United States
Department of
Agriculture

Forest Service

**Pacific Southwest
Forest and Range
Experiment Station**

General Technical
Report PSW-59

Using Goats to Control Brush Regrowth on Fuelbreaks

Lisle R. Green **Leonard A. Newell**

The Authors:

LISLE R. GREEN is a range scientist with the Station's Vegetation Management Alternatives Research and Development Program, with headquarters in Riverside, California. He was formerly in charge of the Station's research on development and maintenance of fuelbreaks. He earned bachelor's (1941) and master's (1948) degrees in range management at Utah State University. He has been on the Station's research staff since 1948, except for 5 years when he taught range management and soil science at California Polytechnic State University, San Luis Obispo. **LEONARD A. NEWELL** is a manager of the California Department of Forestry's Vegetation Management Program, with headquarters in Sacramento, California. He was formerly Resource Officer, Cleveland National Forest, Forest Service, U.S. Department of Agriculture, San Diego, California, and program manager of the Forest's Laguna-Moreno Demonstration Area. He has also served on the Huron-Manistee and White Mountain National Forests in Michigan and New Hampshire. He is a forestry graduate (1967) of the University of Michigan.

Publisher:

Pacific Southwest Forest and Range Experiment Station
P.O. Box 245, Berkeley, California 94701

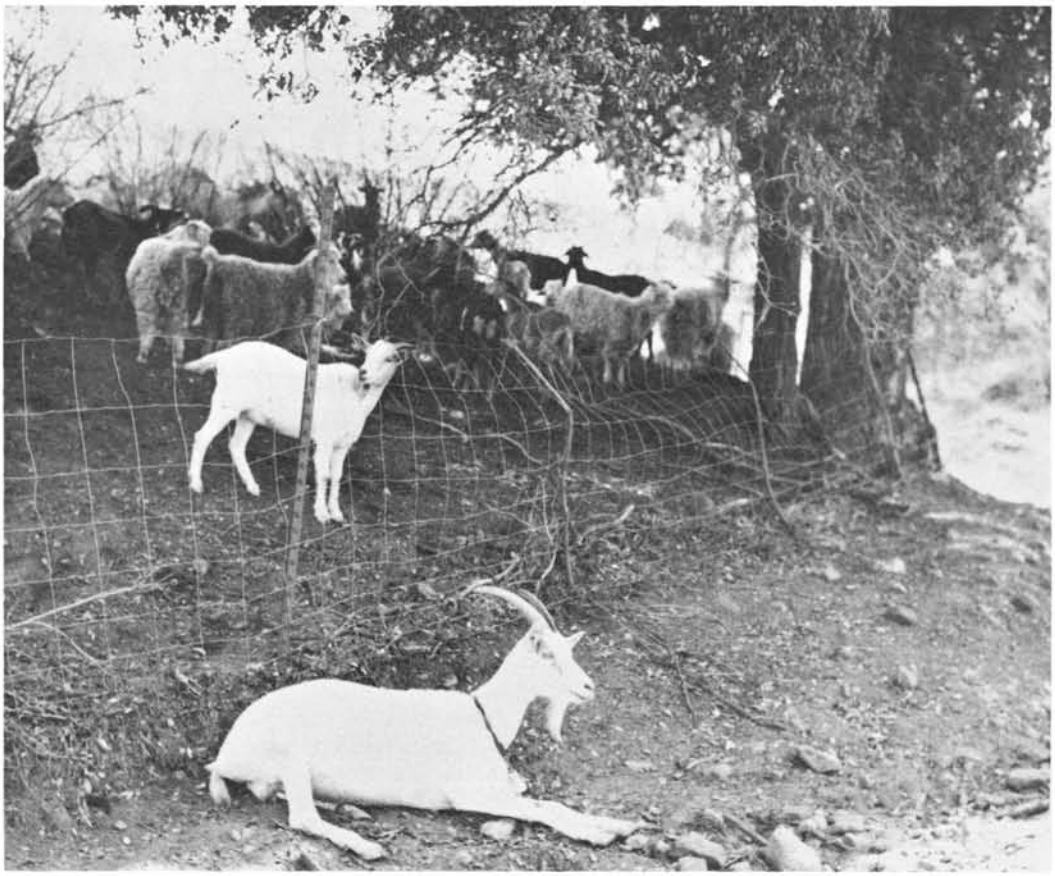
September 1982

Using Goats to Control Brush Regrowth on Fuelbreaks

Lisle R. Green, Leonard A. Newell

CONTENTS

Introduction 1
Do Goats Damage the Resource? 1
Damage to Vegetative Cover 1
Preferences for Plants 3
Comparisons with Other Livestock 5
Goat Management on Fuelbreaks 5
Selection of Breed 5
Breeding and Wether Goats 6
Rate of Stocking 6
Age of Brush 7
Herding and Fencing 7
Water and Supplemental Feeding 8
Other Considerations 9
Goats and the Environment 9
Competition with Wildlife 9
Damage to Native Plants 9
Losses to Cold Weather 9
Losses to Predators 10
Losses to Poisonous Plants 10
Economic Returns from Goat Management 11
Subsidizing Herd Owners 11
Marketing Goats 11
References 12



IN BRIEF...

Green, Lisle R.; Newell, Leonard A. **Using goats to control brush regrowth on fuelbreaks.** Gen. Tech. Rep. PSW-59. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982. 13 p.

Retrieval Terms: Angora, brush control, diet of goats, fuelbreaks, goat losses, predators, Spanish goats, wethers

Fuelbreaks offer a promising approach to the control of wildfires. On these wide strips through brushfields and around communities, vegetation of low volume and low growth is maintained to contribute to firefighting safety and provide a place for backfiring. After mature vegetation has been removed on fuelbreaks, herbicides have been the primary tool for controlling brush regrowth. But the continued use of chemicals is threatened by political and environmental considerations. Using goats to control this regrowth appears to be a promising alternative.

Goats have been accused of destroying the resource, but they generally reap the blame for prior mismanagement involving overgrazing by other animals, indiscriminate use of fire, and baring of the soil by various means. Goats can utilize woody vegetation on which other livestock would starve, and so they are usually present during the final stages of land degradation. Test results show that properly managed goats eliminated or controlled woody vegetation at the same time that herbaceous vegetation reoccupied the site.

Goats will eat a wider variety of plants than other classes of livestock, but unless they are subjected to grazing pressure, will only eat plant parts that are in a favorable growth stage from species they relish. Goat diets, when averaged over a year, usually contain at least half browse, the rest grasses and forbs. During spring, goats seek out the lush herbaceous growth, then concentrate more and more on browse through the other seasons. Forbs are taken more or less in proportion to their abundance.

Goats are least selective on first-year brush regrowth, and become more selective as the brush is older. In mature stands, much or most of the brush is out of their reach.

Goats ate first-year regrowth of chamise, desert ceanothus, California bush buckwheat, and Eastwood manzanita, but scarcely touched 5-year-old plants of these species, except in bedding grounds or other places of confinement. Mountain mahogany and scrub oak were most-favored species in the 5-year-old brush stands.

For fuelbreaks, Spanish goats have some advantages over Angoras. They are larger, and better able to fend off predators, and the marketable kids are larger. They are somewhat better browsers than Angoras, and are more hardy. With good feed, and intensive management, Angoras may be more profitable, however.

Recommended stocking rates for goats are 0.5 to 3 acres (0.2 to 1.2 ha) per goat the first year after clearing, depending on the amount of regrowth, and reduced stocking thereafter. Larger numbers of goats may be used for short periods. Stocking rates that continuously or two or three times annually remove all leaves and small twigs will kill small shrubs in 2 years, and most larger ones in 3 or 4 years.

An economically viable breeding goat herd would be at least 1500 goats. Buying wethers or nonfertile nannies in spring and selling them in fall should achieve management objectives, but a subsidy would probably be needed.

The question of whether goats should be herded or fenced for control is still a moot one. Some combination of practices is probably the best. Getting good herders and good dogs is a problem.

The supply of water and food helps determine whether goats can utilize an area. Fuelbreaks are frequently in dry and remote areas where water must be provided by hauling, development of springs or wells, and piping the water to where it is needed. Supplemental feeding appears to be a desirable practice during the winter, particularly for pregnant animals. Any livestock feed available can be used.

Mountain terrain offers other problems. Roads are frequently not good, especially during the winter. Rough, steep terrain encourages injury or lameness, and remoteness from urban amenities discourages herders.

Goats in southern California have been lost to cold, stormy weather and to predators. Kids are particularly sensitive to cold, wet weather, and protection should be provided for nannies and their kids. Predator losses have not been large when the goats were herded, and the herder could occasionally shoot at a coyote stalking the goats. Poison plants have not caused losses on the Cleveland National Forest, but with goats under grazing stress, poison plants are a potential source of losses.

The inability to show an economic return has restricted use of goats on wildlands. The owner-operators have not been experienced local livestock producers, banks have refused to lend sufficient funds for an economic size unit, and the market for goats is uncertain. Some form of subsidy by the using agency will probably be necessary.

Figure 1—On fuelbreaks, woody fuels on wide strips are reduced or eliminated to assist in control of wildfire.

Fire managers, land managers, and other interested citizens agree on "fuelbreaks" as one strategy to help control wildfire. Fuelbreaks are strips through brushfields or around communities, or other areas of considerable value, 200 to 400 ft (60 to 120 m) wide, on which the values at risk determine the intensity of fuel management (*fig. 1*). Low volume, low growing vegetation that will not support intense fire is generally maintained on the fuelbreaks to contribute to firefighter safety and provide a place for backfiring (Green 1977).

Clearing dense chaparral as part of fuelbreak construction is frequently an expensive procedure, and regrowth from sprouting brush crowns and seed soon negates the clearing unless countermeasures are immediate (Plumb 1961). Maintaining fuelbreaks to the prescribed vegetation level is one of the most serious problems faced by all agencies charged with doing so. The problem is compounded by these constraints:

- Maintenance with herbicides is generally unacceptable from a political and environmental standpoint.
- Maintenance with prescribed fire is often impractical because the young-age brush will burn only under severe conditions, when prescribed burning is unsafe, unless grass is sufficient to carry a light fire.
- Mechanical treatment (brush rakes, heavy disks, and other means) is expensive and possibly damaging to the site.
- Handtool labor is not only expensive (as high as $2000/acre [$5000/ha]), but slow.

Faced with limited budgets, personnel, and other constraints, and with the need to maintain fuelbreaks, some land managers have experimented with livestock—especially goats—as a promising way of lowering maintenance costs. This is an appealing idea because goats naturally consume large proportions of brush species in their diets and because the market for goat meat appears to be expanding. Some ranchers are interested because controlling brush usually improves conditions for grasses and forbs, which cattle and sheep prefer.

This paper examines the various aspects of using goats to control brush regrowth, summarizes knowledge and experience gained to date by the Forest Service and its cooperators, and considers some common misconceptions about goats and their effects on ecosystems—ideas that originate from mismanaged situations.

Our experience is mostly from using goats on fuelbreaks, on the Cleveland National Forest in southern California, but most of the lessons can be applied elsewhere on wildlands.

DO GOATS DAMAGE THE RESOURCE?

A study of the history of goat use in Arizona, California, New Mexico, Texas, and elsewhere indicates that goats under proper management are probably less damaging than any other class of livestock or large wild game. They can, however, eat more woody vegetation than other domestic livestock and because of this, managers can force them to overuse and destroy woody as well as herbaceous vegetation.

Damage to Vegetative Cover

In west Texas on ranges that were in good condition in the late 1940's, ranchers maintained predominantly English breeds of beef cattle—Hereford, Angus, and a few Shorthorn. Ranges in fair range condition were frequently stocked with sheep and Brahma cattle. On ranges in poor condition, goats were stocked alone, or with other livestock. These lands had been grazed, and often overgrazed, for more than 100 years. When grazing abuse had eliminated most desirable vegetation and much of the topsoil, only goats could efficiently harvest the remaining unpalatable, poor quality woody and herbaceous vegetation. But because goats were on the land after the range was in poor range condition, they were frequently blamed for the damage done by many decades of abuse by other classes of livestock.

Goats can survive and become a profitable commodity while consuming only coarse forages on which cattle and sheep have difficulty surviving (Merrill 1975, Merrill and Taylor 1976). Consequently goats can destroy more varieties of vegetation than cattle or sheep under conditions of mismanagement that cause severe range deterioration. With intense overgrazing, cattle are the first to go, then sheep survive for a time, but after their numbers are reduced because of poor range conditions, the goat can and will survive. In studies in Texas, goats were the least destructive grazers under proper stocking, then cattle, sheep, and horses the most destructive (Merrill 1975).

In the Mediterranean area, goats are "really only the last link in a vicious chain of land devastation brought on by indiscriminate burning, cutting, grazing, slope denudation, and cultivation" (Naveh 1972). Most of the world's deteriorated rangelands were caused by overgrazing by cattle and sheep, and this condition eventually left pasturage that only the goat could utilize (Huss 1972).

Accounts about goats damaging vegetation on mid-Pacific Islands are found in the literature (Calvopina and Vries 1979; Coblentz 1976, 1977; Spatz and Mueller-Dombois 1973; Vries 1979; Vries and Calvopina 1979). Goats have been on the Channel Islands off the southern California coast for at least 150 years (Coblentz 1976), as have sheep (Coblentz 1980, Minnich 1980). The goats were released on the Channel and other Pacific Islands during explorations or settlement, and into an environment where they had no natural enemies. To prevent further elimination of native plants and to accomplish recovery efforts for seven threatened and endangered plants and animals, the U.S. Navy removed about 20,000 goats from San Clemente Island between 1973 and mid-1981. An estimated 500 goats remained for later removal effort. Starting in 1877 large numbers of sheep were brought to San Clemente Island (Raven 1963). Sheep were confined to fenced pastures all along the plateau that forms the Island's main land mass. They were removed after the U.S. Navy acquired San Clemente Island in 1934 (Larson 1981).

We believe that a buildup in goat numbers in chaparral areas similar to that which occurred in the Pacific Islands could not occur. Goats in such areas are under the control of herders with dogs trained to bring back animals that might stray. Even more important, predators—especially coyotes but also bobcats, dogs, and occasionally mountain lions—are never far away from a goat herd. If both male and female goats escaped from a herd, any kids born would be harvested by the coyotes and bobcats, even if these predators were less successful at killing the mature goats. Many small goat herds exist throughout California and in some instances, goats were abandoned. If they had the potential to expand their numbers after escaping, this would surely have happened by now.

Goats under moderate or intermittent stocking reduced the brush cover, while annual grasses and forbs increased, during 2- to 4-year browsing periods in both central and southern California. Goats confined in small enclosures over several days or weeks bared the soil as they removed any herbaceous vegetation and the leaves and twigs from all shrubs. The effect of goats in these holding pens and other areas of concentration has evidently not been serious, however, because annual grasses and forbs occupied the bare soil between shrubs a growing season after goat use

Figure 2—Annual grasses increased as volume of brush decreased after heavy browsing for 1 or more years.

was discontinued—even where it had not previously been present under thick brush (*fig. 2*).

As Angora goats grazed at a heavy rate for 23 years at the Research Station in Sonora, Texas, a perennial grass understory developed (Merrill and Taylor 1976). In South Africa, grassland being invaded by brush (658 shrubs/acre or 1625/ha) was burned off, then stocked with goats. At the end of the season when cattle were admitted, grass production did not differ between plots with goats and those without (Trollope 1974).

Our experience then and that reported in the literature is that goats under proper stocking will control brush without damaging the herbaceous vegetation, or the soil.

Preferences for Plants

A popular assumption is that goats will eat practically anything. They will take a wider variety of plants than other classes of livestock (Bryant and others 1979, Fraps and Cory 1940, Huss 1972, Merrill and Taylor 1976, Naveh 1972), but will feed selectively if there is a choice (Green and others 1978). They will select the plant parts and species that are in a favorable stage of growth. Goats include a large proportion of browse in their diets—generally more than 50 percent over a year—and they eat more browse than other classes of domestic livestock (Askins and Turner 1972, Aucamp 1975, Bryant and others 1979, Campbell and others 1962, Dutoit 1972, Huss 1972, Wilson 1969). Grasses and forbs were dominant in goats' diet, especially during spring on lightly grazed range. And grasses and browse were dominant in ther diet on heavily grazed range near Sonora, Texas (Bryant and others 1979, Malechek and Leinweber 1972). Forb consumption tended to be limited by availability. In a west Texas study, goats fed on woody plants 65 percent of their grazing time through the year, and on weeds and grass about 35 percent (Askins and Turner 1972).

In July 1979 in southern California, 400 goats were placed in an 80-acre (32-ha) fenced area that had burned a year earlier. The goats concentrated first on a sparse stand of dry forbs, then the shrub regrowth. When this was browsed to about 50 percent of the available browse, the goats turned to a stand of dry perennial grass, mostly wheatgrass (*Agropyron* sp.), hardinggrass (*Phalaris tuberosa* L. var. *stenoptera* [Hack.] Hitchc.), and some orchard grass (*Dactylis glomerata* L.). Earlier, in 1976, goats placed in small pastures containing 5-year-old regrowth browsed two abundant shrubs—mountain mahogany (*Cercocarpus betuloides* Nutt.) and scrub oak (*Quercus dumosa* Nutt.)—but ignored chamise (*Adenostoma fasciculatum* H. & A.) and bush buckwheat (*Eriogonum fasciculatum* Benth.), except for flowers, and Eastwood manzanita (*Arctostaphylos glandulosa* Eastw.).

During the 1974-76 seasons, Angora goats in a heavily stocked central California pasture kept both woody regrowth and herbaceous vegetation closely grazed. In another pasture stocked at half the heavy stocking rate, goats kept the brush regrowth browsed back but only lightly grazed the annual herbaceous grasses and forbs. When green herbaceous feed became available, the goats in both central and southern California searched out young green grass and forbs and almost ignored brush regrowth. A rancher commented that goats help eliminate tarweed (*Hemizonia* sp.) (Elam 1952).

Goats on the Cleveland National Forest in San Diego County were selective in choosing their diets, as are all animals. They selected green, succulent, tender plants in preference to those that were dry and woody. During early spring, much of what they ate was grass and forbs. As the annuals dried, preferred shrubs made up a larger proportion of the diet. As grazing pressure increased and as preferred species became less available, goats shifted to less preferred shrubs and trees. If confined behind a strong fence, they ate all the available foliage from all woody plants as well as all herbaceous vegetation.

Western or birchleaf mountain mahogany was highly attractive to the goats and always received the heaviest use of any abundant browse during our southern California test (*table 1*). We rated use of 5-year-old regrowth on a scale of 0 = no use to 10 = 100 percent of leaves and small twigs taken. Birchleaf mountain mahogany use was usually rated 9.5 or 9.6 (Green and others 1978). The growth habit of

Table 1—*Preferences of goats for southern California shrubs under moderate grazing pressure*

Common name	Scientific name	Regrowth[1/]	
		1 year	5 years
Chamise	*Adenostoma fasciculatum*	6 to 7	1 to 2[2/]
Red shank	*A. sparsifolium*	ND[3/]	0 to 1
Eastwood manzanita	*Arctostaphylos glandulosa*	7	0 to 1
Mexican or pointleaf manzanita	*A. pungens*	2 to 3	ND
Big sagebrush	*Artemisia tridentata*	ND	2 to 3
Desert ceanothus	*Ceanothus greggii*	7	1 to 3
Whitethorn ceanothus	*C. leucodermis*	5	5
Mountain mahogany	*Cercocarpus betuloides*	10	9 to 10
Bush buckwheat	*Eriogonum fasciculatum*	5	0 to 1[2/]
Honeysuckle	*Lonicera* subsp. *Johnstonii*	ND	10
Toyon	*Heteromeles arbutifolia*	ND	6 to 7
Hollyleaf cherry	*Prunus ilicifolia*	ND	2 to 3
Scrub oak	*Quercus dumosa*	9	8
Scrub interior live oak	*Q. wislizenii frutescens*	ND	5
Redberry	*Rhamnus crocea ilicifolia*	ND	9 to 10
Sugarbush/sumac	*Rhus ovata*	ND	0 to 1
Squawbush	*Rhus trilobata*	8	1
White sage	*Salvia apiana*	0 to 1	ND
Bluecurls	*Trichostema parishii*	ND	0 to 1[2/]

[1/] Rating: 0 = no browsing, 10 = 100 percent consumption of available leaves and small twigs.

[2/] Mostly flowers preferred.

[3/] No data.

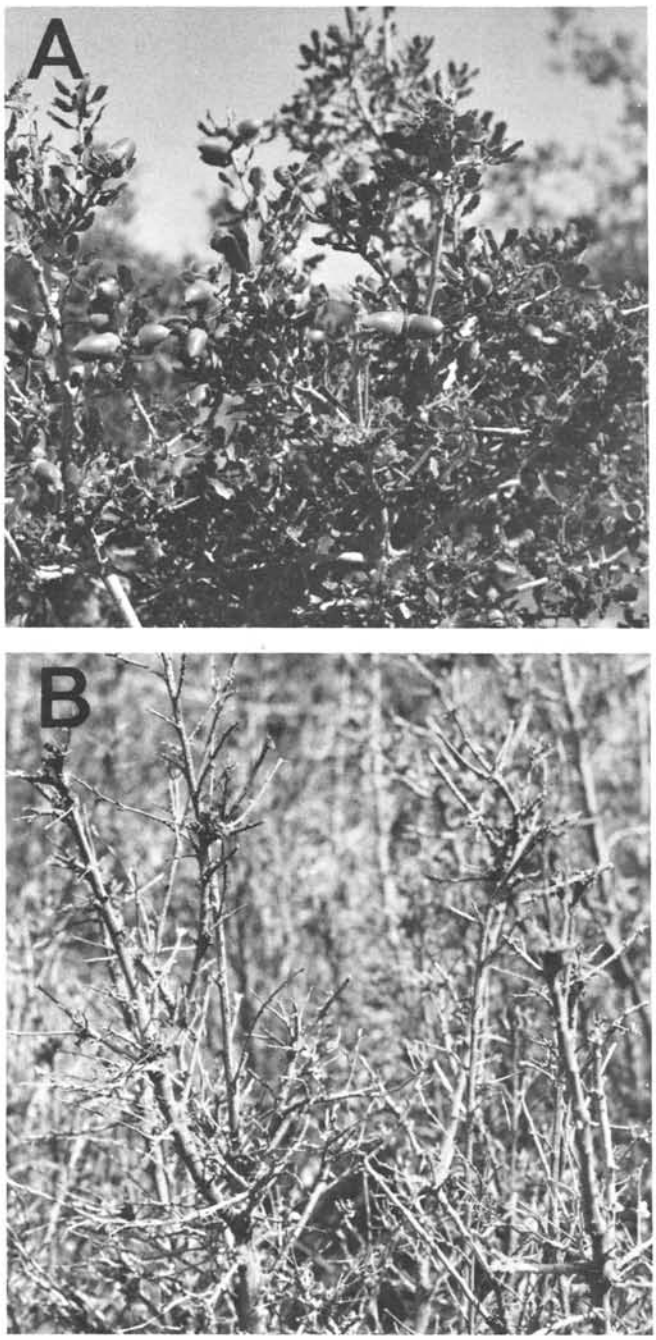


Figure 3—Goats usually favor scrub oak *(A)* and strip the plant of nearly all leaves and fine twigs *(B)*, before consuming shrubs, such as chamise, desert ceanothus, and manzanita.

mountain mahogany is open, with all the twigs readily available, except on tall plants. No sharp spines restrict browsing. Scrub oak was the second abundant, palatable shrub in southern California. Always browsed, it was rated about 8—somewhat less than the utilization of mountain mahogany (*fig. 3*).

Goats are partial to interior live oak (*Quercus wislizenii* A. DC.) sprouts (Sampson 1944). We observed in the central Sierra Nevada foothills that goats ate interior live oak avidly. However, during summer 1979 in southern California, goats seemed less interested in the shrubby form, the variety *frutescens*.

Two other southern California shrubs are palatable but grow in only trace amounts. Honeysuckle (*Lonicera subspicata Johnstonii* [Keck]) was always browsed back to stems ¼ inch (0.64 cm) diameter, or larger. Redberry (*Rhamnus crocea ilicifolia* [Kell.] Greene) was also highly favored. Its defense was to grow with a canopy of dense stiff branchlets which protected some of the leafy growth.

Chamise and Eastwood manzanita are common to abundant shrubs in southern California, but they do not attract goats. While 80 to 100 percent of available browse of some species was being taken, chamise use was rated 1 to 2. It would have been even less had not the goats selected chamise flower stalks. Only a few twigs of Eastwood manzanita were taken—a rating of about 0.5, if the goats had a selection of shrubs. When nine Spanish goat wethers were fenced inside a 0.5-acre (0.2-ha) enclosure for 2 weeks, they concentrated on green grass, forbs, and dry oak leaves during the 3 days they were available, ate mostly scrub oak during the 4 days it lasted, then chose chamise in preference to Eastwood manzanita or desert ceanothus (Sidahmed and others 1981).

California bush buckwheat usually comprised some small percentage of the available browse. Its flowers were eaten by the goats, but not its leaves.

Desert ceanothus (*C. greggii* A. Gray) was sometimes locally abundant, but we rated utilization only 1 to 3. Flowers were browsed, and sometimes twigs from seedlings or other small plants. Whitethorn ceanothus (*C. leucodermis* Greene) occurred as occasional scattered shrubs, and its use averaged about 5. Hollyleaf cherry (*Prunus ilicifolia* [Nutt.] Walp.) utilization was 2.2.

Bluecurls (*Trichostema parishii* Vasey) is a highly scented shrub found in trace amounts. It was not browsed, except for the flower stalks.

Squawbush (*Rhus trilobata* Nutt.) was generally not selected for browsing, although its habit of dropping leaves during the dry summer suggested leaf utilization. Some first-year squawbush regrowth was browsed, however. Neither sugarbush sumac (*Rhus ovata* S. Wats.) nor white sage (*Salvia apiana* Jeps.) was browsed during the limited contact goats had with them. On Santa Catalina Island, laural sumac (*Rhus lauriana* Nutt.) and white sage were abundant where goats concentrated, indicating that they are not browsed by choice (Coblentz 1977, Minnich 1980). Poison oak (*Toxicodendron diversilobum* [T. & G.] Greene) was not abundant, but was eaten wherever the goats found it.

Red shank (*Adenostoma sparsifolium* Torr.) was usually ignored, except the goats sometimes rubbed their heads and horns on it. The first browsing of red shank observed by a herder was at the approach of a storm. When bed grounds enclosed red shank, goats stripped foliage from the plants. Other use occurred in holding pastures under grazing stress.

A green herbaceous plant the goats ignored even under close utilization was wild peony (*Paeonia californica* Nutt.). Telegraph weed (*Heterotheca grandiflora* Nutt.) also had a low palatability rating, even though not quite dry.

A communal group maintained goats on the Santa Barbara Ranger District, Los Padres National Forest for four years (Brotherhood of the Sun 1974).

- Plants browsed yearlong, but especially during the fall and winter, along with dry grass, were: scrub oak (*Quercus dumosa*), coast live oak (*Q. agrifolia*), chamise (*Adenostoma fasciculatum*), California bush buckwheat (*Eriogonum fasciculatum*) (when in bloom), manzanita (during the winter), California sagebrush (*Artemisia californica* and *A. tridentata*), toyon (*Heteromeles arbutifolia*) (uncommon), and blue elderberry (*Sambucus cerulea*) (uncommon).
- Shrubs not browsed were: yerba santa (*Eriodictyon californicum*), sugar sumac (*Rhus ovata*), bigpod ceanothus (*Ceanothus megacarpus*), blue blossom ceanothus (*C. thrysiflorus*), juniper and yucca.

Comparisons with Other Livestock

At the University of California's Hopland Field Station in northern California, browse, mostly from oaks, made up 7.3 percent of the diet of both cattle and sheep during the dry summer months (Van Dyne and Heady 1965). Diet samples showed that chamise and interior live oak were eaten in significant amounts by sheep only when all herbaceous material was removed. Oak was preferred to chamise (Wilson and others 1971). In another northern California study, grazing treatments with cattle and sheep did little to delay the regrowth of brush (Murphy and others 1975). In studies at the San Joaquin Experimental Range in central California, browse made up 1 to 2 percent of the diet of beef cattle in one study (Wagnon 1963). In another Experimental Range study, less than 1 percent of the diet of Hereford steers on fertilized range during summer was browse; but forbs, representing 27 percent of the fertilized herbage, was 23 percent of the diet one year and 25 percent the next (Green and others 1958).

Cattle diets averaged approximately 0 to 3 percent browse, 10 to 20 percent forbs, and 70 to 90 percent grass on 18 large study areas near Roswell, New Mexico during 1979-80. Sheep diets averaged from about 5 to 11 percent browse, 40 to 70 percent forbs, and 20 to 50 percent grass (Beasom 1980). Similarly, in north central Texas, cattle ate only limited amounts of tender browse and did not keep brush regrowth under control (MaGee 1957). On the Angeles National Forest in southern California, sheep did not touch 2-year-old chamise regrowth even though herded through a study area. At Sonora, Texas, 60 percent of the sheep diet averaged over a year was grass, 22 percent was browse, and 18 percent was forbs (Bryant and others 1979).

GOAT MANAGEMENT ON FUELBREAKS

Two breeds of goats—Angoras and Spanish—are used in brushlands. The Angora, developed primarily for mohair production, takes its name from the capital city of Turkey where it was introduced to the western world (Merrill and Taylor 1976, Spurlock and others 1978). The Spanish goat, also known as hair goat or meat goat, is descended from goats brought to the United States from Spain. A third type of goat is the milk goat, which is generally not considered for brush control because of the formidable problem of handling and transporting milk in backcountry areas. The milk goat has been crossed with Spanish goats, however, and the Spanish goat may be descended from milk goat breeds.

Selection of Breed

The Angora nanny or doe should weigh 70 to 80 pounds (32 to 36 kg) if in good condition, the billies 125 to 175 pounds (56 to 80 kg). Spanish nannies in good condition will weigh 80 to 100 pounds (36 to 45 kg), the billies commonly 150 to 175 pounds (68 to 80 kg) (Spurlock and others 1978). The larger size of the adult Spanish goat gives it some advantage in fending off predators.

The Spanish goat is considered to be a somewhat better browser than the Angora. On the Edwards Plateau in Texas, Spanish goats consumed little grass, moderately grazed forbs, and completely utilized available browse. Angoras grazed grasses to a short stubble, took 100 percent of the forbs, and 80 percent of the available browse (Merrill 1975). Taylor (1975) suggested that Spanish goats are more efficient browsers and are more efficient in controlling brush under poor range conditions than the Angora. On ranges in excellent condition at Sonora, Texas, however, Angora and Spanish goats did not differ significantly in what they ate (Bryant and others 1979).

The Spanish goat is considered to be hardier than the Angora and has a wider range of weather adaptability. In Texas, for example, the Spanish goat can be produced in all sections, while Angora production is limited to low rainfall areas (Groff 1973). Angoras probably need more human help during kidding than do the Spanish goats (Spurlock and others 1978), and browsing in brush tends to degrade the mohair more than grazing in grassy areas.

From 1963 to 1972, mohair sold for 40 to 80 cents per pound—an unrewarding price to the grower. Since then the price has escalated rapidly, and $2.50 (in 1973) to $7.00 per pound has made the return from mohair an important consideration when choosing between the two breeds.

Angora nannies will normally kid once each year and frequently produce twins. Spanish nannies will sometimes breed twice a year, or once each 8 or 9 months, and produce

twins (or sometimes triplets) with greater regularity than do the Angoras. Kid crops in either breed run from 40 percent under poor range conditions to 150 percent under a high plane of nutrition (Dollahite 1972, MaGee 1957, Merrill and Taylor 1976, Spurlock and others 1978). Spanish goats on Catalina Island averaged less than one birth per 16 months and only 1.2 young per birth due to the poor nutritional level in areas of high goat density (Coblentz 1976). Nannies that are undernourished tend to miscarry or suffer fetal absorption (Spurlock and others 1978). In southern California during one winter on poor browse, many nannies simply refused to claim their kids, or abandoned them. A kid crop of 100 percent is suggested as a desirable goal under wildland conditions.

Which type of goat then for California brushlands? Spurlock and others (1978) suggested that if the goats will be given only rudimentary care, especially under harsh, dry conditions, the Spanish goat should be chosen. If the flock is to be well and intensively managed, however, an Angora flock will eat almost as much brush and will produce more income.

Breeding and Wether Goats

Besides selecting the breed of goat for the brush control job, the goat operator or forest manager must decide between maintaining a breeding herd or a herd of wethers, the castrated male goats. In some respects, wethers appear to be the better choice for fuelbreaks.

The wether is a large animal, weighing about the same as the billies or bucks, and considerably more than the nannies. This extra size makes him less vulnerable to predators. It also results in a large mohair clip if the wether is of the Angora breed. Wethers can be retained for 5 to 7 years, or they can be sold after 1 or 2 years, and new animals purchased (Plaister and Dal Porto 1973).

Brush eradication with goats frequently requires temporary overbrowsing during parts or all of 3 or 4 years needed to kill brush. Breeding animals are more sensitive to the lack of adequate quality feed, and the kid crop and size of kids produced may be affected adversely by overbrowsing or overgrazing. The needs of wethers are less critical (Spurlock and others 1978).

Another advantage of wethers is that the rancher does not have the bother and expense of kidding his flock. Kidding requires night work, extra fencing, and extra handling of the animals, including maintaining two herds during the kidding season.

Wethers are not without problems that the goat owner and land manager must consider:

- The greatest source of income from Spanish goats is the sales receipts from a good kid crop. With wethers, the sales receipts from the cull goats may be less than the cost of replacements.
- The main source of replacement wethers is the Edwards Plateau area of Texas. Market conditions and transportation costs fluctuate widely through the year and from year to year. Favorable prices may not coincide with needs for fuelbreak browsing.

We believe that a Spanish breed wether goat operation will probably have to be subsidized by the benefiting agency. We are less sure if the wethers are from the Angora breed, and mohair brings a good price. We have not had enough experience to predict whether or not a breeding herd could be economically viable under fuelbreak conditions, but believe subsidy requirements might be less than for wethers. Additional research is needed in these areas.

Rate of Stocking

The stocking rate will depend upon the density and vigor of woody regrowth, on whether the objective is to kill the brush rapidly or to simply restrain it, and whether the goats will be in the pasture continuously or intermittently.

Huss (1972), working in Mexico, stocked goats at 0.9 and 1.8 acres (0.36 and 0.73 ha) per goat year. Grass use was "slight," and there was selectivity among the brush species at both rates. In the Edwards Plateau, of Texas, one animal unit[1] per 18 acres (7.3 ha) is considered moderate stocking. However, this rate of stocking—3 acres (1.2 ha) per goat—did not control brush regrowth, and Merrill (1975) recommended one goat per 2 acres (0.8 ha). In Israel, the recommendation is for 1.6 to 1.8 acres (0.65 to 0.73 ha) per goat on a continuing basis (Naveh 1972). When brush was uniformly dense and continuous in New Zealand, and up to 6 ft (1.8 m) tall, six goats per acre (15/ha) for a 12-month grazing season opened up the stand. Three goats per acre (7/ha) prevented reversion to brush or mixed brush and weeds (Batten 1979).

For northern California, Sampson (1944) suggested that three goats per acre (7/ha) yearlong on productive site and as low as one goat per acre (2.5/ha) on poor sites for 2 years would keep brush regrowth from getting out of the reach of goats. A reduced stocking rate the third and succeeding year would be in order if goat stocking was to the full capacity of browse production the first 2 years.

In Amador County, California, in the Sierra Nevada foothills, the recommended stocking rate is two mature goats per acre (5.0 goats/ha) the first year after brush clearing, one per acre (2.5 goats/ha) the second year, and one goat to 2 acres (1.2/ha) thereafter (Spurlock and others 1978).

The stocking rate may be heavier for short periods and frequently should be to get utilization of unpalatable species

[1]One mature cow, or five or six sheep or goats.

without excessive, continuous browsing of palatable shrubs. Merrill and Taylor (1976) suggest five to eight goats per acre (12 to 20/ha) for 30-day periods on the Edwards Plateau. At the San Juan Basin Research Center in Colorado, gambel oak regrowth was stocked at eight goats per acre (20/ha) for 25 days, with a second browsing period later in the year. The stocking rate was reduced each year for 4 years at which time 95 percent of the sprouts were dead (Davis and others 1975). In southern California, 400 goats on 2.5 acres (1 ha) for 2 days stripped the leaves and small twigs from the palatable species making up 80 percent of the 5-year-old, dense shrub cover. Less palatable species—chamise, Eastwood manzanita, and bush buckwheat making up about 15 percent of the available browse—were not browsed until after available leaves and small twigs had been removed from the palatable shrubs (Green and others 1978).

Age of Brush

For the reduction or maintenance of brush stands, goats are most effective on first-year regrowth—least effective in mature chaparral. The young and tender sprouts characteristic of regrowth following burning or mechanical clearing are more palatable and probably more nutritious (Huss 1972, Sidahmed and others 1982) than the old growth. And they are also more available.

First-year regrowth was more acceptable to goats than 5-year regrowth on the Cleveland National Forest (Green and others 1978). They were selective, but 1-year-old chamise, desert ceanothus, California buckwheat, and Eastwood manzanita were browsed to ratings of 5 to 8 on a 0 to 10 scale, whereas their ratings in 5-year-old stands were 0 to 3. It appeared that goats concentrating on 1-year regrowth would graze all species more uniformly than they would older brush (*table 1*).

When 5-year-old brush regrowth was stocked with goats, herbage preferences were at once apparent. Leaves and tiny twigs were 90 to 95 percent removed from some species while others were untouched. With continued animal pressure, the less palatable species were taken—eventually almost as completely as the palatable species. This occurred where small pastures were used as holding pens at night.

In Colorado pastures in which the gambel oak (*Quercus gambelii* Nutt.) brush had been cut, goats eliminated regrowth in 4 years, but in control pastures, much of the uncut brush grew out of the goats' reach (Davis and others 1975).

In the early 1900's the Forest Service arranged with a goat operator to place goats on the Lassen National Forest in northeastern California, on mature manzanita-dominated brushfields. Neither the goat owner nor the Forest Service was satisfied with the effort to control the mature brush, and the attempt was terminated during the second season (Hatton 1913). On the Cleveland National Forest in 1974, about 5 acres (2 ha) of mature brush was fenced as a holding pasture. The goats were taken elsewhere during the day, but at night they gradually worked through the dense brush and opened it up considerably. Both on the Lassen and Cleveland Forests, kid crops were reduced when browsing mature brush.

After considering South African experience with goats, Dutoit (1972) suggested that goats should not be regarded as brush-clearing agents, that goats cannot destroy mature brush without damage to the environment, but that they can effectively check reversion to brush after initial clearing.

Plants consume energy during production of new growth, but once growth is mostly completed for the year, food storage takes place in roots, stems, and seeds. If the objective of goat browsing is to destroy woody plants, they must be continuously or intermittently browsed so that green leaves cannot accumulate. As new growth is repeatedly browsed away, food reserves are depleted and the shrub eventually dies. Carbohydrate levels in shrubs are low at about the full leaf stage in late spring, and later, after late summer regrowth (Jones and Laude 1960).

In Colorado, at least two defoliations per year for 4 years were necessary to kill 95 percent of gambel oak regrowth (Davis and others 1975). Shinoak (*Quercus havardii Rydb., Q. mohriana* Buckl., *Q. undulata* Torr.) in west Texas was killed in 3 years with two to three defoliations per year. In northern California, Sampson (1944) suggested keeping the area continuously stocked to the full capacity of the browse for 3 to 5 years. In the central Sierra Nevada foothills, small interior live oak plants were killed during 2 years of heavy continuous browsing. Live oak plants with larger root systems were killed in 3 years, although occasional plants sprouted weakly into the fourth or later years. Toyon (*Heteromeles arbutifolia* M. Roem.) was less closely browsed than interior live oak at first, but it was also mostly killed in 3 years. In southern California, after two seasons of repeated heavy browsing, small plants of the favored mountain mahogany and the slightly less favored scrub oak were dead. Goats were not placed in these pastures the third year, but a third year of heavy browsing would have killed much of the brush.

Herding and Fencing

Whether to herd goats or fence them for control is a rather troublesome question in southern California. Knowledgeable opinion and some experience support each position.

Those who favor herding goats claim a lower initial investment, great flexibility in planning and execution of plans, good protection against predators, slightly less environmental/visual impact, and a more fitting pastoral image of biological control.

Among the negative aspects of herding are the difficulty in achieving desired levels of vegetation control because the goats seek better feed before control of all species meets fire

management standards, and the need for skilled, dedicated herders with well-trained dogs to keep the band together and to prevent losses. Such skills are in short supply, and costly. Futhermore, herding without supplementary fencing is expensive for the herd owner and active herding interferes with the kid-nanny relationship and can lead to kid losses.

To keep the goats within bounds with fences, it is necessary to use net fence or special electric fence. Most ranges or pastures fenced for cattle have fences consisting of three to five, usually four, barbed wires. These are adequate for cattle, but they will not confine goats—particularly if feed is not to the goats' liking. In Amador and Calaveras Counties, the center of California's goat industry, the recommendation is for woven wire net fence with 6- by 12-inch (15- by 30-cm) mesh. A barbed wire is placed below and one or two above the mesh. A minimum of 48 inches (1.2 m) total height is suggested. The reason for the 6- by 12-inch mesh specification is that goats sometimes push their heads through the fence as they reach for browse on the outside. With the square mesh typical of hogwire mesh, goats cannot retract their heads, especially if they have horns, but they frequently can extract themselves from the 6- by 12-inch mesh by turning their heads sidewise.

Those who favor fencing rather than herding for control maintain that fencing simplifies the herding. If just one side of a fuelbreak is fenced, the herder's work is reduced by half or more. With dogs, the herder can readily control the herd from the unfenced side. Fencing allows the most natural movement of the goats possible, within the confines of the fence. And it makes possible the confinement of goats until all shrub species are browsed to meet management's objectives.

The negative aspects of fencing are primarily related to costs. A relatively high initial cost investment is required. Goat fence (40-inch [1-m] net wire and two barbed wires) would cost about $1600 per mile ($994/km) for materials alone. Installation costs would be greater than on a mostly level, rock free, accessible site. Another negative aspect is the undesirable visual effect of fencing.

Water and Supplemental Feeding

Supplying water to goats on fuelbreaks can be an irksome and expensive chore. Fuelbreaks are frequently on ridgetops or other dry and remote areas, where water may not be available, especially during dry years. Goats on the Cleveland National Forest, in southern California, consumed about a gallon (3.8 *l*) per day each during hot weather after herbaceous feed was dry.

Water can be provided in three basic ways:

- Truck hauling from a well, spring, or reservoir to where the band is working. This usually requires upslope hauling over rough, truck-trail type roads. It can consume a large proportion of a person's day, and requires a mechanically sound truck, well-maintained and with heavy suspension. Hauls of greater than 2 to 3 miles (3 to 5 km) should probably be avoided in planning unless the roads are good. The cost of hauling water falls most heavily upon the herd owner.

- Development of a spring, reservoir, or well in the area to be worked is a preferable method if a suitable site exists, access for needed equipment is available, and the area is planned for yearly use, or the water developed can be used for other purposes on a continuing basis. The cost of this method could be shared between the herd owner and the benefiting landowner, by agreement. The inducement for the herd owner is the prospect of eliminating or greatly shortening the hauling job.
- Piping water in from an existing source is an option that is controlled by several factors. The elevational difference between source and use area should allow water to be delivered by gravity or at least pumping costs should be low. Each change from upslope to downslope, or vice versa, requires expensive valves to either release air in the line or to allow draining of the system to prevent freezing. Funds for investment in engineering, materials, and a pumping mechanism (windmill or electric pump) must be available. And the need for the water must be on a continuing basis. The incentives for landowner and herd owner are about the same for this choice as for onsite development described earlier.

No one formula is available for determining which of three methods is best in any situation, nor are there any "standard" costs for each method because of the many variables involved. Detailed analysis of alternatives and their costs and benefits should be made while the goat project is in its earliest stage, because water availability is often the most expensive and limiting factor.

Another important consideration in maintaining a goat herd is supplemental feeding. Supplementing the annual range type has long been practiced during fall and winter when feed was not nutritionally adequate for livestock. It appears to be a desirable practice for goats on chaparral ranges. Pregnant animals particularly need to have supplemental feeding. Feeding before kidding increases the mothering instinct, the kid size at birth, the milk supply for the kid, and the size of the kid crop (Spurlock and others 1978).

Feeds used as supplements can be any livestock feed available, such as alfalfa hay, or whatever can be purchased most advantageously. Alfalfa cubes at about 3/8 pound (0.17 kg) per day per head, or 1/4 pound (0.11 kg) cottonseed meal, or grains at 1/4 to 1/3 pound (0.11 to 0.15 kg) per day can be fed (Groff 1973, Spurlock and others 1978). Cottonseed cake and whole corn were fed at times to goats on the Cleveland National Forest during 1978-79.

We do not recommend using goats to control mature brush but if the goats are supplemented while browsing

mature brush, they are less inclined to break through fences in search of better feed.

Other Considerations

In addition to the problems of herding, fencing, and supplying water, other problems associated with managing goats in mountainous areas include these:

- Roads are usually not good, and can be rendered impassable by snowfall or heavy rains. Scheduling of mountain operations in southern California should usually be set for the period April 15 to November 15. At other times, uncertainty increases as to road conditions. In northern California, the dates may be May 15 to October 15, and shorter at the higher elevations.
- Rough, steep, rocky terrain takes a toll on herders, dogs, and horses that is unknown in lowland agricultural areas. The herding efficiency may be greatly reduced because of the difficulty of traversing steep slopes. Dogs, horses, and people have become injured or lame for various periods due to these terrain conditions. Herders must learn to adjust their methods and approaches to the job in order to succeed in the mountains. Strategic fencing is often part of the success formula, allowing less legwork for all.
- Wide diurnal temperature fluctuations (15° to 85° F [−10° to 29° C]) or low temperatures associated with storm fronts may occur in spring and fall, causing hardship or death to kids (when chill factors are too low) and discomfort to herders.
- The general remoteness of most fuelbreak areas from people, stores, and the amenities of life imposes a strong psychological burden to most people who try goat herding. These conditions will continue to severely limit the number of people available for managing goats in the mountains. Yet, there are people who have a cultural background consistent with both the work required and the remote conditions in which it is done.

GOATS AND THE ENVIRONMENT

Competition with Wildlife

Much has been made in some quarters about the prospect of goats out-competing native wildlife species for food and territory. While it is true that goats and mule deer (for instance) have similar diet preferences, several factors tend to mitigate the effects of this competition:

- Few wildland goat operations are active in the State. We estimate that less than 2000 goats are on public land in California. This small number is due primarily to marginal economics caused by high interest rates, mountain conditions, and uncertain markets. This situation will change gradually. Consequently, there is time—in our judgment—to determine desirable areas and carrying-capacity relationships for a planned approach to greater use of goats.
- The use of goats to control brush regrowth, in areas where there are insufficient populations of browsing wildlife species to do so (anywhere in the chaparral), actually benefits the wildlife in two ways: (a) Brush areas, rather than reverting to closed brush stands, are kept open so desirable forbs, grasses, and brush sprouts can grow. (b) Water developments for seasonal goat use become sources of water for wildlife.

Although further research is needed on competition between goats and wildlife, we have concluded that a well-managed operation can contribute to the attainment of wildlife habitat objectives as well as range and fire control objectives. The habits and diet of the goat *per se* are not a threat to wildlife. Intelligent management, or the lack of it, is the factor that determines whether the results reflect an ecosystem improved for wildlife.

Damage to Native Plants

Concern has been expressed that goats will decimate native plant species—particularly rare plants. On the Cleveland National Forest, rare plants were inventoried before goats were brought in. Where such plants were found, goats were excluded by fencing or herding. Another concern expressed has to do with shifts in species composition resulting from the use of goats. Shifts are inevitable but the key point is whether they are desirable within the context of land management objectives, or whether they are uncontrolled. Goats on the Cleveland National Forest have contributed to a change, as an area was converted from brush to a brush-grass or to grass association. This species shift is clearly desirable and, having been well managed, allows all uses to proceed in relative harmony.

Losses to Cold Weather

Goats in southern California have been lost to cold, stormy weather, flooding, predators, and accidents. Losses during unfavorable weather have been most damaging. Goats cannot withstand wet weather that is accompanied by freezing or near freezing temperatures. Such losses started in our goats even before they came to the Cleveland National Forest. The goats had been held on a small ranch near Goleta, California. Brush was mostly too high for the goats to browse, and they were thin, emaciated, and in no condition to withstand stress. The kids were born during January, and 250 were lost to cold weather (Hughes 1976).

On March 12, 1976, 435 nannies, billies, and kids from the Goleta ranch arrived on the Descanso Ranger District, Cleveland National Forest, at about 4000 ft (1220 m) elevation. During the second week of April, on Monday, a storm dropped snow and rain, and the cold continued over 4 days. Nineteen kids and 8 nannies died even though the herder's trailer home was filled with kids. On Friday, there was snow and sleet for 1/2 hour, and 20 to 30 kids whose mothers had died or had left them had to be bottle fed. Some of these died.

A tropical storm caused intense rainstorms in Mexico and into San Diego County on August 13, 1976. Ten goats drowned in a flooded creek, and 24 carcasses were found in the brush later. In early October, three more goats died during stormy weather. The total 1976 weather-related death loss on the Cleveland National Forest stood at not less than 30 adults and 61 kids when the goats were moved to a lower elevation off-forest wintering area.

Later, in 1979, the second owner of goats on the Cleveland National Forest had a kid crop reduced to about 70 percent, mostly by cold weather-related losses.

In 1975, a prospective permittee for the Bureau of Land Management, U.S. Department of Interior, near Redding, California, imported 500 Angora goats. They arrived during a cold October storm and were trailed 3 or 4 miles (4.8 or 6.4 km) through the brush. A few died during the trailing, but around 100 died from pneumonia or other respiratory disease during the next few days (Walker 1975).

An especially critical time for Angoras is immediately after shearing. This is normally done twice yearly, so there is a hazardous period in both spring and fall. The newborn kids are always sensitive to cold, and shelter must be provided for them.

On the Cleveland National Forest, it was necessary to establish a low elevation wintering area. The site selected contained a brushy canyon with large rock outcrops that would help protect against wind. About 200 open, 50 gallon (190 *l*) oil drums were dug in slightly among the brush and rocks so that mothers with kids could escape wind and rain. This appeared to be a simple, effective way to protect young goats from adverse weather. The goats were herded and bedded outside this area during good weather, and the special protection was used only during severe storms.

Losses to Predators

Predators of sheep and goats include coyotes, dogs, bobcats, and mountain lions. Coyotes were the primary predators of sheep and accounted for 82 percent of predator losses; dogs caused 14 percent of the losses; and all other predators, including eagles, lions, and bobcats, accounted for 4 percent (Anonymous 1976). No such figures for goats are available, but goat losses due to predators are probably similar to those of sheep (Pearson and Caroline 1981).

Coyotes in south Texas were primarily responsible for reducing an Angora kid crop to 13.5 percent, even with partial predator control. Coyotes selected the youngest, smallest kids before older kids, and older kids before nannies. Predation on nannies in pastures with no predator control began immediately after kids were eliminated (Guthery and Beasom 1978). Lambs were taken first by coyotes in a California study, then the ewes (Connolly and others 1976).

Predator losses in southern California were not excessive as long as the goats were guarded by dogs and a herder who had access to a gun. One nanny was killed by a bear which was then shot by the herder. Coyotes were always around. We could often hear them as the goats were taken out to graze during the morning or afternoon, and the coyotes sometimes vocalized at night. Herders told of individual coyotes stalking the herd for 2 or 3 days at a time. One goat, tethered near a herder's trailer, was killed by a coyote during the day. Two or three goats that managed to stray away from the main herd when a new truckload was being unloaded were killed by coyotes before they could be rounded up. Goats occasionally got caught in the net wire fence, and if not released soon, were preyed upon by bobcats as well as coyotes. A young nanny, 1 of 15 in a flock, was attacked by a coyote and killed while rounding a corner on a jeep trail in midday. A herder, but no dogs, was in attendance.

Mountain lions were a vexing problem near Goleta, California, where they killed about 100 goats during a 3½-month period (Hughes 1976). Personnel at the Kern River Wildlife Sanctuary, Onyx, California, scared away a lion after it had killed one nanny. Domestic dogs were reported by herders to be more and more of a problem as they were closer to population centers. On the north central Texas Grand Prairie rangelands, death losses after weaning were 8 to 13 percent. A large part of the losses was credited to dogs (MaGee 1957). Goats in southern California were occasionally bitten by rattlesnakes, and there were infrequent losses from snake bites.

Losses to Poisonous Plants

Goats are much less common on the Western Range than are sheep or cattle, consequently, information about the reaction of goats to poison plants is scant. Poison plants are generally less palatable than other plant species and are usually eaten only when livestock are hungry. But with goats sometimes forced to eat shrub species of low palatability, poison plants could cause losses.

While checking a Los Angeles County canyon as a possible site for goat browsing, we found five plants that have caused livestock losses—tree tobacco (*Nicotiana glauca* Grah.), Jimsen weed (*Datura meteloides* A. DC.), cocklebur (*Xanthium strumarium* L. var. *canadensis* [Mill.] T. & G.), a shrubby nightshade (*Solanum* sp.), and groundsel or senecio (*Senecio* sp.).

Tree tobacco has long been recognized as a plant potentially poisonous to all classes of livestock (Los Angeles County Livestock Department 1938, Sampson and Malmsten 1942). Tree tobacco has also caused congenital deformities in calves when the mothers were fed dried, ground tree tobacco during the first third of gestation (Keeler 1979). The young leaves and stems are the most dangerous parts of the plant, and they are readily available in canyon bottoms and disturbed sites in southern California. Fortunately, they are distasteful to goats. On parts of Catalina Island that are heavily browsed by goats, tree tobacco was utilized only when other forage was severely depleted, and then only sparingly (Coblentz 1977).

Seeds and young leaves of Jimsen weed usually do the poisoning if this plant is eaten to excess, but all parts of the plant are dangerous. The burs or seeds of the cocklebur are highly toxic, and the poisonous alkaloids are concentrated in the cotyledons and first true leaves as the seed germinates (Los Angeles County Livestock Department 1938, Sampson and Malmsten 1942).

The woody nightshade we observed, probably Douglas black nightshade (*Solanum douglasii* Dunal), is suspected of poisoning livestock, but this may be partly because of its close botanical relationship with the annual black nightshade (*Solanum nigrum* L.). *Senecios* have been troublesome on the Western Range, and species growing east of the Sierra Nevada Mountains are more frequently reported as causing losses than Senecios growing in California.

Plants that Sampson and Malmsten (1942) report as having caused goat losses in California are black nightshade, laurels and azaleas (*Leucothroe, Rhododendron, Kalmia,* and *Menziesia*), loco weeds (*Astragalus* sp.), and poison hemlock (*Conium maculatum* L.).

Death camas (*Zygadenus* sp.) grows from a bulb, to a height of 2 ft, and has been a serious cause of range sheep losses during early spring. The onion-like leaves of star or chaparral death camas (*Z. fremontii* Torr.) often appear on burned-over chaparral areas before other herbaceous plants. It should be considered poisonous to goats.

In Texas, goats were reported to eat some plants with impunity that cause illness or economic loss to cattle. For example, goats there appeared unsusceptible to most of the nightshades, and they were less susceptible than cattle to *Senecio*, oak, and larkspur (*Delphenium*) (Dollahite 1972).

ECONOMIC RETURNS FROM GOAT MANAGEMENT

The main obstacle to general use of goats on fuelbreaks has been the inability of herd owners to show an economic return. Several reasons account for this condition:

- Operators have been livestock traders rather than local ranchers, and have made some mistakes that ranchers experienced in the area would not have made. Examples of these errors include insufficient supplementing during the winter, insufficient protection during cold, wet weather, and insufficient protection against disease.
- The inability to get financing for an economic unit. Bankers are reluctant to loan money on an operation that they do not understand, especially when potential profits do not appear great enough to pay the current high interest rates. However, many of the costs of running a few hundred goats are not much greater if the flock is 1500 or more, a flock size we believe should be minimum.
- The market for goat meat is somewhat uncertain, seasonal, and decentralized, although for several years, mohair has sold for $4 to $7 per pound ($8.80 to $15.40/kg), depending on hair quality and current demand.

Subsidizing Herd Owners

Despite these obstacles, both land managers with fuelbreaks to maintain and herd owners with goats to feed continue to seek ways to make the idea work. From the land manager's standpoint, fuelbreak maintenance costs of from $20 to $200 per acre ($50 to $500/ha) for other methods are too high. Many managers feel that a subsidy to the herd owner would be cheaper, and also be more environmentally acceptable than equipment or herbicides.

Subsidies can take several forms, including no charge for natural feed; developing water near areas to be worked; providing fencing material and labor; and paying a direct fee under contract for providing goats.

When considering the amount and kind of subsidy that can be afforded, the land manager must consider costs of alternatives and allow a factor for uncertainty. Thus, if the cheapest method were prescribed fire at $18 per acre ($45/ha), the manager might be able to justify an expenditure of $10 to $15 per acre ($25 to $37/ha) as a goat subsidy. The "hold-back" of $3 to $8 represents the cost of a risk that the goat operation will not meet objectives.

Marketing Goats

Several markets in Texas routinely handle goats (Groff 1973), but San Antonio and Los Angeles are the major markets (Dollahite 1972). In California, kids or adult goats can often be marketed on the ranch, or by consignment through local slaughterhouses. Advertisements in local papers and visits to labor camps will attract buyers (Spurlock and others 1978). In 1980, buyers from Mexico offered to purchase the goats being removed from San Clemente Island (Allen 1980).

Demand for young goats is considerable at Christmas and Easter, and a demand for goats is widespread among people of Hispanic and other Mediterranean origin. Goat for barbecuing is becoming more popular with other groups. Young goats are sold as "cabrito," and meat from more mature goats as "chevon." Meat from old animals is commonly used for sausage (Dollahite 1972).

In California, November and December is the best time to sell goats, and spring a good time to buy, according to the owner of goats on the Cleveland National Forest during 1978-79. Spotted or mottled goats are most sought after by buyers, whereas brown or white are the "worst sellers" (Beene 1979).

REFERENCES

Allen, Carl G. [Personal conversation with Lisle R. Green] 1980 August 3.

Anonymous. **Coyote is chief predator.** Calif. Agric. 30(7):11; 1976 July.

Askins, Gary D.; Turner, Everett E. **A behavioral study of Angora goats on west Texas range.** J. Range Manage. 25(2):82-87; 1972 March.

Aucamp, A. J. **Convert bush problem into meat production.** Die Boerbok. Supplement to Landbouweekblad 41:10-12; 1975 October 17. [Transl. from Afrikaans].

Batten, G. J. **Controlling scrubweeds with goats.** New Zealand J. Agric. 32(4);31-32. 1979 October.

Beasom, Samuel L. **Dietary overlap between cattle, domestic sheep, and pronghorns.** In: Sosebee, Ronald E.; Guthery, Fred S., eds. Noxious brush and weed control research highlights—1980. Vol. 11. Lubbock, TX: Texas Tech. Univ.; 1980:40-41.

Beene, Rocky [Personal conversation with Lisle R. Green] 1979 May 29.

Brotherhood of the Sun. **Goat grazing on the Caliente allotment.** Typewritten. 1974 February. 3 p. Located at Pacific Southwest Forest and Range Experiment Station, Riverside, CA.

Bryant, F. C.; Kothmann, M. M.; Merrill, L. B. **Diets of sheep, Angora goats, Spanish goats and white-tailed deer under excellent range conditions.** J. Range Manage. 32(6):412-417; 1979 November.

Calvopina, L. H.; De Vries, T. **Structure of the population of wild goats (*Capra hircus*) and damage caused to the vegetation on the Island of San Salvador, Galapagos.** For. Abstr. 40(7):2193; 1979 July.

Campbell, Q. P.; Ebersohn, J. P.; Von Broembsen, H. H. **Browsing by goats and its effect on the vegetation.** Herb. Abstr. 32(4):273-275; 1962 December.

Coblentz, Bruce E. **Wild goats of Santa Catalina.** Nat. Hist. 85(6):70-77; 1976 June-July.

Coblentz, Bruce E. **Some range relationships of feral goats on Santa Catalina Island, California.** J. Range Manage. 30(6):415-419; 1977 November.

Coblentz, Bruce E. **Effects of feral goats on the Santa Catalina Island ecosystem.** Power, Dennis M., ed. The California Islands: Proceedings of a multidisciplinary symposium; 1978 Feb 27-Mar 1, Santa Barbara, CA.: Santa Barbara Mus. Nat. Hist.; 1980:167-170.

Connolly, Guy E.; Timm, Robert M.; Howard, Walter E.; Longhurst, William M. **Sheep killing behavior of captive coyotes.** J. Wildl. Manage. 40(3):400-407; 1976 July.

Davis, Gary G.; Bartel, Laurence E.; Cook, C. Wayne. **Control of gambel oak sprouts by goats.** J. Range Manage. 28(3):216-218; 1975 May.

Dollahite, J. W. **Spanish goats have what it takes.** College Station, TX: Texas A&M Univ., Agric. Ext. Serv., Texas Agric. Progr. 18(3):21-23; 1972 Summer.

Dutoit, P. F. **The goat in a bush-grass community.** Proceedings of the 7th Grassl. Soc. of S. Africa. 1972; (44-50)

Elam, F. Leland. **Goats cleared our brush.** West. Livest. J. 30:37, 46, 51, 55; 1952 July 15.

Fraps, G. S.; Cory, V. L. **Composition and utilization of range vegetation of Sutton and Edwards Counties.** Bull. 586, College Station, TX. Texas Agric. Exp. Stn. 1940. 39 p.

Green, Lisle R.; Wagnon, K. A.; Bentley, J. R. **Diet and grazing habits of steers on foothill range fertilized with sulfur.** J. Range Manage. 11(5):221-227; 1958 September.

Green, Lisle R. **Fuelbreaks and other fuel modification for wildland fire control.** Agric. Handb. 499. Washington, DC: U.S. Department of Agriculture; 1977. 79 p.

Green, Lisle R.; Hughes, Catherine L.; Graves, Walter L. **Goat control of brush regrowth on southern California fuelbreaks.** Hyder, Donald N. ed. Proceedings of the 1st Int. Rangeland Congr; 1978 August 14-18; Denver, CO. Denver, Colorado Society for Range Management; 1978; 451-455.

Groff, Jack L. **Keys to meat-type goat production.** Fact Sheet L-934. College Station, TX: Texas Agric. Ext. Serv., 1973. 4 p.

Guthery, Fred S.; Beasom, Samuel L. **Effects of predator control on Angora goat survival in south Texas.** J. Range. Manage. 31(3):168-173; 1978 May.

Hatton, John H. **Eradication of chaparral by goat grazing.** In: Review of Forest Service Investigations, Vol. II Grazing Investigations. Susanville, CA: Lassen National Forest, Forest Service, U.S. Department of Agriculture; 1913; 25-28.

Hughes, Catherine L. **First annual report on using goats to control brush regrowth.** San Diego, CA: Cleveland National Forest, Forest Service, U.S. Department of Agriculture; 1976; 87 p.

Huss, Donald L. **Goat response to use of shrubs as forage.** In: Mckell, Cyrus M.; Blaisdell, James P.; Goodin, Joe R. eds. Wildland shrubs—their biology and utilization. Gen. Tech. Rep. INT-1. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1972; 331-338.

Jones, Milton B.; Laude, Horton M. **Relationships between sprouting in chamise and the physiological condition of the plant.** J. Range Manage. 13(5):210-214; 1960 September.

Keeler, Richard F. **Congenital defects in calves from maternal ingestion of *Nicotiana glauca* of high anabasine content.** Clin. Toxicol. 15(4):417-426; 1979.

Larson, Jan, Staff Civil Engineer, Naval Air Station, San Diego, CA. [Telephone conversation with Lisle R. Green]. January 1981.

Los Angeles County Livestock Department. **Poisonous and injurious plants of Los Angeles County.** Los Angeles, CA: Los Angeles County Livestock Department; 1938. 27 p.

MaGee, A. C. **Goats pay for clearing Grand Prairie Rangelands.** MP-206. College Station, TX. Texas Agric. Exp. Stn.; 1957 May. 9 p.

Malechek, John C.; Leinweber, C. L. **Forage selectivity by goats on lightly and heavily grazed ranges.** J. Range Manage. 25(2):105-111; 1972 March.

Merrill, Leo B. **The role of goats in biological control of brush.** Beef Cattle Sci. Handb. 12:372-376; 1975.

Merrill, Leo B.; Taylor, Charles A. **Take note of the versatile goat.** Rangeman's J. 3(3):74-76; 1976 June.

Minnich, Richard A. **Vegetation of Santa Cruz and Santa Catalina Islands.** In: Power, Dennis M., ed. The California Islands: Proceedings of a multidisciplinary symposium; 1978, Feb 27-Mar 1. Santa Barbara, CA. Santa Barbara, CA: Santa Barbara Mus. Nat. Hist.; 1980; 123-137.

Murphy, Alfred H.; Leonard, Oliver A.; Torrell, Donald T. **Chaparral shrub control as influenced by grazing, herbicides, and fire.** Down to Earth 31(3):1-8; 1975 Winter.

Naveh, A. **The role of shrubs and shrub ecosystems in present and future Mediterranean land use.** In: Mckell, Cyrus M; Blaisdell, James

P; Goodin, Joe R. eds. Wildland shrubs—their biology and utilization. Gen. Tech. Rep. INT-1. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1972; 414-427.

Pearson, Erwin W.; Caroline, Milton. **Predator control in relation to livestock losses in central Texas.** J. Range Manage. 34(6):435-441; 1981 November.

Plaister, Robert E.; Dal Porto, Norman. **Angora goats for foothill brush areas.** Amador County, CA: Calif. Agric. Ext. Serv.; 1973. 13 p.

Plumb, T. R. **Sprouting of chaparral by December after a wildfire in July.** Tech. Paper 57. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1961. 12 p.

Raven, Peter H. **A flora of San Clemente Island, California.** Aliso 5(3):289-347; 1963 April 15.

Sampson, Arthur W. **Plant succession on burned chaparral lands in northern California.** Bull. 685. Berkeley, CA: Calif. Agric. Exp. Stn.; 1944. 143 p.

Sampson, Arthur W.; Malmsten, Harry E. **Stock-poisoning plants of California.** Bull. 593. Berkeley, CA: Calif. Agric. Exp. Stn. 1942. 90 p.

Sidahmed, Ahmed E.; Morris, J. G.; Radosevich, S. R. **Summer diet of Spanish goats grazing chaparral.** J. Range Manage. 34(1):33-35; 1981 January.

Sidahmed, Ahmed E.; Radosevich, Steven R.; Morris, James G.; Koong, Ling J. **Nutritive value of chaparral for goats grazing in fuelbreaks.** Calif. Agric. 36 (5 and 6): 12-14, 24; 1982 May-June.

Spatz, Gunter; Mueller-Dombois, Dieter. **The influence of feral goats on Koa tree reproduction in Hawaii.** Volcanoes National Park. Ecology 54(4):870-876; 1973 August.

Spurlock, G. M.; Plaister, Robert; Graves, Walter L.; Adams, Theodore E.; Bushnell, Robert. **Goats for California brushland.** Coop. Agric. Ext., Univ. of Calif. CP-321-100. Berkeley, CA. Cooperative Extension, Univ. of Calif. 1978. 24 p.

Taylor, Charles, Jr. **Spanish versus Angora in controlling brush.** Presentation at the Spanish Goat Conference, San Angelo, TX. Texas A&M Res. and Ext. Center. 1975 September.

Trollope, W. S. W. **Role of fire in preventing bush encroachment in the eastern Cape.** Proceedings of the 9th Grassl. Soc. of South Africa; 1974; 67-72.

Van Dyne, G. M.; Heady, H. F. **Botanical composition of sheep and cattle diets on a mature annual range.** Hilgardia 36(13):465-492; 1965 September.

Vries, T. De. **How the hunting of goats affected the vegetation on the islands of Santa Fe and Pinta, Galapagos.** For. Abstr. 40(7):2195; July 1979.

Vries, T. De.; Calvopina, L. H. **Role of goats in vegetation changes on the island of San Salvador, Galapagos.** For. Abstr. 40(7):2194; July 1979.

Wagnon, Kenneth A. **Behavior of beef cows on a California Range.** Bull. 799. Berkeley CA: Calif. Agric. Exp. Stn. 1963. 58 p.

Walker, Robert [Telephone conversation with Lisle R. Green] 1975 December.

Wilson, A. D. **A review of browse in the nutrition of grazing animals.** J. Range Manage. 22(1):23-28; 1969 January.

Wilson, A. D.; Weir, W. C.; Torell, D. T. **Evaluation of chamise (*Adenostoma fasciculatum*) and interior live oak (*Quercus wislizenii*) as feed for sheep.** J. Animal Sci. 32(5):1042-1045; 1971.

Green, Lisle R.; Newell, Leonard A. **Using goats to control brush regrowth on fuelbreaks.** Gen. Tech. Rep. PSW-59. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982. 13 p.

On fuelbreaks, herbicides have been the primary tool for controlling brush regrowth. Vegetation of low volume and low growth is maintained on these wide strips as an aid to firefighting safety. Goats are a promising alternative to herbicides, and may be the best tool available for controlling brush regrowth on fuelbreaks. They eat a wider variety of plants, and more woody plants, than other livestock. They are less selective on first-year brush regrowth, and more selective as brush is older. Goats should not be expected to control tall, mature brush. A good strategy is sufficient goats to eat all leaves from all brush species two or three times per year. Spanish goats are probably a better choice than Angoras for rough moutainous areas. Wethers have some advantages over a breeding herd, but may require more subsidy. Problems to solve when goats are acquired include road access during wet weather, fencing, herding, water and supplemental feeding, protection from predators, disease, and poison plants.

Retrieval Terms: Angora, brush control, chaparral management, diet of goats, fuelbreaks, goat losses, predators, Spanish goats, wethers