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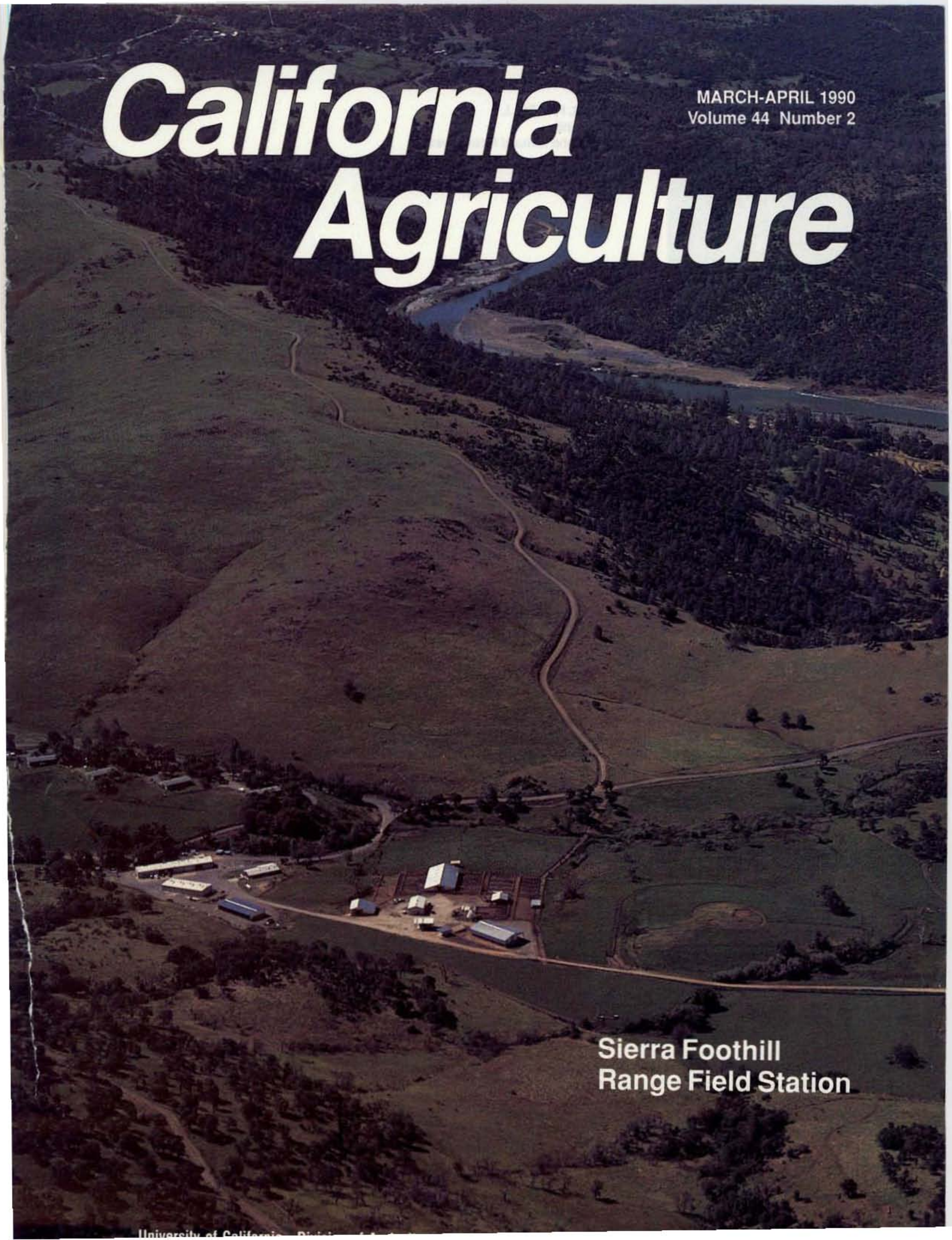

Sierra Foothill
Range Field Station

University of California

KENNETH R. FARRELL
Vice President
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Research and extension centers: vital link in the flow of knowledge

No state in the nation has a more diverse, well developed agricultural economy than does California, growing more than 250 commodities from almonds to zucchini. Nor does any state face more complex technological problems in agriculture, natural resources, and the environment. To help find answers to these problems, the University of California maintains a diverse, sophisticated system of field research facilities.

An integral part of UC's Division of Agriculture and Natural Resources, the nine distinctive agricultural research and extension centers are strategically situated throughout the state. At one extreme is the Tulelake center, 4,000 feet high, on the Oregon border. In the chilly interior mountains, Tulelake can experience frost any month of the year. South by 700 miles, the Imperial Valley center sits below sea level near the Mexican border, where 120-degree temperatures are routine during the summer. The nine centers combined constitute a $6 million program to help maintain the state's economic and environmental well-being.

Commonly known as "field stations," the system of research and extension centers provides a vital link in the flow of new knowledge from campus to commercial application.

Most of the basic agricultural research is conducted on the University's campuses at Berkeley, Davis, and Riverside. But some campus departments also station faculty at the centers. Other faculty, plus Cooperative Extension specialists from the three campuses, and county Cooperative Extension advisors, travel to the centers to conduct hundreds of applied research experiments each year. Through this lab-to-field linkage, basic research findings are tested, adapted, and applied to each region's unique soils, climate, and other ecological and production conditions. The result has been a steady flow of new information and technology to enhance agricultural productivity and management of natural resources for the benefit of farmers and Californians at large.

The centers are thus an integral, essential part of the UC research and extension system:

- Tulelake is in the town of the same name in Siskiyou County. It focuses on small grains, potatoes, and onions, important crops in the mountainous northeastern region. One of its creations is California's horseradish industry, the brainchild of a Tulelake researcher searching for a good cash crop for local farmers. The Tulelake center was the site for testing "ice minus," a genetically engineered bacterium developed at the UC Berkeley campus to enhance frost resistance in plants.
- Sierra Foothill, in the Sierra Nevada foothills near Browns Valley, is a center for research in cattle breeding, range management, and protection of the state's natural lands. The station is celebrating its 30th anniversary this year (see related articles in this issue).
- Hopland, 100 miles north of San Francisco, encompasses coastal foothills and valleys. Work focuses on sheep breeding, plus range improvement, watershed management, and wildlife enhancement, where the center's 5,300 acres allow large-scale natural resource research to be conducted.
- Deciduous Fruit center in San Jose, at age 70, is in a highly populous, urban area. Its 17 acres are surrounded by concentrated commercial development that overwhelmed virtually all of its agricultural neighbors. Yet important work at the center is still conducted in fruits, flowers, vegetables, and strawberries.
- West Side, one of three San Joaquin Valley stations, is noted for cotton research, along with studies in fruit, vegetables, and nut crops. Work at West Side has led to advances in drip irrigation and salinity management, with important findings for growers in the region.
- Kearney, 20 miles southeast of Fresno in Parlier, is the home of numerous varieties of table and wine grapes, tree fruits, including dwarf varieties, and many rare crops. Last year the University dedicated a $5 million research building at Kearney. It is our largest off-campus research facility, with 25 permanent academic research staff. Now funds are being raised for a postharvest research building that offers the promise of important benefits to agriculture.
- Lindcove, a few miles east of Exeter, is situated on the first rise of Sierra slopes from the San Joaquin Valley. Lindcove plays an essential role in citrus research. On its grounds is maintained the Citrus Clonal Protection Program, a priceless repository of more than 400 carefully selected parent trees that form the basis for much of California's citrus industry.
- South Coast, near Santa Ana, is a leading site for citrus, and pest and disease management research. The center is the home of many of the new high-yielding strawberry varieties released by the University. Landscape, turfgrass, and ornamentals are other important research foci of the center.
- Imperial Valley, near El Centro, is the University's low desert research site. Established in 1911, it is California's oldest station still in use. Vegetable and grain crops are important research concerns, along with cattle management and irrigation. Last December the University dedicated a new research and office building for Imperial County Cooperative Extension staff at the center.

With a diversity that matches California's own, the agricultural research and extension centers play an important role in the state's prosperity. As we move into the 21st century, the economic and environmental concerns facing agriculture are enormous and complicated. New knowledge holds the key to dealing with most of those problems. The centers will continue to contribute to development of that knowledge through their unique and irreplaceable role in the University of California's research-extension continuum.

In this issue:

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Jack Kelly Clark

Always popular with visitors, the field station in its foothill setting is the site of research on range and pasture improvement, livestock production, and management of natural resources. Doug McCreary (in checked shirt at left) explains his work on regeneration of native oaks to students on a field trip. Above, sprinklers irrigate a newly planted research pasture.

Sierra Foothill Range Field Station

Much of the research on beef cattle at the Sierra Foothill center focuses on management of cow-calf operations. This cow and her twin calves were part of a study of the use of the embryo transfer technique to increase twinning as a possible means of improving production efficiency.

Thirty years of research: an overview

Charles A. Raguse ❑ Gary A. Beall ❑ John L. Hull ❑ Douglas McCreary ❑ Charles B. Wilson

The Sierra Foothill Range Field Station, the youngest in a statewide network of nine University of California field stations and research centers, is approaching its 30th birthday. Operated by the UC Division of Agriculture and Natural Resources, the station was established June 1, 1960, when the University acquired two large parcels of land near Browns Valley in Yuba County.

The station soon became an important field laboratory for research to support livestock and agronomic productivity of foothill rangelands. Over the years, new research dimensions—management of open spaces, watersheds, hardwoods, and wildlife—have been added to accommodate increasing public concern about management of renewable natural resources.

The station's 5,700 acres range in elevation from less than 300 feet along the scenic Yuba River to nearly 2,000 feet in steep, woodland-brush foothills. The climate, soils, rough terrain, and variety of vegetation types are representative of several million acres of California foothill rangelands.

This report gives an overview of the research program at the station over the last 30 years and complements the following eight companion articles, which discuss current research projects. Additional information about the research and other programs is available from John M. (Mike) Connor, Station Superintendent, Sierra Foothill Range Field Station, P.O. Box 28, Browns Valley, California 95918. Telephone: (916) 639-2501.

Range and pasture development

Range improvement at the station began with chemical treatment of blue oaks, and several major land parcels were control-burned within a few years. Reseeding, with and without phosphorus and sulfur fertilization, and chemical control of stump sprouts followed the burning. Later, vegetation-type conversions combined harvesting trees for wood, brush piling, and stump resprout control. Water delivery systems for irrigated pastures were improved.

The first agronomic research focused on the adaptation of subterranean and rose clover varieties and an inventory of resident herbaceous vegetation.

Difficulties encountered in attempting to introduce new plants into such a highly disturbed and dynamic ecosystem resulted in at least a decade of research devoted to stand establishment. Chemicals were used to suppress stump sprouting, suppress competition of resident species against those of newly introduced species, and suppress or eliminate aggressive populations of weedy species that thrived in these highly disturbed and open areas.

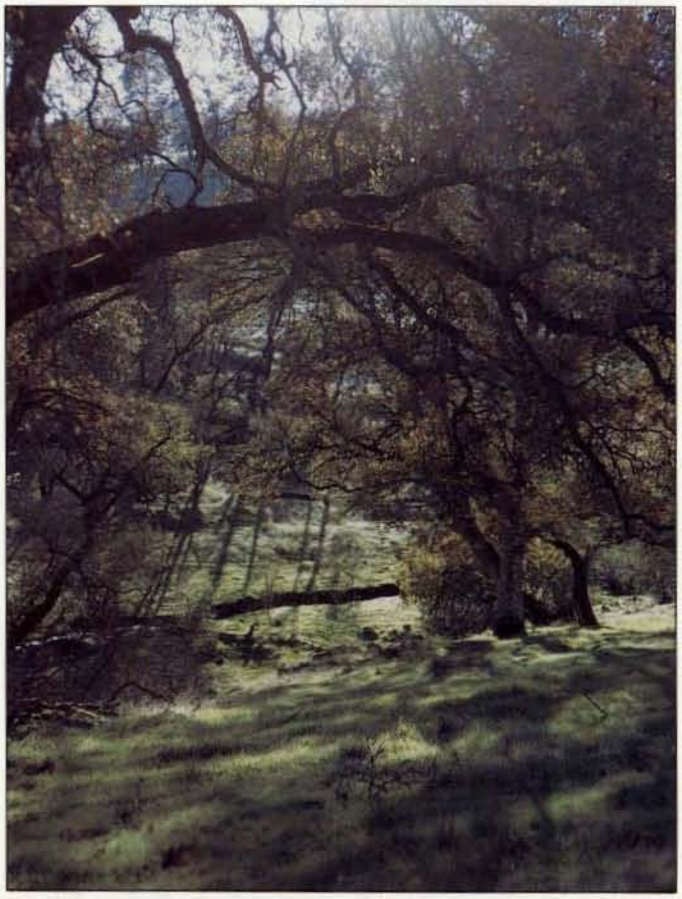
Chemical sprays were combined with seeding equipment designed for operation on rough land. A highly successful technique involved applying a 12-inch band of contact herbicide on germinated and growing resident vegetation while a series of rolling discs and coulters placed seed and fertilizer in mineral soil beneath new growth and plant litter from the previous year. This technique was refined when research showed that spraying a band of activated carbon directly over the planted seed reduced the effect of the herbicide on seedling growth.

Several range and pasture improvement studies looked at the influence of ecological factors on rangeland productivity. In 1963 a series of fenced plots containing new plant introductions and several fertilizer treatments were installed to sample the effect of slope, soil type, and elevation on plant growth. A more sophisticated study using small sensors to determine the influence of slope direction on sunlight received, temperature, and soil moisture found that light is the most important determinant of plant growth differences between north- and south-facing slopes. Two other studies measured condensation of transpirational water by shrub species and seasonal variations in the rate of soil weathering.

On cleared foothill rangelands, dried cow manure can be very slow to decompose, preventing grass from growing over the area it covers. Attempts to introduce Australian dung-burying beetles to break down the dried manure and, at the same time improve soil fertility by burying the manure, were not effective. The beetles were not able to adapt and become established in large enough numbers to have an impact.

Erratic results in a study of rate and time of application of phosphorus and sulfur on clover yield led to additional soil sampling that identified nematode infestation as a contributing factor.

Other rangeland fertilization studies have shown that phosphorus and sulfur are needed if introduced legumes are to do well. These findings were verified by a 3-year, whole-field grazing experiment concluded in 1985.



With terrain and climate representative of the northern California foothills, the station provides excellent conditions for studies of native oak woodlands, watersheds, and wildlife.


Mike Connor

Studies of beef cattle on oak woodland range are concerned with a variety of problems related to herd management, nutrition, and health.

Warm-season perennial grasses are being evaluated in small plots for use in foothill irrigated pastures. At harvest, Placer-Nevada County Farm Advisor Roger Ingram weighs samples to determine production weights.

Studies on seed reserves of range forage species done between 1974 and 1977 include effects of 2 years of drought and an unusual midsummer rain. The drought reduced seed reserves drastically but did not change species composition. Few germinable seeds were carried over from year to year, and only a few species (soft chess, filaree, and rose and sub clovers) showed an ability to germinate during the hot summer.

Control of weedy species in recent years has focused on starthistle and Medusahead. Both have virtually no forage value and compete with beneficial plants. Proper timing of close grazing shows some promise for managing these species.

The management option of applying water to winter annual pastures (rangeland) in late summer or early fall was assessed in a small-plot experiment. Irrigation could produce 0.5 to 1 ton of additional high-quality forage per acre for fall and winter use by livestock without reducing spring growth potential.

In addition to range improvement studies with the important annual legumes, subterranean and rose clovers, attention was given to annual medics, especially after it became apparent that the indigenous burr clover was being eliminated by infestations of the alfalfa weevil. Annual lupines, hardinggrass, and orchard-grass also were studied. Results suggest that a combination of sub and rose clovers was better suited to the wide range of foothill environmental and management conditions than most other species, including the summer-dormant perennial grasses.

More recent evaluations of warm-season perennial grasses, including many Great Plains and Desert Southwest species never before tested under California foothill conditions, produced dry matter yields of up to 4.5 tons per acre on clipped plots in summer irrigated pastures. A companion study showed that several cultivars of bermudagrass and limpograss were more palatable to cattle than the other introductions, but none approached the acceptability of orchardgrass and dallisgrass, generally considered to be an invasive, weedy species.

A long-term study comparing results of blue oak tree removal on forage production indicated increased forage production from tree removal in all but 3 of the first 15 years of the study. Beyond 17 years, however, there was no increase in forage production. After 21 years of data collection, researchers concluded that results were influenced by weather-year differences, especially amount and distribution of precipitation; the number of trees per unit area; canopy extent and density; release of nutrients from decomposing litter and tree roots following tree treatment and removal; and nutrient redistribution resulting from livestock congregating under trees. Regeneration of oak sprouts from untreated stumps replaced much of the original cover, but there was complete absence of regeneration from acorns over the full 23-year study period.

Livestock health and management

Range experiments with beef cattle have focused primarily on management problems associated with year-round cow-calf operations in the Sierra foothills. The first livestock project compared the performance and carcass traits of crossbred Hereford, Angus, and Shorthorn calves with calves of their respective parental breeds. The results helped establish the now common practice of crossbreeding to take advantage of hybrid vigor, mothering ability, and special economic advantages of new breeds.

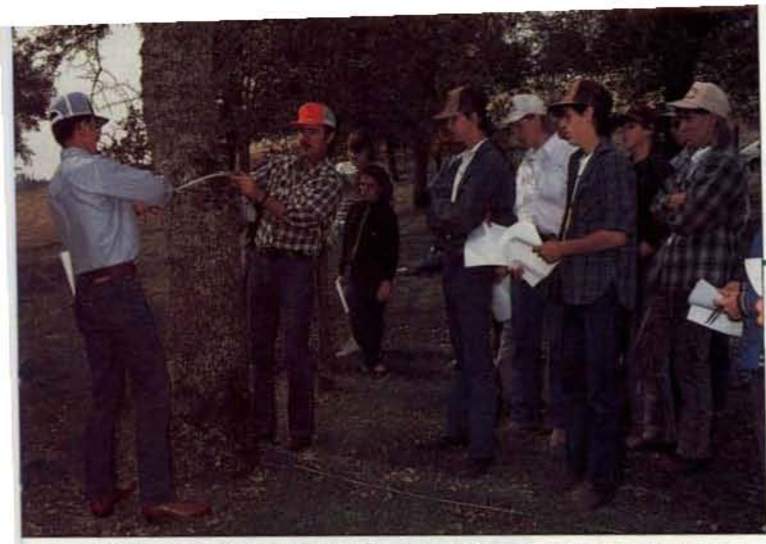
Evaluation of spring and fall calving supports a fall calving system for the Sierra foothills. Research on early weaning of calves showed that the advantages of early weaning (less supplement for the cows and earlier rebreeding) were overshadowed by the disadvantages (increased labor and more disease problems among the calves).

Other research highlighted stress-related breeding problems in range herds, especially when artificial insemination is used. Twice daily observations for estrus detection and the training of observers were emphasized as critical for a successful breeding program. Studies also have clearly shown the advantages of libido tests (servicing capacity) and annual examinations of bulls by a veterinarian before the breeding season.

Studies of year-round cow-calf production with and without seasonal irrigated pasture to supplement the cows' diets showed that irrigated pasture can be used where available, but returns to investment are low. Fertilizing rangeland with nitrogen, phosphorus-sulfur, or nitrogen-phosphorus-sulfur significantly increased forage production and steer liveweight gains per acre and per head.

A major concern with cow-calf enterprises in the foothills is light weaning weight of the calves, especially when heifer calves are kept for replacements and bred to calve as 2-year-olds. Grazing management studies indicated that, although irrigated pasture provides a good growing diet, energy-protein supplementation will economically increase average daily gain over energy supplementation only. Adding monensin sodium to the supplement and using growth-promoting implants at weaning are also recommended.

Epizootic bovine abortion (EBA) studies showed that the abortions result from a disease agent transmitted by the Pajaroello tick. Further research revealed that (1) cows are most susceptible to EBA when they are bitten by the tick during the third to sixth month of pregnancy, and (2) immunity is acquired when non-pregnant 2-



Jack Kelly Clark

Station Superintendent Mike Connor and Extension Natural Resources Specialist Doug McCreary measure tree diameter in a demonstration of stand evaluation techniques to a group of students.

year-old heifers are exposed to the tick. Changing from spring to fall calving in northern areas and calving in September rather than November in warmer areas of California also are effective management practices to prevent exposure to the tick during the critical stages of pregnancy.

Early studies showed that supplementing range cows with nutrients in which the forage is deficient and that are limiting for animal production can increase calf gains and may enhance rebreeding. Recent supplementation studies with protein and energy, however, produced significant responses only for rebreeding of first-calf heifers. Because of the economics involved, supplemental feeding of calves (creep-feeding) on nonsupplemented cows is the only practice that can be recommended from these experiments.

Research on internal parasites has examined seasonal patterns of buildup in beef cattle grazing foothill pastures and the response of the immune system to internal parasite loads. Guidelines were developed for more precise scheduling of available treatment preparations, and coordination of treatment with seasonal changes in pasture use.

Studies also have been done on ear tags for face fly control, selenium supplementation, pinkeye control, energy expenditure by beef steers grazing annual grassland, the development of a method to measure individual cow consumption of supplements, and electronic recording of range cow grazing and rumination behavior.

Trials continue in the areas of cow-calf management, herd health, nutrition, and grazing management.

Natural resource management

During the last decade, station research has diversified, and wildlife, forestry, soils, and watershed management form an important component of current activities.

An extensive wildlife monitoring project during the last 3 years has provided information about species abundance and use and how population levels change from season to season. Such information is vital to understanding current wildlife resources, and it can also be used to help predict how certain vegetation management practices or events (tree or brush removal, fire, or seeding of legumes) will affect wildlife populations in the future. Other wildlife projects have had a more specific focus. For instance, several have examined California quail, including one evaluating social behavior, organization, and reproductive success. Another is examining the effects of brush pile size and loft on use by quail.

The problem of poor oak regeneration is being studied extensively. Some projects are examining factors responsible for poor natural regeneration. Others are evaluating techniques for successfully growing and planting acorns and seedlings. Information from these studies has clarified some of the principal obstacles to successful seedling establishment. It has also provided practical guidelines for artificially regenerating native oaks.

Non-native hardwoods, including eucalyptus and hybrid poplar, are being studied to determine their growth rates and sensitivity to cold. Results will help determine the feasibility of biomass production in the foothills.

Since a third of California consists of rangelands, range management practices can potentially have a large impact on water yield and quality. Research in this area has focused on the effects of rangeland vegetation management on nutrients released to streams, erosion, and changes in water yield. A current study is examining nutrient dynamics among plants, water, and soils in intensively managed hardwood rangelands.

Teaching and public service

The station's teaching activities divide into three categories: class visits and tours; student internships; and student research.

Student interns from northern California colleges and universities, usually partially supported by local or state beef cattle associations, spend a school semester or quarter in residence at the station. They gain practical experience by assisting in cattle management as well as performing field work and data management tasks for various range and livestock research projects.

Results of station research are extended to growers, producers, and the general public through field days, meetings, tours, and onsite visits. The station has provided resources for training farm advisors and professionals from other universities and agencies. It also is popular with foreign visitors.

Conclusions and a forward look

For the last 30 years, the Sierra Foothill Range Field Station has been an invaluable outdoor laboratory, classroom, and demonstration facility. Research findings have traveled around the world, frequently through the wide distribution of *California Agriculture.* The station will continue to serve society as research, teaching, and outreach evolve in response to changes in the broad geographical area it represents.

Major contributions can be made to environmental quality through studies of multiple-use management of hardwood rangelands and oak woodlands, water use and quality relationships, and restoration ecology. Current concepts of stability and sustainability in Central Valley cropping systems also have applications in rangeland and pasture production and management.

Long-term research programs with multiple disciplines and objectives, patterned after the National Science Foundation concept of long-term ecological research (LTER), can dramatically expand the value and application of individual studies. Available communications technology and the network of Cooperative Extension advisors, together with representatives of other state and federal agencies, can make the rapid transfer of information to and from the public a reality.

The station, as part of the UC agricultural field station system, thus is well positioned to meet the challenges of the years ahead.

Charles A. Raguse is Professor, Department of Agronomy and Range Science; Gary A. Beall is Communications Specialist, Division of Agriculture and Natural Resources; and John L. Hull is Specialist, Department of Animal Science, all with the University of California, Davis. Douglas McCreary is Extension Natural Resources Specialist, Department of Forestry and Resource Management, UC Berkeley, stationed at the Sierra Foothill Range Field Station; Charles B. Wilson is Farm Advisor and County Director, Cooperative Extension, Sutter and Yuba counties.

Update on short-duration grazing study on irrigated pasture

Kenneth L. Taggard ❑ Charles A. Raguse ❑ Melvin R. George
John L. Hull ❑ Cynthia Daley ❑ J. M. Connor

Short-duration, or intensive, grazing systems require monitoring of the pastures to ensure an appropriate stocking rate. Researchers above are examining the regrowth of irrigated pasture plants in a study paddock.

Two-year results showed similar responses to two levels of pasture accumulation-grazing utilization management. Orchardgrass height and capacitance probe readings were both useful in monitoring forage availability, but stocking rate predictions using grass height were less variable and change in grass height during grazing was more closely related to seasonal liveweight gain.

If short-duration grazing systems are to be successful, the pastures must be intensively managed and closely monitored to prevent overgrazing or understocking. The manager must determine the optimum time to start grazing, the appropriate stocking rate and length of grazing time, and the number of days needed for pasture regrowth between grazing cycles.

Knowledge of the growth-regrowth pattern of a set of paddocks in a pasture allows the manager to rotate the animals, selecting paddocks with optimum height or weight of forage available for grazing needs. We have previously described the "S-shaped" (sigmoid) regrowth curve common to most grazed forages (*California Agriculture*, July-August 1989). Plant regrowth is slow at the bottom of the curve, increases rapidly as plants become taller (middle of the curve), and slows at the top of the curve as plants mature. Pasture quality and palatability changes also occur over this growth sequence.

The 2-year study reported here involved two management approaches. The "high accumulation-moderate utilization" (high A-U) approach used start and stop grazing points higher on the regrowth curve than did "low accumulation-high utilization" (low A-U) management. We used orchardgrass heights to define the conditions of low or high accumulation-utilization (table 1). Stocking rates were selected to use available forage between these "in" and "out" heights over a 3-day grazing period.

The study was conducted in a research irrigated pasture at the Sierra Foothill Range Field Station. Details of pasture field and paddock layout, design of the grazing experiment, and irrigation management were given in the previous report. These conditions were kept constant over the 2 years.

In 1988, ten paddocks each were assigned to the high and low A-U treatments for the grazing experiment, which began June 1 of each year. Just before the treatments started, the paddocks were maintenance-grazed so that grazing of paddock one would begin at the desired in-height.

The animals were rotated through the paddocks at a stocking rate that would remove forage to the desired orchardgrass out-height in 3 days We used the number of paddocks in the rotation that would allow forage regrowth to reach the target in-height by the start of the next cycle. In 1988, only eight paddocks were needed to give the desired regrowth. In 1989 ten paddocks were used during cycles 2 and 3 of the four-cycle season; cycle 4 was terminated at eight paddocks because of early fall rains.

We used a stocking rate estimator based on the total animal unit (1,000 pounds of body weight equivalent) days per acre inch of forage removed (AUD/IFR) in a 3-day grazing period. By trial and error during the first year, we developed an AUD/IFR of

TABLE 1. Basis for treatments

Year and A-U treatment	Orchardgrass Height in	Orchardgrass Height out
	inches	
1988		
High	10-12	4-6
Low	6-8	3-4
1989		
High	12	6
Low	10	4

7.5. The stocking rate was estimated as follows:

Predicted IFR = predicted forage in-height (current height + [days to entry x height increment per day]) minus the target out-height [1]

Predicted AUD = IFR x 7.5/3 [2]

Since the average weight of the grazing animals differs from (above or below) 1,000 pounds, a correction factor (*a*) is required. The prediction equation for stocking rate for a 3-day grazing period then becomes:

Predicted stocking rate (SR) = IFR x 7.5/3 x *a* [3]

For example, for an average animal weight of 650 pounds and a target IFR of 6 inches, SR = 6 x 7.5/3 x 1.54 = 23 animals per acre.

The Gallegher single-probe capacitance meter was also used to estimate desired stocking rates. To convert the corrected meter reading (CMR) of the probe to forage weight, we used a pooled regression formula developed by Dr. Melvin George and student Marya Robbins (Y = [18.8 x CMR] + 380, where Y = forage pounds per acre). We then developed a stocking rate estimator for the probe based on AUD per 100 pounds weight of forage removed per acre (WFR). Intake equal to 3% of animal body weight was assumed. This estimator, 2.73 in both years, was used as follows:

Predicted WFR = predicted forage in-weight (current weight + [days to entry x weight increment per day]) minus the target out-weight. [4]

Predicted AUD = WFR x 2.73/3 [5]

Predicted SR = WFR x 2.73/3 x *a* [6]

Following the previous example (equation 3) and using estimated forage in- and out-weights of 5,000 and 3,300 lbs, SR = 17 x 2.73 / 3 x *a* = 24 animals per acre.

The between-species and between-plant variations in plant height and weight were minimized by monitoring only the uniformly distributed orchardgrass. A total of 40 heights and 200 probe readings were taken on permanent transects in each paddock before and after each paddock was grazed. We recognized that neither average whole-pasture height nor average whole-pasture forage weight was estimated by this technique, because it did not account for the variation attributable to low-growing clover or bare ground. Our objective was to compare the two indirect estimation techniques with minimum variation in how the data were collected.

The "tester-grazer" method was used to adjust stocking rate. Tester animals were maintained on the experiment throughout the grazing season; these were Hereford heifers in 1988 and English bred steers in 1989. The heifers' average initial weight was 450 pounds, with a final average weight at 96 days of 590 pounds. The steers' initial weight was 600 pounds, with a final average weight at 110 days of 710 pounds. The grazers were added and removed when necessary to increase or decrease consumptive demand to achieve the target out-heights at the end of a 3-day grazing period. The grazers maintained their A-U treatment identity throughout the experiment. Shrunk weights were taken at the beginning and end of the grazing season in 1988 and at the beginning, middle, and end in 1989. Liveweight gains per acre were calculated using tester average daily gain and grazing day totals obtained by adding grazing hours for all animals used.

Results

Botanical composition changes occurred during the three years after the pasture was planted (table 2). In the first year, pastures were legume-dominated (71%). Of the four major plant species, only perennial ryegrass percentages differed between A-U treatments. At the end of the first year's experiment, ladino clover had declined almost 30% and orchardgrass had increased by a corresponding amount. Ryegrass decreased from 10% to approximately 5% and other species increased from 1% to 3%. Ladino clover declined from 42% to 30% between September 1988 and March 1989.

A 5% increase in other species included a prominent increase in sour dock (*Rumex crispus* L.). This common irrigated pasture weed appeared in some of the paddocks in a pattern that suggested the seed was carried in by the irrigation water. Two of the irrigation blocks had a heavy infestation equally divided between both A-U treatments and spread uniformly throughout each paddock—that is, apparently unrelated to wet areas or poor drainage. On February 28, 1989, 2,4-D amine was uniformly applied on all paddocks at 0.75 pound active ingredient per acre to control the sour dock. This could have resulted in the further reduction in the ladino clover percentage at the end of the second year.

There was a significant decrease in the percentage of orchardgrass and a significant increase in other species in the low A-U treatment by September 1989. The latter probably resulted from the opening up of the stand as the legumes decreased with the combination of selective grazing and low target out-height—that is, heavy grazing pressure.

Grass height patterns were similar in both years. Except for cycle 1, when an unexplained interaction occurred, both monitoring methods responded similarly in 1989 (fig. 1). Either measured grass height or probe-estimated forage weight could be used to follow relative differences in forage accumulation and utilization over successive grazing cycles.

Animal unit days (AUD) per acre inch of forage removed (AUD/IFR) were nearly identical between A-U treatments in both years (table 3). However, the treatment average in 1989 (7.5) was higher than in 1988 (6.1). The average AUD/IFR for 1989 cycles 2 to 4 reflect a reduction in stocking rate made because of an overly high rate in cycle 1. The actual forage out-heights averaged 3.8 for the low A-U treatment and 5.5 for the high A-U treatment (very close to target) after this change.

The summary of AUD per 100 pounds per acre of forage removed (WFR) indicated by the single-probe capacitance meter shows high variability for 1988 (CVs of 22% and 27%) and for the high A-U treatment in 1989 (CV = 18%) (table 4). Across both years and treatments, the average CVs for AUD/IFR and AUD/WFR were 7.0 and 19.5, respectively, indicating higher variability with probe-estimated stocking rates. Probe-estimated averages for the two A-U treatments, however, were identical in 1989. This variability may have been caused in part by the partially reclining growth habit of orchardgrass. The taller plants had a higher percentage of leaves lying outside the area measured by the probe. This variability might be reduced by taking a larger number of probe readings per transect sample.

TABLE 2. Botanical composition averaged for eight paddocks in the high and low accumulation-utilization treatments

Treatment	Orchard-grass	Perennial ryegrass	Ladino clover	Strawberry clover	Other species◊
			%		
September 1987 (pre-experiment)					
High	19	7 *	71	1	1
Low	17	12	69	2	1
Mean	18	10	70	1	1
September 1988 (post-experiment)					
High	51	5	40	1	4
Low	47	5	44	1	4
Mean	49	5	42	1	3
March 1989					
High	51	10	30	1	8
Low	53	9	30	1	8
Mean	52	10	30	1	8
September 1989 (post-experiment)					
High	63 *	6	19	1	8 *
Low	54	5	20	1	14 §
Mean	59	5	20	1	11

* Values for high and low treatment differ at $p < 0.05$.
◊ Other species include other pasture species and weeds.
§ Dallisgrass made up 5% for the low and 4% for the high of the other species.

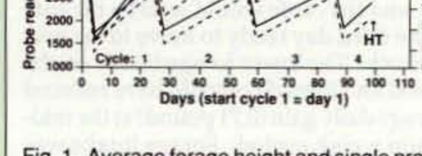


Fig. 1. Average forage height and single probe capacitance meter readings over four cycles for two accumulation-utilization treatments showed both monitoring methods responding similarly in 1989.

TABLE 3. Summary of AUD per acre inch forage removed (AUD/IFR) during 3-day grazing cycle and high and low A-U treatments

	AUD/acre inch forage removed					
	1988			1989		
Cycle	High	Low	Average	High	Low	Average
1	5.7	6.9	6.3	8.0	8.6	8.3
2	6.1	6.6	6.4	6.5	6.7	6.6
3	5.8	6.0	5.9	7.1	7.2	7.2
4	6.0	5.7	5.9	7.7	7.8	7.8
Average	5.9	6.3	6.1	7.3	7.6	7.5
CV %	3	8		8	9	

NOTE: Each value is the average of eight paddocks in 1988, and eight paddocks for cycles 1 and 4 and ten paddocks for cycles 2 and 3 in 1989. Cycle 1 began on June 1 in both years, and cycle 4 ended on Sept. 5, 1988, and Sept. 18, 1989.

TABLE 4. Summary of AUD per 100 pounds of forage per acre removed (AUD/WFR) during 3-day grazing cycle and high and low A-U treatments

	AUD/100 pounds forage removed					
	1988			1989		
Cycle	High	Low	Average	High	Low	Average
1	1.5	1.5	1.5	1.8	2.0	1.9
2	2.1	3.0	2.6	2.7	2.1	2.4
3	1.9	1.8	1.9	1.9	1.9	1.9
4	1.2	2.0	1.6	2.7	2.6	2.6
Average	1.7	2.1	1.9	2.3	2.2	2.2
CV %	22	27		18	11	

TABLE 5. Animal unit months (AUM) and liveweight gain per acre (LG) for four grazing cycles

	AUM		LG	
Cycle	1988	1989	1988	1989
			lb/acre	
Low A-U				
1	2.5	2.7	200 *	117
2	2.0	1.7	195	80 (79)¶
3	1.2	1.5	108	66 (68)
4	1.3	1.6	111	71
Total	7.0	7.5	614§	334
High A-U				
1	2.0	2.6	164 †	112
2	1.8	1.5	168	72 (70)
3	1.2	1.3	108	60 (61)
4	1.1	1.5	94	65
Total	6.1	6.9	533	308

* Based on a seasonal average daily gain of 1.44 lb. in 1988 and 0.96 lb. in 1989.
† Based on a seasonal average daily gain of 1.40 lb. in 1988 and 0.96 lb. in 1989.
§ Total LG are significantly different for low and high A-U treatments.
¶ Average of 10 fields/cycle for cycle 2 and 3.

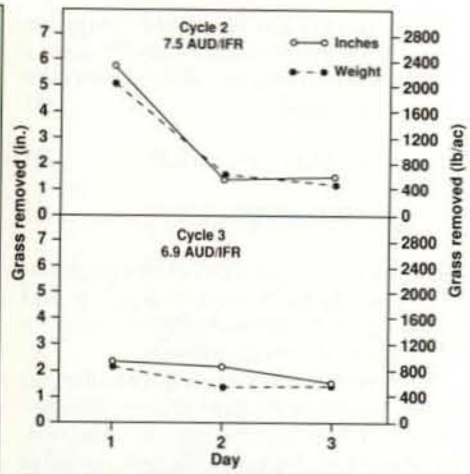


Fig. 2. At the higher AUD/IFR (animal unit days per acre inch of forage removed) values, up to two-thirds of the forage was removed on the first day. Daily forage removal was more evenly distributed at the lower AUD/IFR.

At the higher AUD/IFR value, up to two-thirds of the forage was removed on the first day, and the cattle would wait by the gate on the third day ready to move to the new paddock. The lower forage intake on the second and third days could have reduced average daily gain (0.71 pound) at the mid-season weigh period. Forage intake was more evenly distributed after the AUD/IFR was lowered (fig. 2), and this may be reflected in the higher average daily gain (1.1 pounds) obtained in cycles 3 and 4. Obviously, there also was more total forage available in cycle 2 than in cycle 3 (fig. 2).

Comparison of pasture probe and height measurement techniques in estimating the stocking rate needed to properly graze the paddocks for 3 days showed the height measurement to be more accurate and consistent. The CVs for the height measurement were lower in 1989 than in 1988 and the actual out-heights were very close to target. Even though the accumulation-utilization patterns in figure 1 are similar for height and probe values, the required stocking rates predicted by the probe were more variable and averaged 22% lower than those predicted by grass height. On occasion, the probe-predicted stocking rates were much lower than those predicted by grass height.

Animal unit months obtained were calculated for each grazing cycle and for the season for both years. Liveweight gains per acre were calculated using tester animal average daily gain and tester plus grazer AUD (table 5). The low A-U treatment used 11 and 18 testers and high A-U treatment used 12 and 15 testers in 1988 and 1989, respectively. Numerically, the low A-U treatment was stocked 15% higher than the high A-U treatment in 1988. In 1989 this difference was 9%. Similarly, liveweight gain was a significant 15% higher in 1988 and a nonsignificant 8% in 1989. Liveweight gain in 1989 averaged 56% of that in 1988, in part because of the low average daily gain in 1989 (1.0 pound) for both A-U treatments. Stocking rates in 1989 averaged 110% of those in 1988. The lower 1989 liveweight gain probably resulted from the loss of legumes and an increase in pasture open area. Thus, in 1989, grazing pressure was higher (than in 1988) and available forage probably was less nutritious.

Conclusions

Within each year, average daily gains were nearly identical in the two forage accumulation-utilization treatments. The low accumulation-high utilization treatment resulted in higher animal weight gains per acre in both years, but the difference was not statistically significant in 1989. A lower liveweight gain per acre in 1989 resulted from a reduction in legume content and a lower forage availability. Overall, both A-U treatments probably were on the low to middle region of the regrowth curve.

The use of higher stocking rates typical for short-duration grazing and an initially patchy distribution of legume and grass created very heavy selective pressure against the legumes, which were additionally stressed by the herbicide used to control sour dock. Dallisgrass and other weedy, summer-growing annual grasses were prominent invaders in the second year.

Both the single-probe capacitance meter and orchardgrass heights adequately followed forage availability changes over the 3-day grazing and 21- or 27-day regrowth periods. The probe was less useful in predicting required stocking rates and was less well related to animal liveweight gain than was the case for orchardgrass heights. It should be borne in mind that our monitoring methods differed from those used by others.

Where pasture entry forage levels are moderate to high, the 3-day utilization profiles suggest that stocking for a 2- or even 1-day grazing period could be more efficient.

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Managing bovine pinkeye in beef calves

Lisle W. George

Two field studies showed that a widespread pinkeye epidemic in a herd can be effectively treated with injections of long-acting oxytetracycline, followed by feeding the antibiotic in the ration. When the disease is less prevalent, injecting affected animals with penicillin or oxytetracycline is effective.

Bovine pinkeye is one of the most economically important infectious diseases of beef cattle in the United States. A recent survey of 2,000 American cattle producers has shown pinkeye to be overwhelmingly considered the most troubling disease in their cattle. Annual losses to the disease in the United States have been estimated at $20 million. Because of the ocular pain and the poor vision, calves do not eat properly and fail to thrive. One feedlot study demonstrated 260-day post-weaning depressions of 35 and 47 pounds in calves that had pinkeye in one or both eyes, respectively. Other pinkeye-related losses include the cost of antibiotics and the labor required to administer drug treatments.

During an outbreak of pinkeye, as many as 45% of yearling calves become infected and develop painful corneal ulceration. In approximately half of the cases, the ulcers enlarge, encompass the entire corneal surface and cause blindness. Most corneal ulcers usually heal by 45 days, but about 1% of them perforate, resulting in loss of the vitreous body and eventually producing a small, shrunken, nonfunctional eye. Blind calves are difficult to move and often are discriminated against when they are sold at auction.

Pinkeye is caused by the bacterium *Moraxella bovis*. The bacterium is highly susceptible to antibiotics and is easily eliminated from the eye tissues by three to four daily subconjunctival injections of penicillin. However, the disease often attacks a large number of susceptible animals within a herd and tends to recur frequently over the entire summer grazing season. Gathering a large number of affected calves from the pasture and injecting drugs is difficult. If done improperly, the treatment itself could damage the eye. Failure to disinfect the hands and equipment between animals could foster the transmission of the bacterium to normal eyes. Also, local ophthalmic treatment of affected cattle does nothing for the infected cattle without symptoms that act as reservoirs for the bacterial infection. Studies were therefore conducted to identify alternative methods of drug treatment for bovine pinkeye.

Pinkeye treatment studies

Initial studies investigated a long-acting formulation of oxytetracycline (LA-200). Calves were experimentally infected and then treated at the peak of clinical signs 7 to 14 days later. The treatment consisted of an intramuscular injection of the long-acting formulation into the muscles of the rear leg. The drug was administered at a dose of 20 milligrams per kilogram (mg/kg) of body weight. A second dose was administered 72 hours later.

This treatment was highly effective in eliminating the bacterial infection and reducing clinical signs. A later study showed that selective distribution of the oxytetracycline to the epithelium of the conjunctiva and the cornea was primarily responsible for its effectiveness against *M. bovis*.

During the summers of 1985 and 1986, severe pinkeye outbreaks occurred in the cattle at the Sierra Foothill station. This natural occurrence of the disease provided an opportunity to examine the use of oxytetracycline in a true field situation.

The first of two separate studies compared the effectiveness of two intramuscular injections of the long-acting oxytetracycline formulation with that of furazolidone topical spray (Topazone). The study was conducted between June 13 and August 6.

At the beginning, 103 Hereford female calves (4 to 8 months of age) were assigned to one of three groups: oxytetracycline treated (OTC), furazolidone treated (FZ), and not treated (control). Treatments consisted of two applications (20 mg/kg) of long-acting oxytetracycline two times at a 72-hour interval (OTC group), and three daily applications of furazolidone spray (FZ) group. Treatments were not administered again unless the ocular lesions worsened, the ulcer healed and then recurred, or the opposite eye developed a corneal ulcer.

The calves were examined three times weekly for signs of ocular inflammation. At the time of each examination, a clinical severity score was assigned to each eye, and

Pinkeye, an infectious bacterial disease in cattle, can cause a painful corneal ulcer that in some cases may lead to blindness.

eyes with corneal lesions were photographed. The surface area of each corneal ulcer was measured from the photographic image. Secretions from all of the eyes also were cultured weekly to determine whether the antibiotic treatment successfully eliminated *M. bovis*. Calves were weighed weekly to determine the effects of the drug therapy on weight gains. At the end of the study, all *M. bovis* isolates were tested for susceptibility to the tetracyclines and the nitrofurans.

Corneal ulcers occurred in 102 calves. By the 22nd day of the study, fewer calves in the OTC group had corneal ulcers than in the other two groups. OTC calves had the most rapid healing rate and the lowest incidence of multiple ulcer recurrences. The rate of *M. bovis* isolation from the eyes of this group was significantly less than from the other two groups. Calves in the FZ group had more severe ocular lesions and a greater number of multiple ulcer recurrences than the OTC group calves, but were significantly better off than the controls. The *M. bovis* from the OTC group did not become resistant to either furazolidone or tetracycline, whereas the *M. bovis* from the FZ group calves showed a slight increase in resistance to the nitrofurans.

The average weekly body weights and weight gains were similar for the three treatment groups. Despite the clear therapeutic effectiveness of oxytetracycline over that of furazolidone, a cost analysis of the treatments (including the labor required to gather the cattle and administer the drugs) indicated that the OTC treatment had the highest cost of the three groups.

The second study compared oxytetracycline and penicillin treatments. Beginning on June 10, 119 calves were randomly assigned to one of three groups: 39 designated as OTC, 40 Pen, and 40 nontreated controls. The calves were kept in a common pasture during the entire summer and were examined three times daily as in the first study.

Treatments were administered to the calves of the OTC and Pen groups after an initial 4-day observation period. Affected calves of the OTC group were given two intramuscular injections of the long-acting oxytetracycline formulation (20 mg/kg) 72 hours apart. All of the OTC calves then were fed 2 grams per head per day of oxytetracycline in alfalfa pellets for 10 days. Calves of the Pen group that had corneal ulcers were treated with three daily subconjunctival injections of procaine penicillin G (300,000 IU per injection). In both groups, treatments were administered to individual calves again if they developed a new corneal ulcer in either eye, or if the existing ulcer worsened. Calves of the control group remained untreated for the entire summer.

The prevalence of pinkeye was significantly reduced in the Pen and OTC groups within 12 days after treatment. OTC calves had significantly fewer ulcers than did calves of other two groups. Between days 16 and 44, the prevalence of pinkeye in the OTC calves ranged between 0 and 2 cases, whereas the penicillin-treated calves and controls ranged from 3 to 8 and 19 to 22 cases daily, respectively. Oxytetracycline and penicillin groups had significantly fewer active cases of pinkeye in individual calves than the controls. The two drugs were similar in effectiveness for the individual case. The healing times and average ulcer size for corresponding numbers of days after treatment were similar in the OTC and the Pen groups. The rate of *M. bovis* isolations from the eyes of the OTC group calves was significantly lower than that of the other two groups.

The results of the second study strongly suggest that a combination of "blitz" therapy with a long-acting formulation followed by short-term feeding of oxytetracycline effectively controlled an outbreak of pinkeye. Subconjunctival penicillin treatment, however, was as effective as the long-acting formulation for treatment of individual cases of pinkeye.

A cost/benefit analysis was not performed in this study, but the OTC calves gained an average of 6 pounds more than the controls did and 3 pounds more than the Pen group. Whether this increase in weight gain was sufficient to offset the high purchase cost of the oxytetracycline is unclear.

Conclusions

The findings of these studies suggest that, whenever the prevalence of pinkeye is low (less than 10%), the disease can be managed effectively by treating affected animals with three daily subconjunctival injections of procaine penicillin G (1 ml per injection). If there is significant difficulty in administering the drug into the ocular tissues, intramuscular injection of a long-acting oxytetracycline formulation (20 mg/kg) in two doses given 72 hours apart is also effective.

In a widespread epidemic of the disease where the prevalence exceeds 10% to 20%, or if it is desirable to minimize ocular scarring, the cattle should be "blitz" treated with long-acting oxytetracycline (two injections spaced 72 hours apart, 20 mg/kg per injection), and then fed oxytetracycline (2 grams per head daily for 10 days).

As with all infectious diseases, affected cattle should be removed from the clinically normal animals. Hands and equipment should be washed thoroughly in chlorhexidine solution after each affected animal is examined or treated.

Control of flies with insecticides delivered through backrubbers or dust bags is highly desirable.

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Supplements evaluated for wintering range calves

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In two range feeding trials to evaluate supplemental nitrogen and/or bypass protein source and stocking densities, calves at a low density gained more weight than high-density groups. Dollar return during the supplementation phase, however, was highest from high-density groups fed a combination of urea and corn gluten meal.

California annual rangeland forage is generally of poor quality in the fall and in short supply during the winter. During those periods, supplements are typically provided to wintering calves to correct nutrient deficiencies and improve performance, maintain health, and prevent death loss.

Supplemental nutrients may be provided in many forms, the most common being hay, meals, pellets, cubes, liquids, and blocks. Supplements are usually high in nonprotein nitrogen such as urea, which aids fiber digestion and microbial growth. In many situations, however, urea supplementation may not meet the protein requirements of growing calves. Dietary protein may be digested to a variable degree in the rumen or may be entirely degraded. Protein that is not digested in the rumen, called bypass or escape protein, passes to the lower tract and is either digested postrugluten meal combination gained more in both years than other treatments. Only in 1988-89 did urea treatment significantly improve performance over that of controls.

Monthly average daily gain results for the two stocking rates over all treatments (fig. 1) show more variation than those in table 3 (cumulative average daily gain) because of the short time between weigh periods. The high-stocking-rate groups had a lower average daily gain in both years. The yearly pattern was somewhat different, but in each year the difference between low and high stocking rate gradually increased through the season.

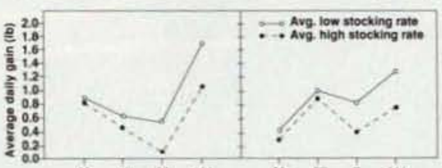


Fig. 1. In both years, average daily gain was higher at the low than the high stocking rate and gradually increased with each weigh period.

Results of overall performance and economic analysis of the trial by year (table 4) cover only the period of supplementation. Dollar return per acre favored the steers supplemented with the combination of urea plus corn gluten meal on the high stocking rate in both years.

Because of a drought in the 1987-88 feed year, the experimental animals were continued on supplements from February 24 to March 23, 1988, then shipped to the University of California, Davis, feedlot for finishing. Random subsets of each group were individually fed identical rations for feed intake, compensatory gain, and feed efficiency comparisons. The steers were fed to an estimated slaughter grade of low choice. The supplemental phase treatments had little influence on finishing phase gains (table 5).

In the 1988-89 trial, urea-supplemented calves gained significantly less than the other treatment groups during the nonsupplemental feeding period on spring range (table 6). Table 7 shows the overall performance of the steers during 1988-89. These figures cover only the nonsupplementation period.

Returns over supplement costs were higher per head for the low stocking rate fields because of higher average daily gains. Returns per acre, however, favored the higher stocking densities. Higher cumulative average daily gains resulted in higher returns in 1987-88 than in 1988-89. This result is due in part to differences in residual dry matter of the test fields at the onset of the trial.

Conclusions

In the two studies of stocking density and protein source in liquid supplements for weaned range calves, performance during the supplementation phase appeared to have little influence on gains during the nonsupplemental phase at feedlot. Steers in the low-stocking-density groups (one head per 5.33 acres) gained more weight than those in the high-stocking-density groups (one head per 2.67 acres) across all supplement treatments. As a result, groups at the lower stocking density returned more dollars per head. Dollar return per acre favored the high stocking density.

The high-density, urea-plus-bypass treatment provided the highest return per acre during the supplementation phase in both years. The cost of supplement used in this analysis does not consider labor expense.

TABLE 4. Performance and economics of supplementation

Supplement, stocking rate	ADG	Daily consumption	Supplement cost/head	Return: Over supplement	Return: Per acre
	lb	*lb*	*$*	*$*	*$*
1987-88					
Control					
High	0.50	—	—	48.45	18.15
Low	0.77	—	—	74.61	14.00
Urea					
High	0.56	1.41	10.93	43.33	16.23
Low	0.92	1.60	12.40	76.75	14.40
Bypass					
High	0.65	1.80	20.09	42.90	16.07
Low	0.91	1.96	21.88	66.30	12.44
Urea + bypass					
High	0.80	2.01	22.14	55.38	20.74
Low	1.11	2.05	22.58	84.98	15.94
1988-89					
Control					
High	0.34	—	—	32.30	12.10
Low	0.65	—	—	61.20	11.50
Urea					
High	0.55	1.62	12.30	40.00	14.80
Low	0.92	1.67	12.70	74.03	13.90
Bypass					
High	0.74	1.95	21.70	39.54	18.00
Low	0.91	1.86	20.70	65.13	12.20
Urea + bypass					
High	0.78	1.70	19.80	57.55	21.60
Low	1.13	1.91	22.20	84.03	15.80

NOTES: 1987-88, 114 days on supplement. 1988-89, 111 days on supplement. Calves valued at $85/cwt. Cost of supplement/ton: urea = $136.60; bypass = $195.80; urea + bypass = $193.20.

TABLE 5. March 23-June 14, 1988, performance in feedlot

Supplement, stocking rate	Weight: Initial	Weight: Final	Daily feed intake	Gain	ADG	Feed/ lb/gain
	lb/head	*lb/head*	*lb*	*lb/head*	*lb*	*lb*
Control						
High	583	879	27.4	296	3.57	7.68
Low	646	948	26.8	302	3.64	7.36
Urea						
High	610	882	25.9	272	3.28	7.90
Low	656	959	27.4	303	3.65	7.51
Bypass						
High	609	928	26.1	319	3.84	6.80
Low	676	957	27.5	281	3.39	8.11
Urea + bypass						
High	636	902	26.1	266	3.20	8.16
Low	658	975	27.8	317	3.82	7.28

TABLE 6. 1988-89 weight gain of steers post-supplementation

Treatment	Average daily gain 1988-89 3/22-5/18
	lb
Control	2.32 a
Urea	2.05 b
Bypass	2.40 a
Urea + bypass	2.29 a

* Means in the same column followed by different letters are significantly different (P<0.05).

TABLE 7. 1988-89 performance of the non-supplementation period (85 days average daily gain)

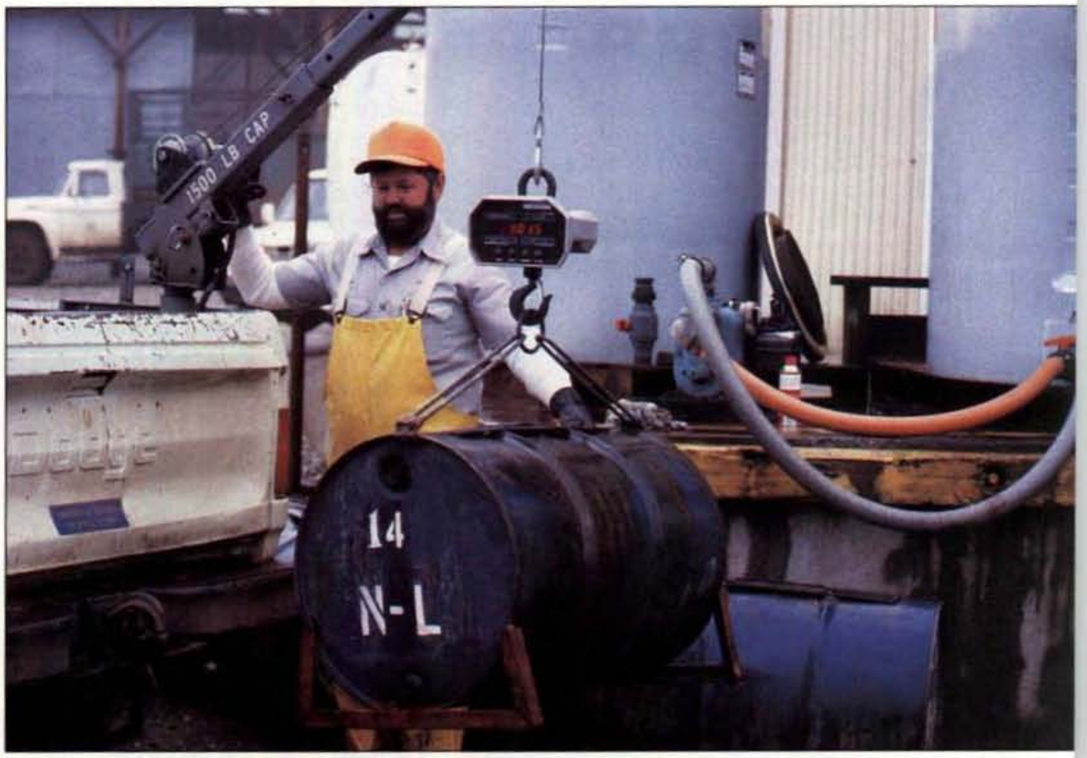
Supplement, stocking rate	Average daily gain	Gain
	lb	*lb*
Control		
High	2.15	183
Low	2.66	226
Urea		
High	1.99	169
Low	2.16	184
Bypass		
High	2.26	192
Low	2.47	210
Urea + bypass		
High	2.38	196
Low	2.13	181

minally or excreted in the feces. The supply of protein to the small intestine consists of the dietary protein that bypasses ruminal degradation plus the microbial protein synthesized within the rumen. Calves fed supplements that contain bypass protein may gain weight faster and more economically than those supplemented with urea.

Increased bypass protein, however, does not ensure increased animal growth, since: (1) microbial synthesis may provide adequate amino acids for growth; (2) bypass protein may be poorly digested in the small intestine; (3) the balance of amino acids in the postruminal protein may be poor; and (4) the energy supply or other nutrients may limit production.

In the past few years, liquid supplements have been based on urea and molasses. Now xanthin gums and clay are being used to suspend small particles such as minerals, natural protein supplements, and other desirable materials in liquid supplements.

We have been conducting studies to determine if steer calves would show a profitable growth response from supplemental nitrogen and/or bypass protein supplied during fall and winter growth of native range pasture. This report presents results from the first 2 years.



Technician Dave Labadie weighs supplement lick tank to measure consumption by calves.

Materials and methods

Liquid supplements were evaluated as potential sources of bypass protein in supplementation programs for stocker calves on annual grasslands at the UC Sierra Foothill Range Field Station. We used 144 head of English breed and English crossbred steers averaging about 500 pounds.

Commercially formulated liquid supplement (molasses based mixtures) containing (1) urea, (2) bypass protein, or (3) urea plus bypass protein were used in the study and compared with (4) unsupplemented controls. Based on previous research, corn gluten meal was selected to supply bypass protein. Each of the four treatments was administered at two levels of stocking density: 6 steers were randomly assigned to a low stocking rate (one head per 5.33 acres) and 12 steers to a high stocking density (one head per 2.67 acres).

The experimental area (512 acres of cleared range) was divided into 16 fields, grouped in 4 blocks of 4 fields per block. In defining the blocks, we attempted to group fields that were similar (based on results of previous trials) in forage production characteristics. Animals were then assigned to one of the eight treatment groups at random. There were two replications per treatment. Subsequently, each treatment was assigned to one of the 16 fields so that each treatment appeared twice in each block.

As the trial progressed, animals (and thus treatments) were moved each month from one field to another so that they repeated no blocks over the 4-month supplementation period. In this way, each animal was in all four blocks, and each treatment was exposed equally to the various types of range represented in the four blocks. Blocking the fields into groups of four made it possible for each block to contain each treatment in each year of the trial.

Supplement lick tanks were weighed weekly and consumption recorded. Animals were fed on rangelands, followed by finishing under feedlot conditions in 1987-88. At the end of the supplementation period in 1988-89, the experimental animals grazed on rangeland during the spring season. A portion of the data was statistically analyzed as outlined by SAS and a portion by CRUNCH.

Results and discussion

We have collected and analyzed 2 years of data. Consumption was lower during the first month on test and increased as animals became accustomed to the lick tanks (table 1). Consumption was lower in urea-supplemented steers than in the other two groups in 1987-88, but there were no significant differences among groups in 1988-89.

Stocking density had no effect on supplement consumption in either 1987-88 or 1988-89. However, stocking density did affect average daily gain (table 2).

The overall performance (cumulative average daily gain) of the steers during the supplemental feeding period is summarized in table 3. Steers offered supplements containing bypass protein tended to gain more rapidly than did the controls. Table 3 eliminates field bias by reporting cumulative average daily gain occurring over a four-field rotation. Calves fed the urea-corn

TABLE 1. Supplement consumption by month and treatment

Month or treatment	Consumption* 1987-88	1988-89
	.... lb/head/day	....
November	1.64 a	1.48 a
December	1.74 ab	1.77 ab
January	1.94 b	1.90 b
February	1.90 b	1.91 b
Urea	1.51 a	1.63
Bypass	1.88 b	1.88
Urea + bypass	2.03 b	1.78

NOTE: Duration of supplementation in 1987-88 = 114 days, 1988-89 = 111 days.
* Means in the same column followed by different letters are significantly different ($P < 0.05$).

TABLE 2. Average daily gain by stocking density

Density	Average daily gain* 1987-88	1988-89
	.... lb	....
High	0.63 a	0.60 a
Low	0.93 b	0.89 b

* Means in the same column followed by different letters are significantly different ($P < 0.01$).

TABLE 3. Cumulative average daily gain (ADG) by supplemental treatment

Treatment	Average daily gain* 1987-88 11/2-2/24	1988-89 11/3-2/22
	.... lb	....
Control	0.63 a	0.44 a
Urea	0.74 ab	0.67 b
Bypass	0.78 b	0.79 bc
Urea + bypass	0.96 c	0.89 c

* Means in the same column followed by different letters are significantly different ($P < 0.01$).

Variations in overall average daily gains between years may be a reflection of residual dry matter differences at the onset of each trial.

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Blue oaks withstand drought

Douglas D. McCreary

Many blue oaks in California lost their leaves early in 1987 and 1988 after prolonged periods of low rainfall. A study found that summer defoliation had little short-term effect on growth or survival, suggesting that blue oaks are well adapted to withstand periodic droughts.

In mid-August 1987, many oak trees in California began turning brown and dropping their leaves. While most of the trees affected were deciduous species that normally lose their leaves each year, this event was unusual in that it happened about three months "ahead of schedule." During most years, deciduous oaks don't change color until the short days and cold temperatures of November.

The occurrence of brown trees was widespread, ranging from southern California to the northern portions of the Sacramento Valley. Not all trees were affected, however. In general, dense stands were the most severely affected; trees in clumps or thickets began changing color while most single trees in the open remained green. It also appeared that trees in shallow, rocky soils, or on south-facing slopes, were affected more than those in valleys or swales. One of the principal species affected was *Quercus douglasii*, commonly called blue oak. This species occurs on vast ranges in the foothills surrounding California's Central Valley.

Because the winter of 1986-87 had been exceedingly dry (fig. 1), and there had been little or no precipitation in much of California since March, most observers felt the reason for the trees changing color so early was drought. This is consistent with knowledge of tree physiology. During drought, soil moisture becomes depleted more rapidly than usual, and by midsummer, little is available for plants. By dropping their leaves, trees greatly reduce their moisture requirements, minimizing the potentially disastrous consequences of dehydration.

Oaks have turned brown prematurely before, most recently during the drought of 1976-77. In the summer of 1976, after a dry winter, many oak trees reportedly changed color and lost their leaves early. The following winter was even drier than the preceding one, and many trees had little or no foliage during the next spring and summer. During the following winter, however, when rainfall returned to normal, most trees apparently recovered. By spring, normal growth patterns resumed, and green foliage remained on the trees throughout the summer and into the fall.

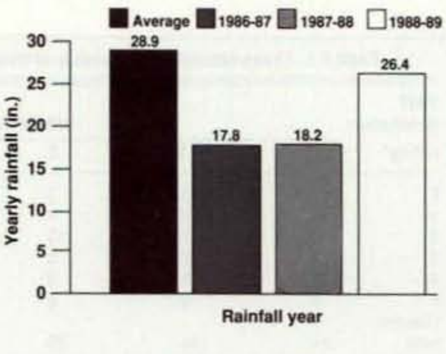


Fig. 1. Yearly rainfall at the field station. The winters of both 1986-87 and 1987-88 were extremely dry.

Although most oak trees that turn brown early survive and recover the following winter, the effects of drought on the trees are not known. It is reasonable to assume that severe moisture stress prompting leaf loss is not good for trees. Shedding foliage early eliminates the apparatus for photosynthesis. As a result, growth is reduced, and trees may become more susceptible to insect and disease attacks.

Since current photosynthate is also used for acorn development, the loss of foliage before acorns have fully ripened (usually in October) probably retards acorn development and maturity. This may negatively affect wildlife species that rely heavily on acorns for food. It probably also reduces the number of acorns that will become sufficiently mature to germinate in the soil and develop into seedlings.

A study was undertaken to identify some of the effects of drought on blue oak trees. The goal was to document what happens to trees in the Sierra foothills that turned brown so early in 1987 by monitoring survival, bud burst, and acorn production.

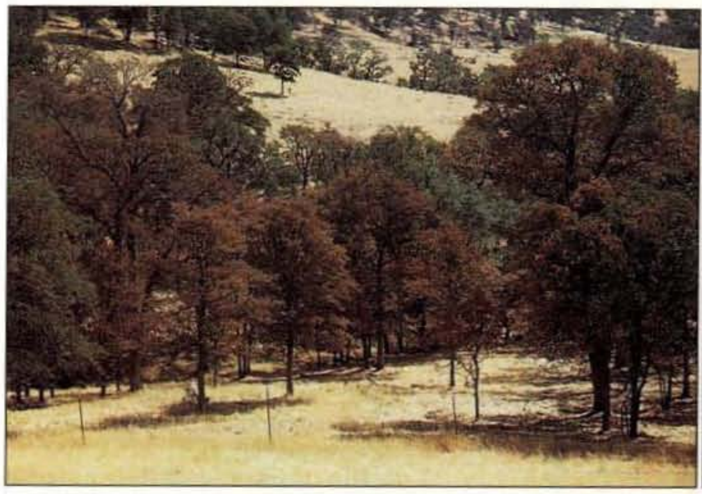
Methods

Two adjacent 100-tree plots of blue oaks were established in mid-August 1987 at the Sierra Foothill Range Field Station. These plots were selected because the oaks in them varied greatly in degree of browning from healthy looking green trees with abundant foliage to those that had turned completely brown or were bare. There were no obvious site factors such as slope, aspect, or soils to explain the differences in browning. The plots were at an elevation of approximately 600 feet and ranged in size from 0.6 to 1 acre.

Within each plot, all trees larger than 3 inches diameter at breast height (DBH) were tagged with aluminum tags, and sequentially numbered from 1 to 100. As each tree was tagged, it was assessed for the degree of foliage browning, leaf loss, or both, and given a defoliation rating (table 1).

In September 1987, each tree was evaluated again. DBH was recorded and each tree was given a visual acorn rating according to a standard rating system on a scale of 1 to 4 developed by the California Department of Fish and Game for assessing California oaks (see table 2 footnote). In addition, the percentage of dead branches on each tree was recorded. Each tree was also given a dominance rating indicating whether it was suppressed, intermediate, dominant, or co-dominant.

Starting in February 1988, each tree was evaluated twice a week to determine leaf-



Trees in the study plot showed extensive browning in mid-August 1987, following an extremely dry winter and little or no rain after March.

Normal rainfall patterns resumed in 1989, and the same trees were just beginning to turn brown toward the end of November.

out date and survival. Leaf-out was the date when green foliage could first be observed emerging through the bud scales.

All trees were evaluated again the following year. The rainfall season 1987-88 was also dry, and many of the trees within the plots began turning brown again prematurely, though several weeks later than during the preceding summer. In early September 1988, each tree was rated for defoliation, followed by an acorn evaluation later in the month and a leaf-out assessment the following spring. For each of these evaluations, the same rating criteria were used as in the previous year. In 1989, normal rainfall patterns resumed and all trees remained green into the fall.

Analysis

The initial analysis examined whether or not there were significant relationships between the degree of defoliation and subsequent growth and development, including survival, acorn production, and leaf-out date. Since the means of the variables were very similar for each plot, the data were combined and correlations between variables were calculated using 200 pairs of observations (one for each tree). An analysis of variance was also used to compare leaf-out date between trees from several of the defoliation groups. In addition, defoliation was correlated with DBH, the percentage of dead branches, and dominance rating to determine if size, health, or position in the stand influenced which trees turned brown early.

Since each tree was evaluated for two consecutive years, we also correlated defoliation rating, acorn production, and leaf-out data between years to find out if there was a consistent pattern in these variables over time. Cross-tabulation tables showing the number of trees in each defoliation and acorn category are provided. All differences reported as significant were at the $p \leq 0.01$ level.

Results and discussion

All 200 trees survived both years' defoliations and leafed out the following springs. There were marked differences in leaf-out date, however, depending on the severity of defoliation the previous summer. For both the first ($r = -.43$) and second year ($r = -.42$) there was a significant negative correlation between defoliation rating and leaf-out date. That is, defoliated trees tended to leaf out earlier than those that remained green. The most severely defoliated trees (greater than 95% leaf loss) leafed out 7 days earlier than the least defoliated (less than 25% leaf loss) in 1988 and 6 days earlier in 1989 (fig. 2). Both of these differences were statistically significant.

There are numerous possible explanations for this surprising relationship. From an anthropomorphic standpoint, one could hypothesize that trees that lost their leaves early were trying to "catch up" by beginning growth sooner. More likely, some trees were genetically more sensitive to changes in growing conditions. These trees may have responded to an unfavorable dry environment by losing their foliage, and responded to favorable spring conditions by rapidly developing new leaves. It is also possible that microsite conditions causing greater moisture stress for some trees in the summer also favored early bud burst in the spring. Perhaps those trees lost their leaves early because air or soil temperatures in their immediate environment were slightly warmer than for neighboring trees. If temperatures were also warmer the following spring, earlier bud burst could be stimulated. These trees are being evaluated for bud burst this spring to determine if these leaf-out patterns are the same after a normal rainfall year when no premature leaf loss occurred.

There was little relationship between tree size, percent dead branches, or dominance,

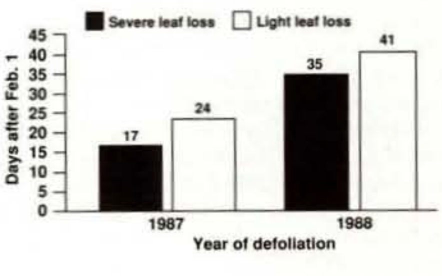


Fig. 2. Average leaf-out date the spring after summer leaf drop. Defoliated trees leafed out earlier than least affected trees.

TABLE 1. Cross-tabulation of number of trees in defoliation rating groups for 1987 and 1988

1987 defoliation rating*	1988 defoliation rating 0	1	2	3	4	5	Row total
0	11	5	3	2	0	0	21
1	2	19	4	2	0	0	27
2	0	7	13	4	1	0	25
3	1	2	6	12	7	0	28
4	0	1	3	13	23	8	48
5	0	0	0	2	16	33	51
Column total	14	34	29	35	47	41	200

* Defoliation ratings are on a scale of 0 to 5: 0 = < 5% of leaves brown or dropped from tree; 1 = 5% - 25%; 2 = 26% - 50%; 3 = 51% - 75%; 4 = 76% - 95%; 5 = >95%.

and degree of defoliation. The only significant correlation in either year was between DBH and defoliation in the first year. In this instance, smaller diameter trees tended to have greater leaf loss, although the variability in DBH accounted for only about 5% of the variability in defoliation.

Efforts to compare acorn production with defoliation were hampered by the fact that overall acorn production was relatively low each year, with fewer than 30% of the trees having any visible acorns and no trees with a rating of 4. However, there was a significant negative correlation ($r = -.27$) between these variables the first year, indicating that greater defoliation was associated with less acorn production. It is possible that this relationship was even stronger than indicated, since the data may have been biased by the fact that it was easier to observe acorns on defoliated trees since the foliage did not obscure them. There was not a significant correlation the second year.

Trends

There were significant correlations between defoliation, leaf-out date, and acorn production from year to year. The strongest relationship was for defoliation ($r = .87$). The same trees that turned brown early in 1987 also did so in 1988 (table 1). This similarity may be due to physiological condition, microsite differences, genetic factors, or a combination.

There was also a consistent pattern of leaf-out date between years ($r = .86$). Trees that leafed out early the first year also did so the second. However, the average leaf-out date the second year was more than 2.5 weeks later than in the first year (fig. 2). Such a large difference in leaf-out date suggests that growth initiation and cessation in blue oaks are very sensitive to changes in environmental conditions.

The correlation of acorn production from year to year was weaker, but also highly significant ($r = .32$) (table 2). This supports the current view that certain trees are consistently better acorn producers in a stand, even though the actual magnitude can fluctuate greatly from year to year.

TABLE 2. Cross-tabulation of number of trees in acorn rating groups, 1987 and 1988

1987 acorn rating*	1988 acorn rating 1	2	3	Row total
1	129	33	1	163
2	16	19	1	36
3	0	1	0	1
Column total	145	53	2	200

* Acorn ratings on a scale of 1 to 4: 1 = no visible acorns; 2 = acorns visible after very close examination; 3 = acorns readily visible but not covering whole tree; 4 = acorns covering entire tree and limbs sagging from their weight (no trees were found with this rating).

Conclusions

The results of this study suggest that summer defoliation of blue oaks from drought has little short-term impact on growth or survival. Even after two consecutive years of early leaf loss, not one of the 200 trees died. In early fall 1989, all trees were leafed out and appeared healthy with very little leaf loss. While size, dominance, or the percentage of dead branches had little relation to defoliation, trees that lost leaves early tended to leaf out early the following spring.

California's blue oaks are apparently well adapted to withstand the adverse effects of periodic droughts. It is still too early to tell if drought has longer term consequences on the susceptibility of blue oaks to insects or diseases. Plot trees will be monitored for another 3 years to evaluate these relationships.

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Selective oak removal does not harm water quality

Michael J. Singer ❑ Xiaohong Huang ❑ Charlette Epifanio

Measurements before and after removal of oaks from 14% of a 250-acre watershed indicated small but not statistically significant increases in the runoff/rainfall ratio and no change in nutrient or sediment removal. Careful, selective oak removal appeared to have no harmful effect on water quality.

For the past 10 years we have measured amounts of rainfall and runoff, and concentrations of suspended sediment, major cations and anions, pH, and electrical conductivity in two watersheds at the Sierra Foothill Range Field Station. One has a perennial flowing stream, and the other, a stream that flows only in the winter. The watersheds are used for winter and spring grazing by beef cattle, and our purpose was to learn what effects selective oak removal for range improvement would have on watershed hydrology and water quality.

The uppermost portions of the watersheds were cleared of all trees between 1964 and 1966 to enhance range production. There was no further management of the watersheds until 1984 when additional, selective oak harvesting was initiated. Cutting and removal of the trees by a firewood contractor was done primarily during the dry summer months to minimize watershed disturbance. Nonmerchantable wood was piled and, after a few years, burned.

Water measurements began in 1980 before the selective removal of oak trees on the two watersheds. In this report, we discuss the effects on the 254.4-acre watershed with the perennial stream. Oaks were harvested on about 14% of the watershed beginning in July 1984 and ending in May 1986. Approximately 1,350 trees were removed on 37 acres.

Results and discussion

Water yield. An annual average 27.5 inches of rainfall was measured in the watershed during the last nine years. The average consists of two heavy rainfall years (1981-82 and 82-83) and several years that were well below the station average of 29 inches a year (table 1). Runoff from the watershed varied between 3 and 30 inches and averaged 15.8 inches. The annual ratio of runoff to rainfall varied between 0.143 and 0.775 (table 1). This ratio is useful when comparing runoff among years.

There was no statistically significant difference between the average precut and postcut rainfall, runoff, or runoff/rainfall ratio for the watershed. Rainfall (34 versus 22 inches) and runoff (18 versus 14 inches) were higher in the four precut years than in the postcut years, and the ratio was slightly higher postcut (0.610) than precut (0.489). We conclude that careful removal of this small area of oaks did not have a major impact on water yield. There is a possibility that there may be a long-term increase in water yield. If the first postcut year is not

Charles Raguse

Researcher demonstrates the flume used to measure the amount of water flowing out of the field station's Schubert watershed.

included in the analysis, the average runoff/rainfall ratio is 0.665 but the difference is not statistically significant.

Comparisons between similar years show an apparent increase in runoff for the same rainfall. For example, in the 1980-81 precut year, 21 inches of precipitation generated 3 inches of runoff, while in the 1987-88 postcut year, 19 inches produced 11 inches of runoff (fig. 1). The higher runoff in the postcut year can be attributed to the distribution of rainfall, particularly the "priming" effect of the November and December storms followed by heavy rainfall in January. The early winter storms refilled the depleted soil moisture storage so that the January precipitation quickly saturated the soil and produced runoff. A similar pattern occurs when precut 1983-84 is compared with postcut 1988-89. In the precut year, 29 inches of precipitation caused 14 inches of runoff, while in the postcut year, 28 inches of precipitation caused 19 inches of runoff.

The two precut years with highest rainfall (1981 through 1983) had a combined runoff/rainfall ratio of 0.66 compared with a ratio of 0.64 for the one postcut year (1985-86) when rainfall was above average. In the precut year 1980-81, runoff during every month of the rainy season was far less than rainfall (fig. 1). In the postcut year 1987-88, runoff exceeded rainfall during two months (fig. 1). This surprising result probably is due to the heavy rainfall in the three previous months. There are several springs in the watershed, and it is clear that a source of water in addition to the rain supplies the runoff. This does not appear to be due to the cutting.

Statistical tests (simple linear regressions of runoff as a function of rainfall) were run for precut and postcut years, but no significant correlation was found. (Although the R^2 was >0.83 for both, there were too few degrees of freedom to show significance.) From examination of the annual values and storm data, the oak harvest does not appear to have increased the runoff significantly during above-average rainfall years. Although not statistically significant, the overall average ratio of runoff/rainfall was higher from the watershed after than before cutting.

Sediment yield. The amount of sediment leaving the watershed is very small and was not adversely affected by oak harvesting. Fewer tons of sediment left the watershed after cutting than before, and tons per inch of runoff decreased about 50% after cutting. Total sediment depends on sediment concentration and runoff volume. Average suspended sediment concentration was weakly correlated to the average volume of runoff ($r = 0.509$). The suspended sediment concentration was not significantly different between precut and postcut years (table 1). The amounts of sediment leaving the watershed may be somewhat underestimated, because samples are taken at only one location and depth, and no bedload estimate is included.

Year-to-year comparisons between similar years are less clear for sediment production than for runoff. In the postcut year 1987-88, tripling the runoff tripled the total sediment load compared with the sediment load for the precut year 1980-81 (table 1). The 35% greater runoff in 1988-89 produced nearly 2 tons less sediment than the precut 1983-84 year. Timing and intensity of precipitation events are evidently more important to the total sediment load than the removal of oaks on 14% of the watershed.

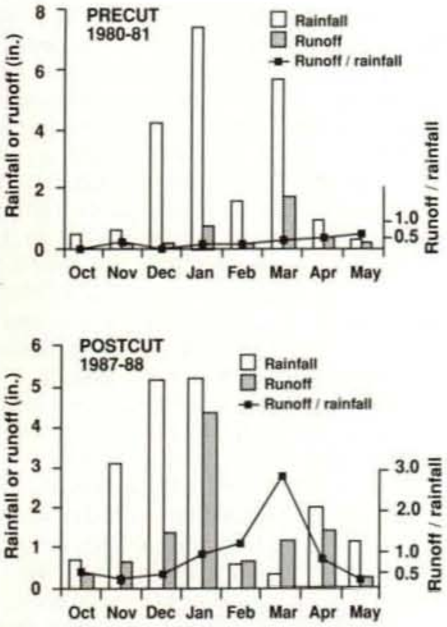

Fig. 1. Comparisons between years with a similar amount of rainfall in the watershed suggest that runoff increased somewhat after selective oak cutting.

Nutrients in runoff. There were no significant differences between the precut and postcut sum of cations (calcium, magnesium, potassium, and sodium) leaving the watershed (table 2). The totals for both groups of years are small. The average annual sum of cations removed from the watershed during the precut years was 39.4 tons compared with 37.0 tons postcut. Additional cations were lost with the suspended sediment.

The chloride data are included because

TABLE 1. Annual rainfall (RF), runoff (RO), runoff/rainfall ratio (RO/RF), suspended sediment concentration (SUS), and total sediment load (SED) for Schubert watershed S2, Sierra Foothill Range Field Station, 1980-89

Year	RF	RO	RO/RF	SUS	SED
	in/yr	in/yr		mg/L	tons
80-81	21	3	0.143	14.6	1
81-82	47	26	0.553	47.2	32
82-83	40	31	0.775	32.4	25
83-84	29	14	0.483	32.3	12
Mean	34	18	0.489	31.6	18
84-85	18	7	0.389	13.6	2
85-86	33	21	0.636	15.1	8
86-87	13	10	0.769	40.2	10
87-88	19	11	0.579	10.7	3
88-89	28	19	0.679	21.2	10
Mean	22	14	0.610	20.0	6

NOTE: Rainfall and runoff values are rounded to the nearest whole number.

TABLE 2. Annual NO_3-nitrogen, sum of cations (SC), chloride (Cl), and suspended sediment load (SED) for the Schubert watershed S2, 1980-89

YEAR	NO_3	SC	Cl	SED
	tons			
80-81	0.048	8	ND	1
81-82	0.355	68	ND	32
82-83	0.431	47	ND	25
83-84	0.005	35	0.9	12
Mean	0.210*	39	ND	18
84-85	0.579	21	1.2	2
85-86	1.309	69	3.0	8
86-87	0.411	26	0.7	10
87-88	0.655	32	0.3	3
88-89	2.124	36	0.6	10
Mean	1.016*	37	ND	6

ND = not determined.
*Significantly different at 90% by Fisher's Protected Least Significant Difference.

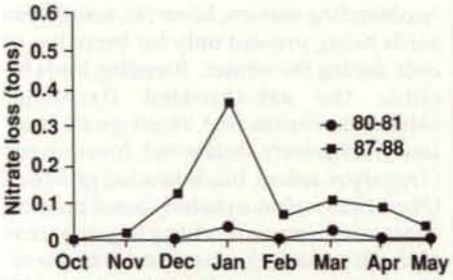

Fig. 2. Monthly nitrate loss during the rainy season was greater after oak harvest (1987-88) than before (1980-81).

chloride contamination of some wells in the valley has been a concern. Small amounts of chloride are leaving the watershed, presumably from weathering of chloride-containing rocks as soils form. We did not collect sufficient precut chloride analyses to make a precut versus postcut comparison.

Nitrate was significantly higher in postcut years (table 2). The precut average nitrate loss was 0.21 ton, and the postcut average was 1.016 tons. A comparison of monthly nitrate losses in the runoff shows that runoff and nutrient concentration were the same for precut and postcut years when there was no precipitation (June through September), but during months with precipitation, more nitrate was removed from the watershed after cutting than before (fig. 2). This appears to be related to nitrate concentration in the rainwater. Average nitrate concentration in precut years from two collection points in the watershed was 0.006 mg/L and was 1.63 mg/L from the same two collection points in postcut years. Oak harvest could not affect the concentration of nitrate (NO_3) in rainfall. We must conclude that the increase in nitrogen in the stream was not due to the oak harvest.

Conclusions

Our results from 10 years of field monitoring of precipitation, runoff, and runoff water quality indicate that a small amount of carefully controlled oak removal has little effect on runoff volume and no effect on sediment or nutrients in the runoff. The runoff/rainfall ratio was numerically but not statistically higher for the five postcut years compared to the four precut years.

Nitrate nitrogen in runoff and rainfall was significantly higher in the postcut years. This may be a result of our collection system or analytical method. It cannot be said with any certainty that the increase in nitrogen in the stream water is due to the cutting. The total nutrients lost from the watershed are small and pose no water quality hazards.

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Wildlife diversity of the central Sierra foothills

William M. Block ❑ Michael L. Morrison

A 3-year study of wildlife-habitat relationships in the oak woodlands of California's Sierra foothills found a wide range of species. This was directly related to the diversity of habitats provided by oak woodlands.

California oak woodlands provide habitats for many wildlife species, including amphibians, reptiles, birds, and small mammals. Each species requires a unique set of resources to survive and reproduce, and the needs of wildlife change throughout the year. Animals found in oak woodlands only during the breeding season may use different resources than those found year-round or those occurring only during the winter. Besides oak trees, these resources include shrubs, grasses, forbs, seeds, fruits, insects, and countless other elements. The types, amounts, and juxtaposition of resources determine the composition, abundance, and diversity of wildlife present.

Such habitat diversity exists at Sierra Foothill Range Field Station, where we studied primarily nongame wildlife year-round from November 1986 through April 1989. This was part of an extensive statewide study to determine habitat relationships of wildlife in oak woodlands. Before our study, little information was available on the distribution, abundance, seasonal occurrence, and habitat needs of most wildlife in oak woodlands. This report summarizes some of our findings from the field station.

Our study, which included sampling by bird counts, live traps, pitfall traps, and timed searches, was conducted over most of the station's 5,700 acres. Only Forbes Hill (an area denuded of most woody vegetation) and the irrigated pastures were not sampled. Our sampling efforts incorporated much of the diversity of plant life and terrain typical of the central Sierra foothills. This diversity was the result of both natural events and human activities, such as grazing, fuelwood harvest, and fire suppression.

Except for two natural areas, one each in the Koch and the Schubert areas, most of the field station is grazed by cattle. Cattle grazing has modified the structure and composition of both woody and herbaceous vegetation. Natural areas have a denser shrub layer, less browsing on woody plants, and a taller herbaceous layer than the grazed areas.

Bird counts

We used a systematic-random sampling design to establish 100 sampling points. Points were spaced about 1,000 feet apart, a distance required to avoid recording the same bird at adjacent points. We recorded birds present at each point three times during each of the 1987 and 1988 breeding seasons (late March through May), and five times during the 1987-88 nonbreeding season (November through February).

The counts revealed 113 species, including 43 birds that were year-round residents, 11 species that resided only during winter but bred at other locations, 17 breeding species that wintered in other habitats, 21 migrant birds that used the area on the way to and from their breeding grounds, and 21 incidental species (table 1). More species were detected during breeding (82 in 1987 and 89 in 1988) than nonbreeding counts (60).

More species were recorded at Sierra Foothill Range Field Station than at two other areas—San Joaquin Experimental Range, Madera County, and Tejon Ranch, Kern County—where we also conducted bird counts. Most differences between Sierra Foothill and the other two areas were in the numbers of incidental species. Many of the incidental species at the field station were birds that used adjacent habitats such as Englebright Reservoir, Yuba River, and agricultural lands, and passed over or temporarily used the station's woodlands to or from their preferred habitats. Similar types of habitats were not adjacent to the other two study areas, possibly accounting for the differences in numbers of incidental species.

Discounting incidental species, 92 species used the field station for breeding, cover, or food. Species were similarly ranked by

TABLE 1. Residency status and relative abundance of birds detected during 1987 and 1988 breeding and 1987-88 nonbreeding seasons, Sierra Foothill Range Field Station, Yuba County, California

Species	Status*	Relative abundance° Breeding	Relative abundance° Nonbreeding	Species	Status*	Relative abundance° Breeding	Relative abundance° Nonbreeding
Great egret	I	R	N	Plain titmouse	R	A	A
Great-blue heron	I	R	N	Mountain chickadee	I	R	R
Tundra swan	I	N	U	Bushtit	R	C	C
Anser spp.	I	N	R	Brown creeper	W	N	R
Common merganser	I	N	R	White-breasted nuthatch	R	C	C
Killdeer	R	R	R	Red-breasted nuthatch	I	R	R
Turkey vulture	R	C	U	House wren	B	C	N
Golden eagle	R	R	R	Bewick's wren	R	C	C
Bald eagle	I	N	R	Canyon wren	R	R	R
Sharp-shinned hawk	R	R	R	Rock wren	I	R	R
Cooper's hawk	R	R	R	Ruby-crowned kinglet	W	U	C
Red-tailed hawk	R	U	U	Blue-gray gnatcatcher	B	C	R
Osprey	I	R	N	Western bluebird	R	C	A
American kestrel	R	R	R	Townsend's solitaire	I	R	N
Prairie falcon	I	N	R	Hermit thrush	W	R	U
California quail	R	C	C	American robin	R	C	A
Mountain quail	I	R	R	Loggerhead shrike	I	N	R
Peacock	I	R	N	Northern mockingbird	R	R	R
Ring-necked pheasant	R	R	R	Cedar waxwing	I	U	U
Wild turkey	R	R	R	Phainopepla	R	U	U
Band-tailed pigeon	I	U	U	European starling	R	C	C
Mourning dove	R	C	R	Hutton's vireo	R	C	C
Common barn-owl	R	R	R	Solitary vireo	M	R	N
Great-horned owl	R	R	R	Warbling vireo	M	R	N
Western screech-owl	R	R	R	Orange-crowned warbler	B	C	R
Northern pygmy-owl	R	R	R	Nashville warbler	M	R	N
Anna's hummingbird	B	U	R	Yellow-rumped warbler	M	C	C
Calliope hummingbird	M	R	N	Black-throated gray warbler	M	R	N
Rufous hummingbird	M	R	N	Townsend's warbler	M	U	N
Allen's hummingbird	M	R	N	Hermit warbler	M	U	N
Northern flicker	R	U	C	Yellow warbler	M	R	N
Acorn woodpecker	R	A	A	MacGillivray's warbler	M	R	N
Lewis' woodpecker	I	R	R	Wilson's warbler	B	C	N
Red-breasted sapsucker	W	N	U	Yellow-breasted chat	B	R	N
Downy woodpecker	W	N	R	Black-headed grosbeak	B	C	N
Hairy woodpecker	W	R	R	Lazuli bunting	B	C	N
Nuttall's woodpecker	R	C	C	Rufous-sided towhee	R	C	C
Western kingbird	B	C	N	California towhee	R	C	C
Ash-throated flycatcher	B	A	N	Song sparrow	M	R	N
Olive-sided flycatcher	M	R	N	Lark sparrow	R	C	R
Western wood-pewee	M	R	R	Rufous-crowned sparrow	R	C	U
Black phoebe	R	R	R	Chipping sparrow	B	C	N
Say's phoebe	I	N	R	Dark-eyed junco	W	U	C
Gray flycatcher	M	R	N	White-crowned sparrow	W	N	C
Dusky flycatcher	M	R	N	Golden-crowned sparrow	W	C	C
Hammond's flycatcher	M	R	N	Fox sparrow	M	N	R
Pacific-slope flycatcher	M	R	N	Western meadowlark	R	C	C
Tree swallow	B	U	N	Red-winged blackbird	W	U	R
Violet-green swallow	B	C	N	Brewer's blackbird	R	U	R
Bank swallow	B	U	N	Northern oriole	B	C	N
Cliff swallow	B	U	N	Western tanager	M	U	N
Barn swallow	I	R	N	Pine siskin	M	C	C
Scrub jay	R	C	C	American goldfinch	I	R	N
Steller's jay	W	R	U	Lesser goldfinch	R	A	C
American crow	R	C	C	Purple finch	R	C	C
Common raven	R	C	U	House finch	R	C	C
Wrentit	R	C	C				

NOTE: Rankings of birds were correlated between breeding seasons ($r_s = 0.90$, $P < 0.01$), but not between breeding and nonbreeding seasons ($r_s = 0.24$, $P > 0.20$).

* Status: B, breeding species; I, incidental species; M, migrant species; R, resident species; W, wintering species.

° Relative abundance: A, abundant; C, common; U, uncommon; R, rare; N, not recorded.

numbers of detections between the two breeding seasons, but not between breeding and nonbreeding seasons. These results demonstrate that the types and abundances of birds can be quite variable between seasons.

Populations of resident birds might increase or decrease between seasons. For example, numbers of American robins (*Turdus migratorius*) and western bluebirds (*Sialia mexicana*) increase during the winter when fruits of toyon (*Heteromeles arbutifolia*), coffeeberry (*Rhamnus californica*), redberry (*R. crocea*), and other plants ripen. Conversely, some resident birds decline in numbers when part of the population migrates to a different location, as in the case of turkey vultures (*Cathartes aura*), lark sparrows (*Chondestes grammacus*), and lesser goldfinches (*Carduelis psaltria*).

Most differences between breeding and nonbreeding seasons, however, result from birds being present only for breeding or only during the winter. Breeding birds include the ash-throated flycatcher (*Myiarchus cinerascens*), violet-green swallow (*Tachycineta thalassina*), house wren (*Troglodytes aedon*), black-headed grosbeak (*Pheucticus melanocephalus*), lazuli bunting (*Passerina amoena*), chipping sparrow (*Spizella passerina*), orange-crowned warbler (*Vermivora ruficapilla*), Wilson's warbler (*Wilsonia pusilla*), and northern oriole (*Icterus galbula*). Wintering birds include the ruby-crowned kinglet (*Regulus calendula*), dark-eyed junco (*Junco hyemalis*), and golden-crowned sparrow (*Zonotrichia atricapilla*).

Much of the bird species diversity is directly related to the plant diversity at the field station. Species such as the Hutton's vireo (*Vireo huttoni*), orange-crowned warbler, and Wilson's warbler were closely associated with interior live oak (*Quercus wislizenii*). Those such as the white-breasted nuthatch (*Sitta carolinensis*) and western bluebird were closely associated with blue oak (*Q. douglasii*).

Over 60 species actually bred at Sierra Foothill, but the station is no less important for birds that do not breed there. Wintering and migrant birds need the resources provided by the woodlands for survival. Further, the specific habitats used by birds during breeding may differ from those used during fall and winter. For example, many resident birds gleaned insects from foliage of blue and interior live oaks during the breeding season but were restricted to live oaks during winter when blue oaks had no leaves. Management of oak woodlands for birds therefore should not be confined to breeding birds but should consider the habitat needs of all birds—breeding, wintering, migrant, and resident—that require the resources provided there.

Live traps

We used Sherman live traps to sample small mammals. The traps were spaced 50 feet apart in four 8 x 8 grids (8 lines with 8 traps per line). One grid was randomly placed in each of the two natural areas (Koch and Schubert); the other two grids were randomly placed outside each natural area. Traps were opened at dusk and baited with peanut butter and rolled oats. Cotton was placed in the traps to provide insulation for animals during cool nights. Traps were checked at dawn. Captured animals were identified to species, age, and sex, and were measured, marked by toe clipping, and released. All four grids were trapped for six nights each during March and November 1988. Two grids (one inside and the other outside the natural area) in the Schubert drainage were also trapped for five nights during April 1987.

Lazuli buntings are among the many breeding birds recorded at the field station.

We captured 200 small mammals representing five species during 3,332 trap nights (table 2). Significantly more animals were captured in grazed areas (136) than in ungrazed, natural areas (64). The brush mouse (*Peromyscus boylii*) was the most abundant species during the spring accounting for 86 of 90 captures. The other four captures were of the pinyon mouse (*P. truei*). Five species were captured during the fall; brush and pinyon mice were the most abundant. Fewer deer mice (*P. maniculatus*), dusky-footed woodrats (*Neotoma fuscipes*), and ornate shrews (*Sorex ornatus*) were captured. Comparable numbers of animals were caught during fall (110) and spring (90).

The actual number of animals captured was quite small, averaging about one per 17 trap nights. Apparently, there are few small mammals in oak woodlands, or they are not readily captured by the standard methods we employed. Substantially more animals were captured in grazed than in ungrazed areas, suggesting that (1) there were more small mammals in grazed areas, or (2) small mammals in grazed areas needed to range farther to find resources than in ungrazed areas and thus were more likely to encounter a trap.

Small mammals have been cited as a major factor contributing to the lack of regeneration by white oaks. Given the low population levels of small mammals we found, however, it is doubtful that they alone could have sufficient effect to limit oak regeneration. Thus, implication of small mammals in the perceived lack of regeneration is premature.

Pitfall traps

We used pitfall traps to sample populations of amphibians, reptiles, and small mammals. The traps were 2-gallon plastic buckets sunk to ground level and covered with a square piece of plywood. We distributed 128 traps in three 6 x 6 grids and one 4 x 5 grid with traps spaced 65 feet apart. Two 6 x 6 grids were paired in the Koch area with one inside and the other outside the natural area. The other two grids were placed in the Schubert drainage with the 6 x 6 grid inside the natural area and the 4 x 5 grid outside.

Traps remained closed for at least a month after placement to allow the area to recover from the disturbance of digging the holes and to let animals become accustomed to the presence of the trap. Traps were opened by propping the plywood 2 to 4 inches above the lip of the buckets with twigs or small rocks.

We sampled the three 6 x 6 grids for 60 consecutive days from January to March 1988; all four grids were sampled for 60 additional days from November 1988 to January 1989. Traps were checked every other day, and captured animals were identified to species, aged, sexed (if possible), and measured. Animals were taken to a different location more than 3,000 feet from any other trapping grid to avoid recapturing the same animal.

We captured 209 animals including one species of amphibia, three reptiles, and seven mammals in pitfalls during 14,060 trap nights (table 3). Significantly more reptiles (145) were captured than mammals (62). The western fence lizard (*Sceloporus occidentalis*) was the most frequently captured reptile; the other two reptiles captured were the western skink (*Eumeces skiltonianus*) and southern alligator lizard (*Gerrhonotus multicarinatus*). Brush and pinyon mice were the most frequently captured small mammals. There were no significant differences, however, between grazed and ungrazed areas in total numbers of animals, numbers of reptiles, or small mammals captured.

As in the live trapping, few animals were captured in pitfalls. Fewer small mammals

TABLE 2. Numbers of small mammals captured in live traps, Sierra Foothill Range Field Station, spring 1987 and 1988, fall 1988

	Natural areas		Grazed areas	
Species	Spring (n=1068)*	Fall (n=748)	Spring (n=1070)	Fall (n=752)
Brush mouse	18	13	68	27
Pinyon mouse	0	27	4	29
Deer mouse	0	3	0	5
Dusky-footed woodrat	0	3	0	2
Ornate shrew	0	0	0	1

NOTE: Total captured in grazed areas was significantly greater than in natural areas (x^2 = 25.9, P<0.01). Totals captured in fall and spring were comparable (x^2 = 2.0, P>0.10).
* Number of trap nights.

TABLE 3. Numbers of animals captured in pitfall traps in natural and grazed areas at Sierra Foothill Range Field Station during spring and fall 1988

Species	Natural areas (n = 8640)*	Grazed areas (n = 5420)
AMPHIBIAN		
California slender salamander	2	0
REPTILES		
Western fence lizard	60	62
Western skink	10	3
Southern alligator lizard	5	5
MAMMALS		
Brush mouse	10	6
Pinyon mouse	7	8
Deer mouse	1	2
California vole	6	3
Western harvest mouse	6	3
Botta's pocket gopher	1	0
Ornate shrew	7	2

NOTE: Number of reptiles captured was significantly greater than mammals captured (x^2 = 33.8, P<0.01). There were no significant differences between grazed and ungrazed areas in total animals (x^2 = 0.01, P >0.90), reptiles (x^2 = 0.6, P>0.90), or small mammals (x^2 = 0.9, P>0.80) captured.
* Number of trap nights.

Dusky-footed woodrats are closely associated with live oaks and chaparral at the station. The researchers used live traps to sample populations of small mammals, which were identified, measured, marked, and released.

were captured in pitfalls than in live traps. An advantage of pitfalls was that we captured three additional species—western harvest mouse (*Rheithrodontomys megalotis*), California vole (*Microtus californicus*), and Botta's pocket gopher (*Thomomys bottae*)—not captured by the live traps. Only one pocket gopher was captured, far fewer than at San Joaquin Experimental Range or Tejon Ranch, where we used identical trapping methods. This species is frequently regarded as a pest by range managers, but our findings suggest there are too few gophers at Sierra Foothill to have a substantial effect on forage or oak seedling establishment.

Time-constraint searches

Additional surveys for amphibians and reptiles were conducted by a time-constraint sampling method. Two or more persons actively searched for animals in rotten logs and leaf litter, under logs, branches, and rocks, or in plain sight (on the ground, in a tree, or otherwise visible). When an animal was found, search time was halted and the animal was identified, aged, sexed (if possible), measured, and released. We also recorded characteristics of the substrate where the animal was located and a general description of the habitat. Time was then resumed, and observers searched for another animal. This procedure continued until 4 person-hours of active searching elapsed. Four time-constraint searches were conducted during March 1988, and five during November 1988 in different stands representative of the diversity of habitats at the field station.

The nine time-constraint searches resulted in 95 captures consisting of two species of amphibians, three lizards, and four snakes (table 4). More animals were captured during spring (70) searches than during fall searches (25). Lizards made up 93% of the spring captures, but only 48% of the fall captures. All snakes were captured during the spring, and all but one amphibian was captured during the fall. These seasonal differences in captures probably reflect seasonal differences in activity patterns.

More than half of all animals were found under downed logs; rocks were the second most used substrate (about 25% of the captures). The California slender salamander (*Batrachoseps attenuatus*) was the most restricted animal in distribution, found exclusively in stands of interior live oak. Other common species (western fence lizard, southern alligator lizard, western skink) were more widespread, found in both live and blue oak stands.

TABLE 4. Numbers of amphibians and reptiles captured during time-constraint searches, Sierra Foothill Range Field Station, spring and fall 1988

Species	Spring ($n = 4$)*	Fall ($n = 5$)
AMPHIBIANS		
California slender salamander	1	10
Foothill yellow-legged frog	0	3
REPTILES		
Western fence lizard	41	6
Western skink	4	3
Southern alligator lizard	19	3
Racer	2	0
Ring-necked snake	1	0
Striped whipsnake	1	0
Western rattlesnake	1	0

NOTE: The number of animals captured during spring was significantly greater than during fall ($x^2 = 22.0$, $P < 0.01$).
* Number of searches conducted.

It is obvious from our results at Sierra Foothill, and from similar surveys at San Joaquin Experimental Range and Tejon Ranch, that downed woody debris may be the most important component of the habitats of most reptiles and amphibians. Much of this woody debris consists of fallen limbs from dead or dying trees. The value of such trees for many species of birds is well known. As these trees continue through their life cycle and ultimately die, they are of continuing value to many other species of wildlife as well. Management of oak woodlands for wildlife must consider retention of such trees and also trees in all stages of vigor to ensure a continued supply of this habitat component.

Conclusions

We found a wide variety of wildlife at the field station, much of which was directly attributable to the vegetative diversity of the central Sierra foothills. Each type of oak woodland offers different arrangements of resources used differently by each species of wildlife. These resources are not limited to trees, but also include shrubs, logs, leaf litter, grasses, forbs, and other habitat elements.

All of these components are interrelated, and alterations to one affect the others. For example, changes in tree density, such as through fuelwood removal or urbanization, also change the light regime, microclimate, shrub layer, dead woody debris, leaf litter, and countless other factors. The effects on wildlife will vary among species. Some species use a wide variety of resources and may not show a pronounced response in population. Other species are more restricted in distribution and may decrease in number.

No oak woodland at the Sierra Foothill Range Field Station goes unused by wildlife. In the management of oak woodlands, a rich diversity of wildlife can only be ensured by maintenance of the diversity of habitats.

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Seasonal activity of two human-biting ticks

Robert S. Lane

In northern California, the western black-legged tick is considered the primary vector of the spirochete that causes Lyme disease. That tick and the Pacific Coast tick also can be carriers of several other diseases. In one study to learn when humans and other animals are at greatest risk of exposure, adults of both tick species were found to be most abundant during the cooler seasons.

Lyme disease, also known as Lyme borreliosis, is the most commonly reported vector-borne infection of humans in the United States and other temperate regions of the world, such as Europe. The disease initially appears with a slowly expanding, ring-like skin rash in 50% to 75% of patients, often accompanied by flu-like symptoms. Cardiac, neurologic, arthritic, and sometimes further dermatologic manifestations may occur weeks to months later. First recognized in the United States in Lyme, Connecticut, in the mid-1970s, the disease is caused by a spirochete, a flexible, helical, slender bacterium, named *Borrelia burgdorferi* for its discoverer, Dr. Willy Burgdorfer, of the U.S. Public Health Service, Rocky Mountain Laboratories.

The Lyme disease spirochete is transmitted to humans and other vertebrates mainly by the bite of several species of hard-bodied (ixodid) ticks. In northern California and southern Oregon, the western black-legged tick, *Ixodes pacificus*, a vicious biter of humans, has been implicated as the primary vector of the spirochete to humans, dogs, and possibly other domestic animals such as horses. Both the nymphs and adult females commonly attach themselves to humans. This tick has been reported from 53 of California's 58 counties at elevations from sea level to over 7,000 feet. Approximately 80 species of lizards, birds, and mammals have been recorded as hosts of this tick throughout its distribution in western North America (along the Pacific Coast from California north to British Columbia, and in Nevada, Utah, and Idaho).

Since 1974, I have been studying the ecology and epidemiology of several tick-borne bacterial, rickettsial, and viral diseases in northern California, with emphasis on Lyme disease during the 1980s. Many of these investigations have been conducted at the University of California Hopland Field Station in Mendocino County, an endemic area for Lyme disease, Rocky Mountain spotted fever, tularemia, and other tick-borne diseases.

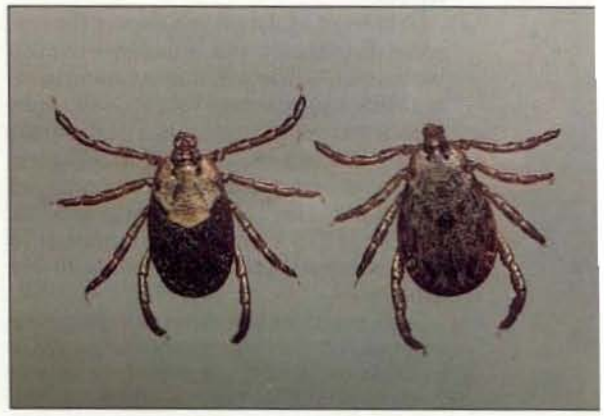
More recently, the field studies of Lyme disease were expanded to the UC Sierra Foothill Range Field Station in Yuba County. In 1987, the investigation reported here was undertaken at both field stations to determine the seasonal distribution and abundance of adults of the western black-legged tick and the Pacific Coast tick, *Dermacentor occidentalis*. The latter is another human-biting tick with a broad host range; in California, it has been collected from approximately 25 species of small to large-sized mammals or vegetation in 54 counties. Several bacterial, rickettsial, and viral agents have been detected in or isolated from the Pacific Coast tick in California. This tick is known also from Oregon and northern Baja California, Mexico.

Procedures

The Hopland Field Station (HFS) is a 5,300-acre agricultural sciences research facility on the western slopes of the Mayacmas Mountains in the Russian River Valley in northwestern California. The terrain consists of rolling hills and scattered ravines covered by seven major vegetational types including grass, woodland-grass, dense woodland, and chaparral. Elevations are between 500 and 3,000 feet. The climate is Mediterranean with hot, dry summers and cool, wet winters.

The Sierra Foothill Range Field Station (SFRFS) also has hot, dry summers and cool, wet winters. The soil, terrain, and vegetation are typical of the steep western Sierra Nevada foothills mixed with small local valleys.

At Hopland, ticks were swept from chaparral with a flannel tick-drag about 10 square feet in surface area. Sampling, starting at 8:15 to 9:20 a.m., was conducted at approximately weekly intervals on 69 dates from February 10, 1987 to August 15, 1988. The study site was the south-facing slope of a mountaintop (2,900 feet) covered by chaparral and grassland. Chamise (*Adenostoma fasciculatum*), oaks (*Quercus* spp.), and California lilac (*Ceanothus*) were the principal chaparral species; chamise was the dominant plant.



Male (above left) and female (above right) western black-legged tick. Actual size of the unfed female is about a tenth of an inch. Below, the female (left) and male (right) Pacific Coast tick. Actual size of the unfed female is about an eighth of an inch.

Chaparral abutting grassland was sampled for ticks along four 164-foot transects. The number of drags taken along each transect and the number of adult ticks collected by species and sex were recorded. Each drag-sample was taken by slowly sweeping upward from the base of a plant to a height of 1.6 to 3.3 feet and then downward in an approximate 180-degree arc. Drag-samples were checked individually for ticks, all of which were identified in the field and released on vegetation at the site of capture.

At Sierra Foothill, sampling usually was in the morning, starting at about 8:30, on 38 dates (January 28, 1987, to June 15, 1988) at one site and on 36 dates (January 29, 1987 to June 9, 1988) at another. On 9 dates, sampling began in the early afternoon between 2:00 and 3:00 at either site. Blue oak (*Quercus douglasii*) was the dominant tree species at each site; lesser numbers of California black oak (*Q. kelloggii*) and interior live oak (*Q. wislizenii*) also were present. One site (K-21) was at an elevation of 1,700 feet and the other (SH1-31) at 650 feet; both sites were on north-facing slopes.

Three 164-foot, parallel transects were established about 33 feet apart in the grass understory at each site. The operator took individual drag-samples as he walked slowly along each transect, laying the drag horizontally on the grass at his right side, then slowly sweeping the drag in front of him in a 180-degree arc to his left. Ticks in each drag-sample were identified to species and sex and released at the site of capture. The number of ticks collected and the number of drags taken per transect were recorded.

Data were analyzed to compare the seasonal distribution and abundance of male versus female ticks within species and western black-legged versus Pacific Coast adults within and between localities (HFS versus SFRFS) and between sites at SFRFS. Figures presented here are based on data gathered at HFS and at the SH1-31 site at SFRFS; site K-21 at SFRFS yielded results similar to those obtained at the SH1-31 site with few exceptions.

Daily maximum-minimum temperatures were recorded with hygrothermographs in outdoor weather shelters at elevations of 2,900 feet (HFS) and 675 feet (SFRFS). The temperatures were averaged over weekly intervals and compared with the seasonal abundance and distribution data gathered for each tick species at each location.

Results

At Hopland, few western black-legged ticks were collected from chaparral early in 1987, but a slight fall peak occurred in November (fig. 1). In the first half of 1988, adults became active in January and ceased host-seeking by early June with a pronounced peak of activity in early March (37 ticks per 100 drags). The seasonal distribution and abundance of males and females were similar (data not shown). The small peak of activity in the fall of 1987 occurred when air temperature was approaching its annual low, whereas the much larger peak in early March 1988 occurred after temperatures had risen considerably (maximum and minimum temperatures on the date of peak abundance were 64° and 44°F).

At both Sierra Foothill sites, the western black-legged tick was active from about mid-fall until mid-spring with a single peak of activity in winter at the SH1-31 site (fig. 2) and identical peaks in fall and winter at the K-21 site (data not shown). The greatest abundance occurred on March 4, 1987 (24 ticks per 100 drags) and on January 21, 1988 (28 ticks per 100 drags) at the SH1-31 site, and on February 19 and November 20, 1987, and February 3, 1988 (each 20 ticks per 100 drags) at K-21. Seasonal occurrence and abundance of females and males were similar at both sites, except that females contributed significantly more than males to the fall 1987 peak, and males contributed more than females to the early February 1988 peak at the K-21 site.

Seasonal western black-legged tick activity appeared to be associated inversely with temperature, beginning in fall as air temperature approached its annual low and peaking in winter as temperatures rose slowly. The maximum and minimum daily temperatures on the single fall and four winter peaks of tick activity at both sites ranged from 54° to 68°F and from 30° to 54°F, respectively.

The Pacific Coast tick was usually active at Hopland from winter until late spring/early summer, with greatest abundance in late winter or early spring (March 7 to 31) (fig. 1). More than twice as many ticks were collected during the seasonal peak in 1988 as in 1987 (35 versus 15 ticks per 100 drags). Most tick activity began at about the time daily maximum/minimum temperatures had reached their annual lows and then increased gradually thereafter as temperature increased. The seasonal distributions of female and male ticks overlapped considerably and their abundance was comparable (data not shown).

Similarly, the Pacific Coast tick was active primarily in the winter and spring and, to a lesser degree, in the fall at both Sierra Foothill sites (fig. 2 and data not shown). However, this tick was significantly less abundant at each Sierra Foothill site than at Hopland; the seasonal peaks in abundance (early February to mid-April) ranged between only 1.4 and 5.8 ticks per 100 drags at Sierra Foothill. There also was considerable variation between sites and years; for example, tick abundance was much greater in the late winter/spring of 1987 than in these same periods in 1988 at the K-21 site, whereas the reverse was true for the SH1-31 site. Seasonal distribution and abundance of females and males were similar, and appeared to be associated with rising mid-winter temperatures.

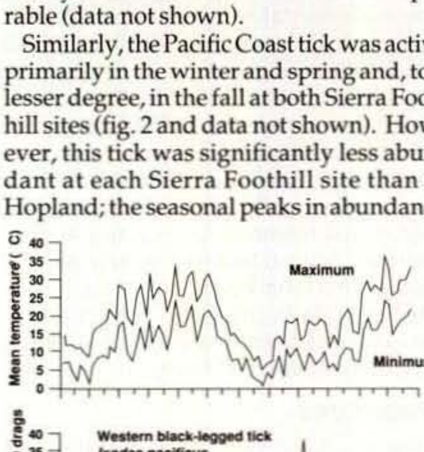


Fig. 1. At Hopland Field Station, adult western black-legged tick activity showed a small peak in the fall of 1987. WBT was active from January to June 1988, with a large peak in early March 1988. Pacific Coast tick activity peaked in late winter or early spring.

Conclusions

Adults of both tick species are active mainly during the cooler seasons in coastal (Mendocino) and inland (Yuba) counties of northern California. Other climatological factors besides temperature, either singly or in combination, may influence host-seeking by such ticks: solar radiation, relative humidity (inversely related to temperature in Mediterranean climates), and day-length (photoperiod). Although the seasonal activity periods of these ticks are similar in both counties, considerable variation occurs within sites between years; as shown at Sierra Foothill, variation in abundance also occurs between sites within years.

Chaparral was swept for ticks at Hopland because it is one of the major vegetational types there, and earlier studies had revealed that it is heavily tick-infested. Chaparral, however, is quite restricted in distribution at Sierra Foothill. Therefore, woodland grass, the predominant vegetational type there, was sampled instead.

The abundance of the western black-legged tick was comparable at both field

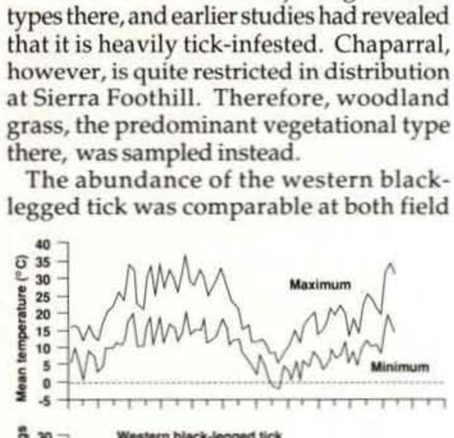


Fig. 2. At the Sierra Foothill Range Field Station site SH1-31, adult western black-legged ticks were active from mid-fall to mid-spring, peaking in winter. Pacific Coast ticks were active in the winter and spring, and somewhat in the fall.

stations, but Pacific Coast ticks were much more numerous in chaparral at Hopland than in grassland at Sierra Foothill in both years. The annual activity periods of adults of these two species span several seasons, particularly fall to spring, but the western black-legged tick usually reaches its greatest abundance in mid to late winter, while Pacific Coast tick populations normally peak in late winter to early spring. These tick species seem to have primarily one peak of activity annually, although the western black-legged tick may have a fall peak of variable height preceding a major winter/early spring peak. It is unclear whether the fall peaks observed for the western black-legged tick originated from different or the same cohorts of subadult ticks or merely from sampling differences due to variable climatic conditions.

The seasonal periods of activity of these two tick species on vegetation had not been determined systematically before. An earlier study of western black-legged ticks (primarily adults) on 71 Columbian black-tailed deer at Hopland found that more deer were infested in winter and spring than in summer or fall, but that tick abundance was actually greater in fall and winter. Tick abundance on deer in fall and winter did not differ significantly, but the prevalence of infestation was greater in winter (100%, n=12) than in fall (56%, n=18). It is not surprising that these results and my findings agree, since ticks collected with a drag represent the same host-seeking component of the population that infests deer moving through vegetation.

Knowledge of the seasonal activity of all parasitic stages (subadults and adults) of vector ticks is needed to identify periods of greatest risk of exposure to tick-borne agents. Although adults of the western black-legged and Pacific Coast ticks commonly infest people, recent collection records demonstrate that nymphs of these ticks bite humans more often than was realized previously. Moreover, spirochete-infection rates in nymphs of the western black-legged tick are sometimes comparable to those in adult ticks (usually about 1% to 2%).

Besides the Lyme disease spirochete, the western black-legged tick has been found infected naturally with an unclassified rickettsia of the spotted fever group and the bacterial agent that causes tularemia, and it has been implicated as an occasional cause of tick paralysis in dogs. The Pacific Coast tick has been found infected naturally with Colorado tick fever virus, spotted fever group rickettsiae, the agents producing Q-fever and tularemia, and, more recently, the Lyme disease spirochete (although less frequently than the western black-legged tick). It also has been implicated as a cause of tick paralysis in cattle, deer, and ponies in California.

Robert S. Lane is Associate Professor, Department of Entomological Sciences, University of California, Berkeley. *The author thanks Manfred Hoben, Robert J. Keiffer, Tony Wanzer, and Ken Whittaker, Hopland Field Station, and Tim A. Clark, Sierra Foothill Range Field Station, for collecting ticks; Nancy O'Ferrall, HFS, and Carol L. Hollingsworth, SFRFS, for weather data; and Esther Omi-Olsen and Stephen A. Manweiler, UC Berkeley, for help with data analyses and preparation of figures.*

Eucalyptus shows unexpected cold tolerance

Janine K. Hasey ❑ J. M. Connor

Although some species of eucalyptus trees in an experimental plantation were damaged in a 1989 cold snap, several species and clones survived temperatures lower than previously thought to be tolerated. The trees are in a low-elevation Sierra foothill test planting used for studies assessing fuelwood growth rates.

Eucalyptus are fast-growing hardwood trees used in California for firewood, biomass, and pulpwood, but cold sensitivity is a major limitation determining where they can be grown successfully. Many species of this genus commonly planted in California are native to the subtropical regions of Australia and are sensitive to freezing temperatures. Eucalyptus plantings throughout California have suffered damage or have been killed because the species that was planted was not sufficiently cold-tolerant for the site.

One objective of a fuelwood test planting at the Sierra Foothill Range Field Station was to compare cold tolerances of selected eucalyptus species and clones at a low-elevation foothill site. In February 1989, an arctic cold front swept through northern California, giving us the unique opportunity to test the limits of reported minimum temperatures that certain eucalyptus species could tolerate.

Fuelwood plantation cultural practices, yield data, and growth characteristics at 3.5 years of age were presented in *California Agriculture*, November-December 1988. Our purpose in this article is to report and illustrate comparative freeze damage, injury ratings, and short-term recovery of the eucalyptus trees in a foothill plantation.

Methods

In March 1984, six eucalyptus fuelwood species or clones were planted as seedlings in a randomized complete block design with four replications. Each replicated block contains 49 trees planted on 6- by 6-foot spacings. A second plot, without replication, was planted for observation purposes in 1986 next to the main plot. It contains four clones also planted on 6- by 6-foot spacings. The elevation at the site is 575 feet with a 7% slope.

Air temperatures were measured at standard weather stations on the field station at elevations similar to that of the plantation. Low temperatures measured were 14°F on the mornings of February 4 and 5, 1989, and 18°F on February 6. Fourteen hours of temperatures below 20°F occurred on February 4, followed by 10 hours below 20°F the next day.

The species, clones, seed sources, and minimum temperatures below which severe freeze damage is expected are listed in table 1. Many factors influence the lowest temperature tolerated by a given species, including duration of the cold weather, the temperatures immediately preceding the cold snap, and physiological condition of the tree at the time of the freezing temperatures.

We used a freeze injury rating system with a six-point numerical scale, which was developed by University of California researchers following a severe freeze in northern and central California in 1972 (see table 2 footnotes). Injury was evaluated on two dates. The early rating on March 13, 1989, assessed the initial extent of the cold injury. Damage was visually estimated for each species by block (replicate). During the late rating on July 28, 1989, each tree was examined separately for short-term recovery.

Results

Early evaluations of the 1984 plot showed substantial damage to the C-1 clone and a lesser degree of damage to *E. globulus* (blue gum) (table 2). By the time of the later evaluation, the C-1 clone had made considerable recovery. The wide range in ratings within the species grown from seed (non-clones) is

Fuelwood plots in May 1989 (above left) showed overall damage from a severe February freeze. In August 1989 (above right), after the late evaluation, trees had recovered.

At the early evaluation in March 1989, injury was rated on a scale of 1 to 6 (no visible damage to above-ground plant dead; see table 2 footnotes). *Eucalyptus dalrympleana* at left in photo above was rated 1, and the C-1 clone next to it was rated 4. At right, *E. globulus* was rated 3; freeze damage was especially variable among individual trees. Below left, the C-2 clone had a 2 rating, compared with adjacent *E. viminalis* with a 1. Below right, severely injured *E. grandis* on left was rated 5, next to a C-2 clone with a 2.

Recovery was seen at the late evaluation in July 1989: *Eucalyptus grandis* clones (above left) showed the trunk sprouting of a 4 rating (two trees in foreground were rated 5). In close-up at left, secondary bud on trunk has sprouted following death of primary branch. Some *E. grandis* showed basal sprouting only (5 rating, above right).

TABLE 1. Species or clones, seed source, and reported minimum temperatures tolerated

Species or clone (common name)	Seed source	Reported mininimum temperature
		°F
1984 PLOT		
Eucalyptus globulus (blue gum)	Barnback, Australia	20
E. camaldulensis (river red gum)	Lake Albacutya, Australia	20
E. camaldulensis, C-l clone	Unknown—random selection	20
E. camaldulensis, C-2 clone	Improved Spanish seed	20
E. viminalis (manna gum)	South Coast, NSW Australia, 200-ft. elevation	16
E. dalrympleana (mountain gum)	Australia, longitude unknown, latitude 35 S, 800-ft. elevation	10
1986 PLOT		
E. grandis (rose gum), G-8 clone	Florida	25
E. grandis, G-12 clone	Florida	25
E. grandis, G-13 clone	Florida	25
E. camaldulensis, C-2 clone	Improved Spanish seed	20

* The low temperatures reported are from *Planting Eucalyptus for Firewood*, Leaflet 21297, University of California, Division of Agriculture and Natural Resources, ANR Publications, 6701 San Pablo Avenue, Oakland, CA 94608-1239.

TABLE 2. Eucalyptus freeze injury rating

Species or clone	Early evaluation*	Late evaluation† Mean	Range
1984 PLOT			
Eucalyptus globulus	3	2.7	1-6
E. camaldulensis	2	2.2	1-6
E. camaldulensis, C-l clone	4	2.0	1-6
E. camaldulensis, C-2 clone	2	1.2	1-2
E. viminalis	1	2.1	1-6
E. dalrympleana	1	1.2	1-6
1986 PLOT			
E. grandis, G-8 clone	5	4.1	4-5
E. grandis, G-12 clone	5	4.0	4
E. grandis, G-13 clone	5	4.0	4-5
E. camaldulensis, C-2 clone	2	2.6	2-3

* Early evaluation ratings: 1 = no visible damage; 2 = slight injury to leaves, new growth, terminal bud; 3 = moderate to severe injury to leaves and twigs; 4 = severe leaf injury, defoliation, major bark injury; 5 = branches mostly killed, main trunk alive; 6 = aboveground plant dead.

† Late evaluation: 1 = complete recovery, or no damage visible; 2 = few dead twigs and leaves apparent; 3 = few dead branches, twigs, and leaves apparent; 4 = sprouts on trunk and primary limbs (top and major branches dead); 5 = basal sprouts only (all other parts dead); 6 = dead, no recovery.

TABLE 3 Diameter at breast height (DBH) of live versus dead eucalyptus

Species	Live trees*	Dead trees◊
	inches	*inches*
E. globulus	5.1 ± 1.4	2.5 ± 0.7
E. viminalis	3.8 ± 1.8	1.5 ± 0.8
E. camaldulensis	4.3 ± 2.0	2.0 ± 0.4

* Mean of 13 trees per replication ± standard error.

◊ Mean of 25, 18, or 8 trees for all 4 replications of *E. globulus*, *E. viminalis*, and *E. camaldulensis*, respectively, ± standard error.

probably due to inherent genetic variability. Cold tolerance variability was especially evident in *E. globulus*, *E. viminalis* (manna gum), and *E. camaldulensis* (river red gum). At the late evaluation, 25 *E. globulus*, 18 *E. viminalis*, 8 *E. camaldulensis*, and 2 *E. dalrympleana* (mountain gum) were dead (rating six). In contrast, no C-2 clones and only 2 C-l clones were dead at that evaluation. The dead trees were the smaller individuals within a block (table 3).

In the 1986 observation plot, all three *E. grandis* (rose gum) clones showed severe damage at the early evaluation. The C-2 clone had light damage, as in the older plot. Trunk or basal sprouts were evident on *E. grandis* clones by early June. By the late evaluation, trunk and basal sprouts had grown substantially.

Conclusion

The eucalyptus species at this site survived temperatures lower than the minimums previously reported for those other than *E. dalrympleana*. That species is reported to tolerate temperatures as low as 10°F. Freeze damage was most severe on *E. grandis*. Annual measurements of diameter at breast height, tree height, and volume per acre will continue in an effort to determine optimum harvest time. As we accumulate data, we will attempt to learn whether freeze damage affected annual growth.

Janine K. Hasey is Farm Advisor, Cooperative Extension, Sutter-Yuba counties; and J.M. Connor is Superintendent, Sierra Foothill Range Field Station, Browns Valley. *The authors are grateful to Don Springsteen and staff at the station for field assistance.*

Use of long-range weather forecasts in crop predictions

Bryan C. Weare

Uncertainties in weather forecasts still present the greatest problem in making useful crop predictions. Weather variables needed for crop growth models are minimum and maximum temperatures, precipitation, and solar radiation. Each of the three potential sources of long-range forecasts of such variables has deficiencies, but improvements offer some encouragement.

Farmers, commodities dealers, water managers, and others have long sought to forecast production of major crops through the use of models requiring some sort of weather input. Steady strides have been made recently in developing physiological models of crops such as wheat and rice. Such models should include daily minimum and maximum temperatures, precipitation, and solar radiation. Up to now, these crop models have generally been used with past weather observations or statistical weather generators. This report inquires into whether meteorological forecasts can provide variables accurate enough to provide skillful crop predictions.

Types of weather forecasts

Three general types of medium- and long-range weather forecasts are available: (1) 3- to 10-day forecasts of daily weather made by the same numerical weather models used for the typical 1- and 2-day forecasts seen in newspapers or on television; (2) 90-day weather outlooks generated by the National Weather Service and others based on statistical forecast methods; and (3) the relatively recent 10- and 20-day average forecasts made 5 to 30 days in advance from special runs of the operational weather forecast models. To understand the use of these forecasts in preparing crop models, attention must be given to the kind of the forecast weather variables used in each case and to the overall quality of the forecasts.

Numerical forecasts. The numerical models are large physical/mathematical computer models of the global atmosphere. These solve six or more coupled equations governing atmospheric behavior for a large number of horizontal and vertical points on the globe. Figure 1 shows the typical grid structure of such models. The spacing between horizontal grids is commonly about 200 km (120 miles). Between 10 and 30 levels are in the vertical columns. Using this system, complicated physical equations can be solved at 150,000 to over 400,000 points around the earth.

These forecasts are begun from observed initial conditions, based on surface, weather balloon, satellite, and various other meteorological observations. Variables are updated in model "time" at intervals of about 30 minutes. The results represent the combined values of weather variables at each of the grids for each 12-hour period in the future. All important weather variables are potentially available, including those necessary for the physiological crop models.

One problem, however, in using numerical forecast variables in crop models is that the model grid spacing of about 120 miles is much larger than the usual agricultural regions of tens of square miles. Moreover, a single model grid may include such diverse surface features as oceans, deserts, and mountains. A question is how one should interpret the average temperature or precipitation for such a large region in terms of the weather actually affecting a crop. Such problems are often overcome by applying model output statistics (MOS). MOS compares large-scale model predictions of temperature or precipitation with observed weather variables for subregions the size of agricultural regions.

An even bigger problem is the uncertainty of weather model forecasts and how they lead to possibly overwhelming uncertainties in crop production forecasts. Figure 2 illustrates a measurement of forecast skill for 500 millibars geopotential height, the most important variable describing large-scale air flow, for the model developed at the European Center for Medium-range Weather Forecasting (ECMWF). This model is generally recognized as the best in the world.

The skill is assessed in terms of "anomaly" correlations between the forecast weather minus the model's "climatological mean" and the actual observed weather on the forecast date minus the observed climatological mean. These correlations are very near the maximum value of one for 1- and 2-day forecasts and decrease steadily thereafter. These relatively short-range forecasts have improved since 1972, mainly with the introduction of new computers and finer grid spacing.

The horizontal line on figure 2 is the approximate skill of a persistence forecast, a forecast specifying that the weather tomorrow will be exactly the same as today's. This is generally assumed to be the standard of accuracy that a numerical model must beat to be respectable. At present, this standard is met by the ECMWF forecasts out to 6 or 7 days. The variable geopotential height shown in figure 2 is a measure of the force driving the atmospheric circulation and is the most common measure of forecast skill. Model skills for other variables are generally lower, especially for precipitation,

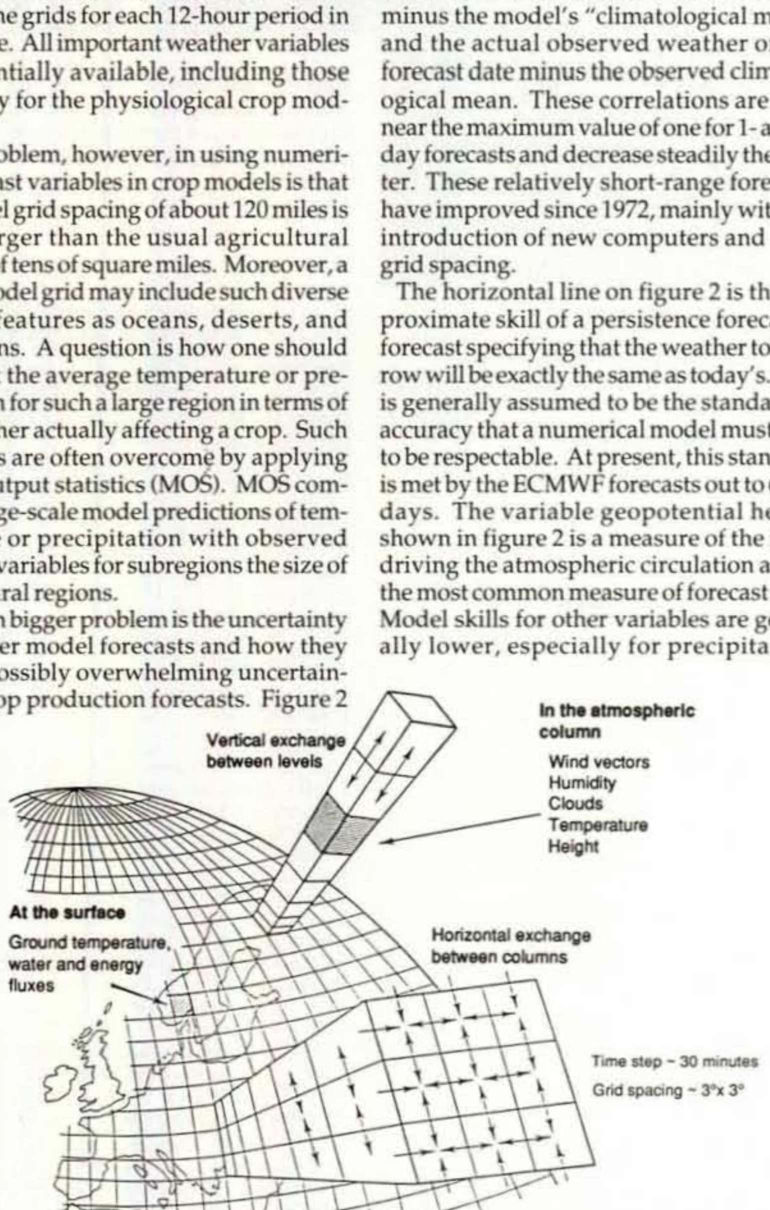


Fig. 1. Grid system for a typical global weather forecast model. (Source: Henderson-Sellers and McGuffie, *A Climate Modelling Primer*)

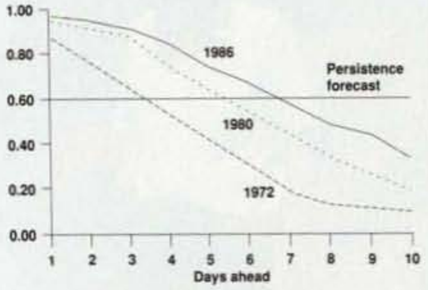


Fig. 2. Measurement of skill in forecasting daily 500 mb geopotential height, the variable describing large-scale air flow. Anomaly correlations relate forecast heights to observed values.

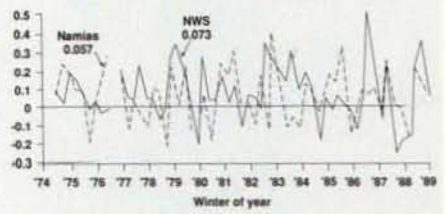


Fig. 3. Forecast skill, indicated by fraction of grids correct minus fraction attributable to chance, for seasonal U.S. precipitation forecasts made by National Weather Service and J. Namias. Average skills are 0.073 and 0.057, respectively. Skills less than zero are poorer than chance.

whose forecasts are probably about half as accurate as those shown in figure 2.

Outlooks. The second kind of medium- to long-range forecasts available are statistically derived from models using predictors such as 500 mb geopotential heights, sea surface temperatures, and areas of snow cover. These are made for the United States at the beginning of each 3-month season by the National Weather Service and Jerome Namias, a researcher at the Scripps Institution of Oceanography at the University of California, San Diego. The outlooks are made for average temperature and total precipitation for the contiguous United States on spatial grids like those in figure 1. Outlooks are not forecasts of actual temperature or precipitation, as in the case of numerical models, but are only forecasts of whether the average temperature or precipitation will be above, near, or below the climatological mean. There are thus only three equally likely forecast possibilities.

As with the numerical weather model forecasts, use of outlooks in crop predictions requires estimates of how changes in large-region average temperature and precipitation would affect individual growing areas. Furthermore, estimates of minimum and maximum temperature, rather than mean temperature, and solar radiation would have to be made using statistical analyses of past observations. In addition, seasonal means would have to be translated into typical daily weather. Professor S. Geng at UC Davis has shown that this is possible for monthly mean data using a

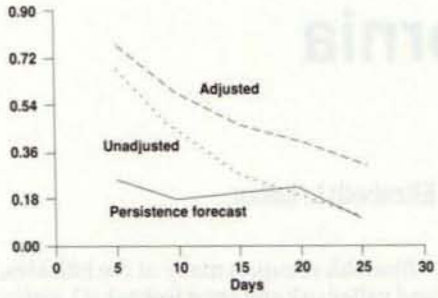


Fig. 4. Skills of forecasts made 5 to 25 days in advance using observed averages. "Adjusted" results incorporate statistical information of past model errors.

weather generator, which calculates typical day-to-day weather variations based on past daily statistics for individual weather stations.

As with the numerical weather forecasts, the largest obstacle to the use of the seasonal outlooks in crop forecasts is the uncertainty in the forecast weather. Figure 3 shows another measure of forecast skill for the precipitation outlooks made by the National Weather Service and J. Namias from 1974 to the present. The skill score in figure 3 is the fraction of grids in the United States with the correct forecast (above, below, or near normal) minus the fraction that is expected to be correct from chance alone, 33%. Both sets of outlooks have both positive and negative skill values. The negative values correspond to forecasts that are poorer than a simple guess. The average skills are positive, but they are quite small. Skill scores for average temperature are similar.

Although these results are discouraging, the outlooks are sometimes accurate and they may eventually be relatively skillful. Although some other long-range weather forecasters might suggest skills much better than those illustrated in figure 3, careful assessment would probably indicate similar results.

Average forecasts. In the last few years, national meteorological centers have begun to experiment with a third type of medium- to long-range weather forecast. The 10- and 20-day average forecasts are done 5 to 30 days in advance and are based on longer runs of the models similar to those used for the 10-day daily forecasts. The skills of the daily forecast decrease rapidly after 10 days, in part because of the nearly chaotic nature of the atmosphere. Nevertheless, it is believed that the skills for multiday averages are likely to be relatively large.

Figure 4 illustrates examples of the skills of such forecasts made by the climate model at the Geophysical Fluid Dynamics Laboratory at Princeton. The anomaly correlations are generally higher for a 10-day average forecast than the daily results shown in figure 2. The correlations also remain higher than those expected from persistence, even for the 25-day forecasts. Furthermore, adjustments of the model predictions, taking into account known model deficiencies, improve the skills considerably. These results are encouraging, because they seem to imply skill considerably greater than those of the statistical/empirical outlooks. As has been true of other numerical model forecasts, the skills of these 10- or 20-day average forecasts seem likely to improve.

Although these average forecasts derived from numerical models seem encouraging, several factors suggest caution in their use. As with all of the forecasts discussed, weather values corresponding to the averages over very large regions must be transformed to values appropriate to the scale of a crop model. Similarly, daily weather variables must be estimated from the 10- or 20-day means. Most importantly, such forecasts have been made for relatively short times. The skill scores in figure 4 thus may be overly optimistic, or perhaps pessimistic.

Conclusions

Before the available weather forecasts can be used in crop production models, a number of technical problems must be overcome. These include the effects of the differences between weather forecast results and crop model requirements in horizontal resolutions, temporal sampling, and specific weather parameters. Most importantly, it is necessary to resolve the question of how to incorporate large uncertainties in any of the long- or medium-range weather forecasts into the crop models.

Even if improvements occur in the future, uncertainties in the forecasts could suggest that crop predictions based only on a single set of forecast variables would be of little value. The known uncertainties will probably require that the crop models be run a number of times with various weather inputs, ranging around the predicted values. In this way, a range of crop predictions will be available whose variations will give a measure of the uncertainties of the prediction.

It will be necessary to assess how best to use the crop predictions. One question, for instance, is whether there are any management decisions likely to be profitable that can be made using a 10-day crop forecast with an average skill of 50%. The ultimate goal must be to maximize the utility of predictions given realistic assessments of their uncertainties.

Bryan C. Weare is Professor, Department of Land, Air, and Water Resources, University of California, Davis. *This work was supported by the University of California Agricultural Experiment Station. The author thanks Shu Geng and Terrel Barry for their help in explaining the crop models. Figure 1 is taken from* A Climate Modelling Primer *by Henderson-Sellers and McGuffie, published by John Wiley and Sons, 1987.*

Grafting California native oaks

William D. Tietje ❑ John H. Foott ❑ Elizabeth L. Labor

Preliminary results of grafting blue oak and valley oak scions to blue oak rootstock are encouraging. It appears that grafting of California native oaks has potential research and management applications.

Californians have become increasingly concerned about loss of native oak trees and their contribution to the state's natural beauty, wildlife habitat, and economy. During the past century, some oak species have not regenerated well in some parts of the state, especially blue oak (*Quercus douglasii*), valley oak (*Q. lobata*), and Engelmann oak (*Q. engelmannii*). Acorns and seedling oaks are often trampled or eaten by livestock. Since European settlement of California, deer (*Odocoileus hemionus*) and small rodents, which feed on acorns and seedlings, have increased in number. Mediterranean annual grasses, introduced in the mid-1700s, have gradually replaced native perennial bunch grasses. There is increasing evidence that Mediterranean annuals inhibit oak regeneration by competing for available space and soil moisture. Poor regeneration is only part of the problem: in the past 20 years, residential and commercial development has occurred on over 275,000 acres of oak rangeland, and use of native oak trees for firewood has increased.

The University of California and the California Department of Forestry and Fire Protection, under the auspices of the Integrated Hardwood Range Management Program, currently fund studies of several aspects of the oak problem. A principal focus is oak regeneration. On the site of a stump-sprouting study in southern San Luis Obispo County, a deer-proof fence was constructed around 1-1/2 acres of dense blue oak. Availability of an enclosed area protected from foraging by deer and livestock provided us with an opportunity to explore whether blue oak could be grafted successfully in oak rangelands.

Study area

The blue oak grafting site is on a private ranch in San Luis Obispo County about 6 miles southeast of Pozo, California. Average monthly temperatures range from about 43°F in January to 70°F in July. Average annual rainfall totals 20 inches. Typically, no rain occurs during May to October. Sandy-loam soils dominate the area.

Blue oak occupies many of the hillsides, and valley oak and coast live oak (*Q. agrifolia*) are scattered over the more moist valleys and gently rolling areas. Western sycamore (*Platanus racemosa*) and digger pine (*Pinus sabiniana*) are frequently interspersed with the oaks. Woody understory vegetation consists mostly of toyon (*Heteromeles arbutifolia*), manzanita (*Arctostaphylos* spp.), and poison oak (*Rhus diversiloba*). Forbs and annual grasses occupy the woodland floors and grassy open areas.

Methods

Because rainfall was low during the previous 3 years, blue and valley oak trees on the study site did not produce suitable scion wood for grafting in 1989. We therefore collected scion wood (current season's growth) on March 8 about 20 miles from the study area along a county road where runoff had provided better growing conditions. Scion wood, averaging 1/4 inch in diameter at the cut end and 2 feet in length, was taken from branches of small blue and valley oak trees. Immediately after harvest, the wood was put in a portable ice chest and, upon return from the field, stored for about a month in a refrigerator at 37°F.

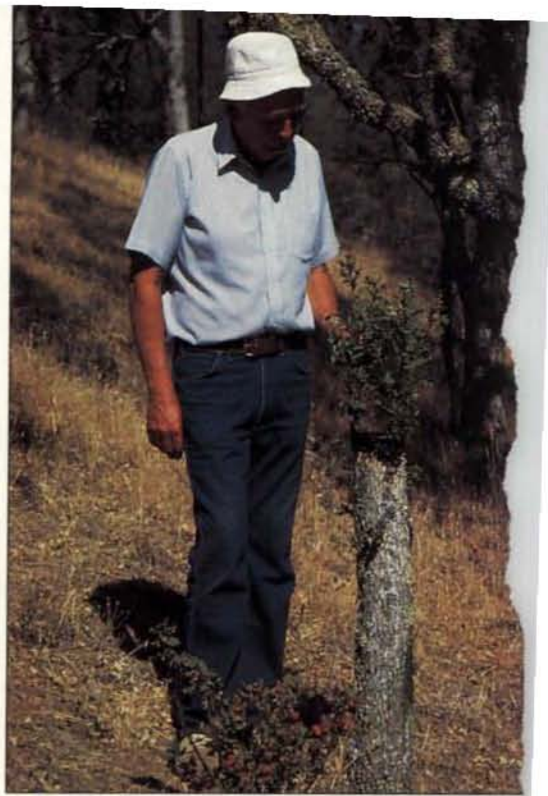
Leaf flush occurred among blue oaks on the study site in early April. On April 7, just before grafting, six 3- to 8-inch-diameter blue oak rootstock trees were cut at about a 3-foot stump height, and 4-inch-long scions were cut from the scion wood collected in March. Each scion had several buds.

Blue oak scions were grafted onto three of the blue oak stumps and valley oak scions onto the three other stumps. Except for one blue oak stump grafted with two scions, three scions were grafted per stump. We used the modified bark grafting technique (as described in *Propagation of Temperate-zone Fruit Plants*, Leaflet 21103, by H. T. Hartmann and J. A. Beutel, UC Division of Agriculture and Natural Resources). After grafting, an asphalt sealant was applied to the cut surfaces of the stumps and scions to minimize water loss and potential infection.

Preliminary results

We measured scion shoots on June 23 and September 12 (table 1). In June, scion growth was present on two of the three stumps grafted with blue oak and on all three stumps grafted with valley oak. Two of eight blue oak scions had shoots, one on each of two stumps. One scion had two and the other three shoots; the longest shoot was 6 inches. Five of the nine valley oak scions had shoots, one each on two of the stumps and all three on the third stump. Living scions had one to three shoots each, the longest of which was 15 inches.

In September, six of the seven scions alive in June were still alive; one valley oak scion



At the study site in San Luis Obispo County in September 1989, Farm Advisor Jack Foott examines an oak graft. Three valley oak scions had been grafted onto blue oak rootstock the previous April (below).

TABLE 1. Results of grafting blue oak scions onto blue oak rootstock (BB) and valley oak scions onto blue oak rootstock (VB) in southern San Luis Obispo County

Tree No.	Scion, rootstock*	Number of scions: Per stump	Number of scions: Alive (Jun/Sep)	Longest shoot (Jun/Sep)
				inches
73	BB	2	1/1	6.0/8.5
77	BB	3	0/0	—
87	BB	3	1/1	4.0/10.0
28	VB	3	3/3	14.0/14.5
54	VB	3	1/1	15.0/15.0
75	VB	3	1/0	1.0/—

* Stump diameters where grafted were 3 to 7 inches.

(tree No. 75) that had a 1-inch sprout in June had died. The other scion shoots appeared healthy and vigorous. Little scion growth occurred between June and September, except for a blue oak shoot that grew 2-1/2 inches (tree No. 73) and another that grew 6 inches (tree No. 87).

Conclusions

Based on our preliminary results, it appears that at least one native oak species, blue oak, can be grafted. The grafts have been monitored for only one season and sample size is small. Future incompatibility of the grafts may occur, especially with the valley/blue oak combination. Many years of study are needed to evaluate the grafting technique adequately.

If grafting of California's native oaks proves successful, it may have research and management applications. For example, seed orchards from genetically superior oak trees could be established; this is the most common use of grafting with conifer trees. Another research application of grafting would be detection of genetic variability by collecting scion wood throughout one oak species' distribution and grafting it to a mother tree (K. Rice, personal communication).

Grafting has possible uses in managing a firewood harvesting operation. Studies show that blue oak trees over 10 inches in diameter are poor sprouters. Further study may show that grafting could be used to regrow some of the larger trees cut for firewood. Also, grafting genetically superior scions onto rootstock may result in faster growth and more rapid establishment of a stand of trees.

Because of these potential applications, grafting of California native oaks is a suitable subject for continued research. The following studies are planned: (1) increase sample size of the grafting trial to 20 blue/blue and 20 valley/blue oak grafts; (2) graft onto trees that are poor sprouters (those over 10 inches in diameter); and (3) graft valley oak scions onto coast live oak rootstock.

Our intention in the 1989 experiment was to test the feasibility of grafting blue oak. Preliminary results are encouraging. With continued study, the usefulness and application of grafting California native oaks can be more fully assessed.

William D. Tietje is Natural Resources Specialist/Central Coast, Department of Forestry and Resource Management, University of California, Berkeley; John H. Foott is Farm Advisor; and Elizabeth L. Labor is Extension Horticulture Student Intern. All three are stationed at the UC Cooperative Extension office, San Luis Obispo County. *The authors thank Jim Sinton, Avenales Ranch, for permitting access to his land for study purposes.*

Control of two avocado mite pests

J. Blair Bailey ❑ Kirk N. Olsen

Several materials were tested for possible use when avocado brown mite and sixspotted mite populations build up, threatening to cause extensive leaf drop. Sulfur was effective against avocado brown mite. Others, at present unregistered for this use, were effective against both mites.

Avocado brown mite and the sixspotted mite are the two most common mite pests of California's 75,000 acres of commercial avocados. Generally, outbreaks of avocado brown mite occur in areas with a coastal or intermediate climate in southern California. Sixspotted mite infestations have been largely confined to lemons and avocados growing in the coastal areas of Santa Barbara and San Luis Obispo counties. In most instances of sixspotted mite infestations on avocados, the grove has been near an infested lemon grove. Highest populations of both mite species are usually seen during late summer and early autumn. Both mites produce webbing on leaf surfaces.

Avocado brown mite, *Oligonychus punicae* (Hirst), is found on the upper sides of avocado leaves. Feeding injury begins on the midrib and extends out along the lateral veins, eventually covering the entire upper surface. When populations are very high, this mite will move onto lower leaf surfaces. Feeding removes chlorophyll, causing leaves to turn a brownish color, commonly referred to as bronzing. The avocado brown mite also removes chlorophyll from the surface of avocado fruit, which sometimes results in downgrading by packinghouses.

Studies have shown that bronzing reduces transpiration and photosynthesis rates (*California Agriculture*, May-June 1982). Leaves can recover from this injury, but may not if the infestation persists. Extensive leaf drop is likely to occur if avocado brown mite population densities reach an average of 75 to 100 adult females per leaf for short periods, or when densities remain at 50 females per leaf for several weeks.

The sixspotted mite, *Eotetranychus sexmaculatus* (Riley), is found on the undersides of leaves and is not confined to any particular area. In high populations, however, they seem to prefer areas immediately adjacent to the midrib and larger lateral veins. Feeding causes removal of chlorophyll and development of grayish spots or blisters. Leaf drop occurs when population densities reach an average of 5 to 10 adult male and female mites per leaf.

Only sulfur or narrow range 415 (NR-415) spray oil are currently registered for use to control mites on bearing avocados in California. The use of NR-415 spray oil is restricted to the Hass variety of avocado. However, neither material has been considered entirely effective for controlling either pest.

In search of more reliable materials, we tested six products in two field trials. Products tested were Plictran (cyhexatin), Omite (propargite), Vendex (fenbutatin oxide), flowable sulfur, insecticidal soap, and NR-415 spray oil. The first three materials are well-known acaricides used on many food and ornamental crops. Insecticidal soap is safe to use around human habitation, and other researchers have reported that it gives fair to good control of other mite species. Sulfur and NR-415 spray oil were included for comparison.

TABLE 1. Control of avocado brown mite (ABM) with acaricides, Santa Barbara County, September-October 1982

Treatment and formulation/ 100 gallons	Average number mites/ 20 leaves*† ABM	Predacious
Omite 30W, 24 oz	0.8 a	0.2 a
Flowable sulfur, 20 oz	0.8 a	6.4 bc
Plictran 50W, 6 oz	1.4 a	0.2 a
Vendex 50W, 6 oz	3.6 a	9.4 c
Insecticidal soap, 3 gal	17.0 b	2.4 ab
NR-415 spray oil, 5 qt	21.4 b	5.4 bc
Untreated check	328.2 c	28.0 d

* 7 days after treatment
† Means followed by the same letter are not significantly different ($P = 0.05$, Duncan's Multiple Range Test).

TABLE 2. Control of sixpotted mite (SSM) with acaricides, Santa Barbara County, September-October 1982

Treatment and formulation/ 100 gallons	Average number mites/20 leaves, days posttreatment* SSM 7	SSM 21	Predacious 7
Plictran 50W, 6 oz	28.6 a	28.8 a	0.4 a
Omite 30W, 24 oz	58.4 ab	157.4 b	2.4 ab
Insecticidal soap, 3 gal	84.4 b	222.8 bc	2.4 ab
Flowable sulfur, 20 oz	95.4 b	205.2 bc	7.6 bcd
Vendex 50W, 6 oz	149.8 b	221.6 bc	13.8 d
NR-415 spray oil, 5 qt	169.8 b	259.6 bc	8.0 bc
Untreated check	375.8 c	353.6 c	11.2 cd

* Means followed by the same letter are not significantly different ($P = 0.05$, DMRT).

Avocado mite control (continued)

Methods

In both trials, materials were applied by handgun from an orchard hydraulic spray rig at 400 pounds per square inch. The dilution factor for all materials was based on 1,000 gallons per acre, that is, 10 gallons spray per tree times 100 trees per acre. All trees were sprayed to the point of runoff. Rates of chemicals applied in both studies are presented in tables 1 and 2.

A randomized block experimental design was used with five single tree replicates of each treatment and a single tree buffer separating each test tree. Treatments were evaluated by taking random samples of 20 leaves, at a height of 2 to 8 feet above the ground from each of the treated and untreated trees. Samples were taken to the UC South Coast Field Station, where they were kept at 40°F until examined.

All samples were examined with a dissecting microscope within 3 days of collection. Only motile stages of the mites, on both sides of one-half of each leaf, were counted. Leaves were examined for both pest mites and predacious mites, in particular *Euseius hibisci* (Chant).

Avocado brown mite trial

The avocado brown mite trial was conducted in a 9-year-old Hass avocado grove in Santa Barbara County. The population before treatment was high, providing useful conditions in which to evaluate acaricide efficacy.

A count taken 7 days after treatment showed Omite, Plictran, Vendex, and sulfur to be significantly superior in mite control to insecticidal soap or oil. However, the latter two provided considerable suppression (table 1).

All treatments substantially reduced predacious mite populations. Omite and Plictran treatments resulted in the greatest reduction of beneficial mites, whereas Vendex, sulfur, and oil were the least damaging. Declining avocado brown mite and predacious mite populations precluded any further sampling.

Sixspotted mite trial

The other trial was conducted in a 20-year-old Hass avocado grove on a 20- by 40-foot spacing, also in Santa Barbara County. A pretreatment leaf sample taken on the day of treatment showed an average of 28 sixspotted mites per leaf. This is four to five times the number generally observed to cause leaf drop; leaf drop was extensive.

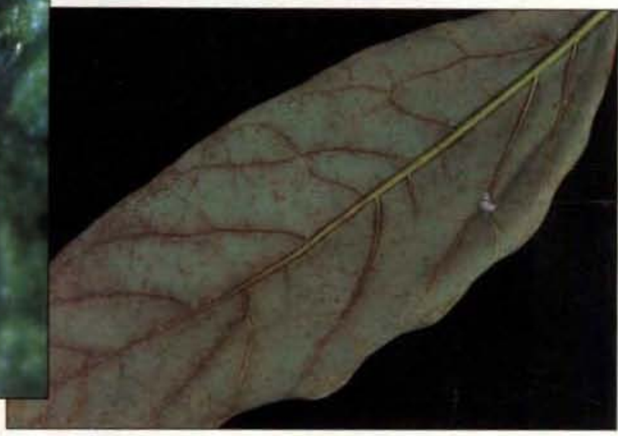
Plictran out-performed all other materials tested for control of sixspotted mite at both the 7- and 21-day intervals after treatment. Omite provided adequate control at the 7-day count (table 2). At that count, Omite, Plictran, and insecticidal soap also significantly reduced predacious mite populations. Vendex and sulfur had the least effect. Beneficial mites were not counted 21 days after treatment.

Omite 30 W caused some spotting on the undersides of leaves in both trials. However, Omite CR has produced fewer phytotoxic effects in other tests. No phytotoxicity was noticed on the leaves or fruit of any of the other treatments.

Max Badgley

Avocado brown mites (above left) may feed on the fruit surface. On leaves, they usually feed on the upper surface, where injury (above) begins on the midrib, extends along lateral veins, and eventually covers the surface. Sixspotted mite (below left) feeds on the underside of the leaf (below).

Jack Kelly Clark



Max Clover

Conclusions

Omite, Plictran, Vendex, and sulfur were equally effective in controlling avocado brown mite. Of the materials tested in our study, both Vendex and sulfur were effective and caused the least reduction of predacious mites. Vendex, as well as Omite and Plictran, however, are not registered at present for this use on bearing avocados in California.

Even though less common than avocado brown mite on avocados, sixspotted mite appears to be more damaging because low population densities can cause extensive leaf drop. Omite was the only effective material, other than Plictran, against sixspotted mite in our studies.

Generally, both avocado brown mite and sixspotted mite are kept under adequate control by the predacious mite *Euseius hibisci* as well as another fairly common predator, the *Stethorus* beetle, or even less common predators. The misuse of chemical treatments can significantly reduce populations of beneficial species and, in turn, can result in outbreaks of mite pests. Chemical treatments for mite control may be desirable to prevent extensive leaf drop, if mite populations threaten.

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