.1	2256	4232	7195	10732	13959
8000	1.2	1805	3385	5756	8585	11168
6000	1.4	1354	2539	4317	6439	8376
4000	1.7	903	1693	2878	4293	5584
2000	2.4	451	846	1439	2146	2792
1000	3.4	226	423	720	1073	1396
800	3.8	181	339	576	859	1117
600	4.4	135	254	432	644	838
400	5.4	90	169	288	429	558
200	7.6	45	85	144	215	279

*$Y = 1.9052/(1. + (15.8193)e^{-0.377X})$, where Y = total plant biomass in kilo-grams and
X = age of the plant in years since last burned or manipulated.
†Plant growth assumes no interplant competition.
§Equilateral spacing.